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19th Cambridge International Manufacturing Symposium | 24-25 September 2015

International Manufacturing - revisited

embracing new technologies, capabilities and markets

CONFERENCE PROCEEDINGS

IfM MANAGEMENT TECHNOLOGY POLICY

UNIVERSITY OF CAMBRIDGE

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PRESENTATIONS | THURSDAY 24 SEPTEMBER

The tailored supply chain. Exceeding customer expectations and invigorating growth
Vincent Megglé, Senior VP, Global SC Transformation, **Schneider**

Enabling supply chain transformation at Johnson Matthey through collaborative relationships
Paul Mayhew, Global SC Director, ECT Division, **Johnson Matthey**

Ensuring supply chain functions keep pace with massive industry and organisational change
Mark Lincoln, Global SC Director, **Cambridge University Press**

Global brands; local business: how Coca-Cola brings sustainability to life within its supply chain
Steve Adams, Director SC Operations & Nicholas Nixon, Operations Director **Coca-Cola Enterprises**

The JLR international manufacturing and supply chain story
Dr Ralf Speth, Chief Executive & Dr. Wolfgang K. Epple, Director, Research and Technology **Jaguar Land Rover**

Breakthrough value captured through an internet of everything supply chain
Mike Lydon, VP Worldwide SC Management, **Cisco**

Integrating vertical and horizontal plant networks
Professor Kasra Ferdows, Professor of Global Manufacturing at Georgetown University

IT-driven innovation in manufacturing supply chains
Professor B. Ravi, Professor of Mechanical Engineering at the Indian Institute of Technology, Bombay

International Manufacturing – anticipating the next industrial challenge
Professor Sir Mike Gregory, Head, Institute for Manufacturing, University of Cambridge

Next generation global sourcing (Chair: Jag Srai)
A literature-based reference process for global sourcing
Harri Lorentz, Olli-Pekka Hilmola and Jagjit Singh Srai
Supply Chain Network Design Considerations for Pharmaceutical Companies that Implement Continuous Manufacturing Processes
Leda Todorova
Supply chain opportunities and challenges from disintermediation and network integration strategies
Claire Rosenberg and Jagjit Singh Srai

Risk & resilience (Chair: Steve New)
Supply Network Resilience: A Review and a Critique of Recent Research
Steve New and Tomomi Kito
Risk and Resilience of Global Supply Networks: Identifying and Mitigating the Water Stress Risk of the Californian Wine Industry Supply Chain
Pavan Manocha, Mukesh Kumar and Jagjit Singh Srai
An Expanded Supply Chain Risk Framework: Incorporating the Complexities of Services, Emerging Industries and Large Scale Systems
Laird Burns

International manufacturing networks I (Chair: Ann Vereecke)
Market Expansion and Firm Value Creation through International Joint Ventures and Strategic Alliances: An Empirical Analysis of Emerging Market Multinational
Aysun Ficici
The dynamics of global plant networks
Ann Vereecke
Chinese Industrialisation in the Last Thirty Five Years and its Implications to the International Manufacturing Theories
Yongjiang Shi

Sustainability I (Chair: Ettore Settanni)
A study on stabilised electric power supply for solar energy based micro-grid systems
Haishun He, Koichi Murata and Hiroshi Katayama
Recycled Multifunctional Artificial Reefs – a technology favouring sustainable operations in coastal lifestyle
Isabel Duarte de Almeida, J. M. Vilas-Boas da Silva, and Pedro Bargado de Sousa
Methods for measuring environmental sustainability in the pharmaceutical industry
Georgi Aleksiev and Athanasios Rentizelas

Business Ecosystems I (Chair: Mark Phillips)
Towards a systems approach to investigating business and innovation ecosystems
Mark Phillips
Conceptualising Business Ecosystem Health: From Regional and Evolutionary Perspectives
Xianwei Shi and Yongjiang Shi
From the University to the Industry: A Chinese case study on 'transplant with the soil' and the establishment of the innovation ecosystem
Ran Michelle Ye

Corporate Lean Programmes - special Track (Chair: Torbjørn Netland)
A study on improving corporate lean problem in manufacturing industry through learning visual management cases in other industries Koichi Murata and Hiroshi Katayama
Do Formal Assessments Help Implementation of Corporate Improvement Programs? A longitudinal controlled experiment in a global production network Torbjørn H. Netland, Jason Schloetzer and Kasra Ferdows
Way of lean thinking and an evolutional technology for greenness Hiroshi Katayama

Network Design (Chair: Gary Graham)
Fifty shades of greywater: an outcome perspective on wastewater system operations' performance Ettore Settanni, Linda Newnes and Jon Wright
Improving resource efficiency through the adoption of 3DCE throughout the product life cycle Aristides Matopoulos, Wendy Tate and Brian Price
Smart City production systems Mukesh Kumar, Gary Graham, Patrick Hennelly

International Manufacturing networks II (Chair: Afonso Fleury)
Governance in Global Value Chains based on Digital Platforms: the Importance of Network Effects and Volume of Participants Luiz Ojima Sakuda and Afonso Fleury
How do some Emerging Multinationals Become Global Leading Innovators Xingkun Liang
Evaluation of Global Manufacturing Networks – A Matter of Perspective Jan Hochdoerffer, Tobias Arndt, Jens Buergin, Emanuel Moser, Markus Scherb, and Gisela Lanza

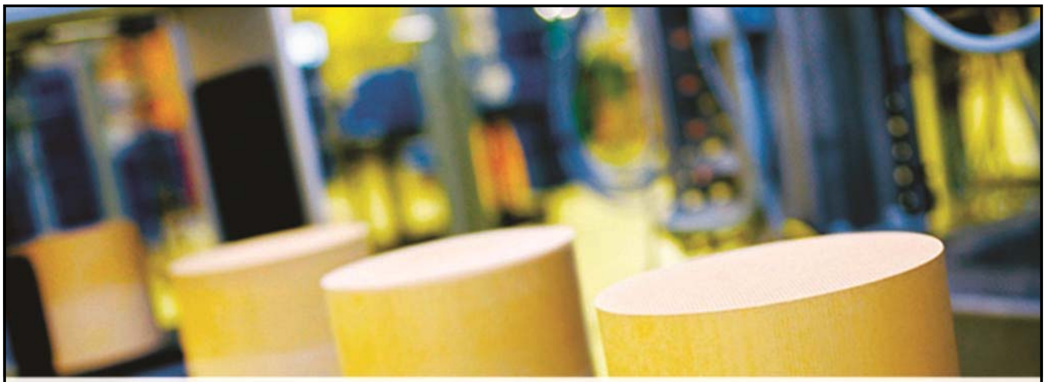
Sustainability II (Chair: Jag Srai)
Green Planet Strategy - How Social Responsible Multinational Manufacturers Can Create Shared Value Strategies Arild Aspelund, Silje Erdal Rødland and Lise Fjell
Local Water Stress Impacts on Global Supply Chains: Network Configuration and Natural Capital Perspectives Ekaterina Yatskovskaya, Jagjit Singh Srai and Mukesh Kumar
Assessing disturbances in food supply chains: Insights from the Indian dairy operations Gyan Prakash

Business Ecosystems II (Chair: Laird Burns)
Solution approach and effect measurement method in design and engineering Akira Tezuka and Takehiro Ikeda
Innovation ecosystems: the role of Business Model Evolution as an 'adaptive exploration' Mark Phillips
Development of an analytical framework for assessing the impact of a national policy on supply network – application in textile sector Arsalan Ghani and Jagjit Singh Srai

Pharmaceutical supply chains - special session (Chair: Tomás Harrington)
Literature review and discussion Paul Beecher
Setting the future research agenda in Pharmaceutical supply chains Panel: Jag Srai, Tomás Harrington, Ettore Settanni

International Manufacturing networks III (Chair: Maria Tereza Leme Fleury)
Revisit and Contrast Two Bodies of Knowledge - International Manufacturing and Internal Business Yongjiang Shi
Industry network embeddedness of emerging multinationals Michał Zdziarski
Framing the performance of international manufacturing networks Silas da Costa Ferreira Jr., Afonso Fleury and Maria Tereza Leme Fleury

Food supply chains - special session (Chair: M K Tiwari)
Setting the future research agenda in Food supply chains Panel: M K Tiwari, Mike Gregory, Mukesh Kumar, Gary Graham and Gyan Prakash



Enabling Supply Chain Transformation at Johnson Matthey Through Collaborative Relationships

Johnson Matthey

Cambridge International Manufacturing Symposium
24th September, 2015

EMISSION CONTROL TECHNOLOGIES

Presentation outline

Johnson Matthey, Who are we?

Overview of JM Group and ECT Division.
ECT Sales and Operations organisational map
Overview of Customer profile
Legislation Changes and Market Dynamics Drive Growth
Catalytic Convertor Supply Chain
Collaboration with Global Customers
Future Challenges

Johnson Matthey

- A speciality chemicals company and a world leader in advanced materials technology
- Origins date back to 1817, floated 1942, FTSE 100 company since June 2002
- £11.1 billion turnover for year end March 2014
- £3.0 billion turnover for year end March 2014 – Excluding Precious Metal
- Operations in over 30 countries with 11,300 employees
- Leading global market positions in all its major businesses

Group Structure

Johnson Matthey

Emission Control Technologies

- Light Duty Catalysts
- Heavy Duty Catalysts
- Stationary Emissions Control

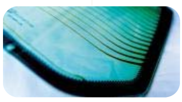
Process Technologies

Chemicals

- Chemical Technologies (DPT)
- Syngas
- Chemical Catalysts (inc. Formox)

Oil and Gas

- Refineries
- Purification
- Tracerco



Precious Metal Products

Services

- Platinum Marketing and Distribution
- Refining

Manufacturing

- Noble Metals
- Colour Technologies
- Chemical Products

Fine Chemicals

- Active Pharmaceutical Ingredient (API) Manufacturing
- Catalysis and Chiral Technologies
- Research Chemicals

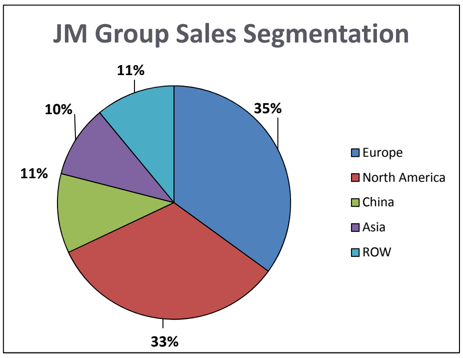
New Businesses

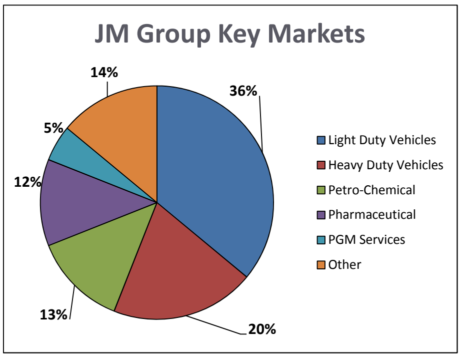
- New Business Development
- Water
- Battery Technologies
- Fuel Cells

Johnson Matthey - World Leadership

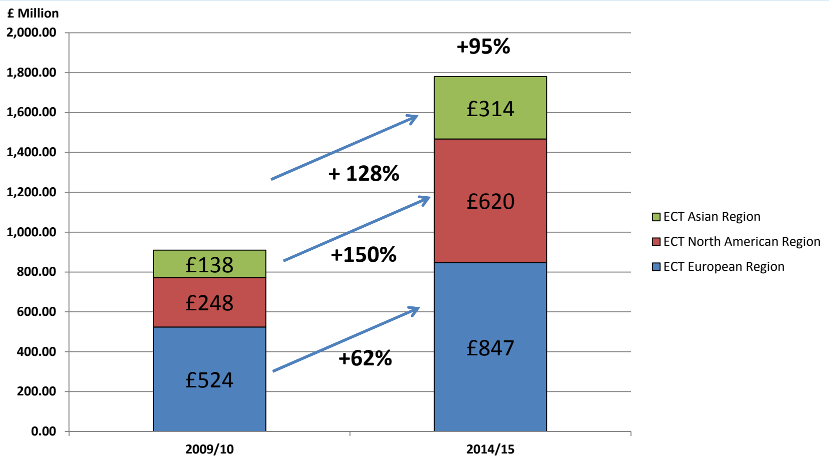
- Autocatalysts
- Heavy duty diesel emissions control
- Fuel cell catalysts and components
- Chemical process catalysts
- Platinum trading
- Secondary platinum group metal refining
- Active pharmaceutical ingredients

JM Group Sales Structure





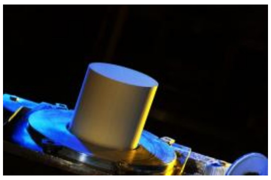
JM ECT Division Global Sales – Excluding Precious Metals



Emission Control Technologies

Automotive/Light Duty

- Johnson Matthey pioneered the use of autocatalysts
- World's first autocatalyst manufacturing plant in 1974
- Johnson Matthey supplies 1 in 3 autocatalysts fitted to new cars worldwide
- Johnson Matthey has manufactured over 600 million catalysts



Emission Control Technologies

Global Manufacturing and Technology Centres

Major Customers – Europe & North America

Major Customers - Asia

ASHOK LEYLAND, DAIHATSU, KOMATSU, SAIC 上海汽车工业(集团)总公司 SHANGHAI AUTOMOTIVE INDUSTRY CORPORATION (GROUP), BAJAJ, DFM, Great Wall, Mahindra, Brilliance Auto 华晨汽车, FAW, MITSUBISHI FUSO, Haima 海马汽车, MITSUBISHI HEAVY INDUSTRIES, LTD., SUZUKI, 北京汽车集团 BEIJING AUTOMOTIVE GROUP, FOTON 福田汽车, NISSAN, TATA, BYD, 广汽长丰 GAC CHANGFENG MOTOR, HINO, HONDA, PERODUA, TOYOTA, CHANA, 广汽集团 GAC GROUP, ISUZU, PROTON, TVS, CHERY, JMC, ROYAL ENFIELD, YANMAR

Key Technology Drivers for Light Duty

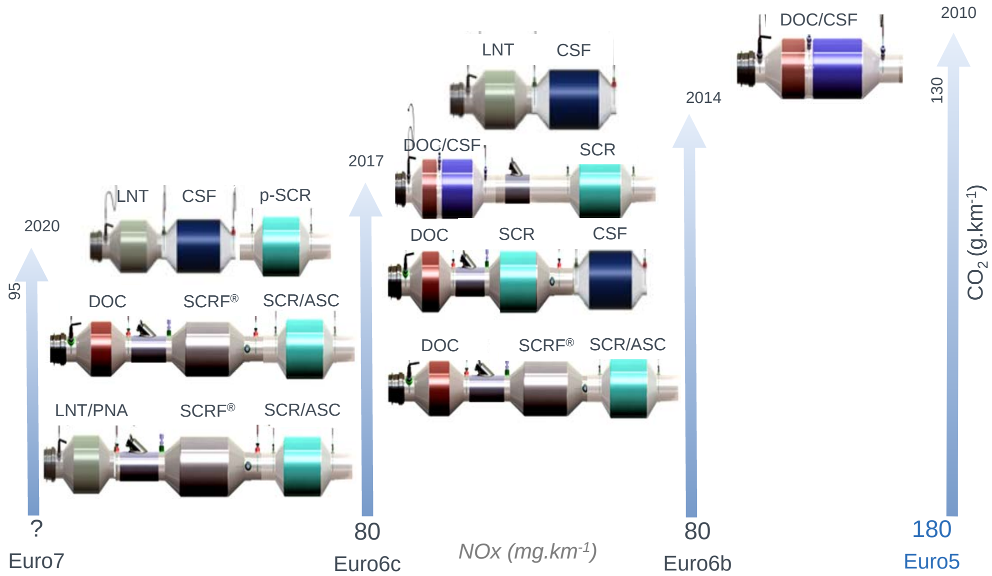
- Lower Diesel NOx limit for Euro 6b (2014/15)
  - Reduces from 180 to 80 mg/km
- Gasoline Particulate Number Control for Euro 6c
  - DI limit reduces to $6x10^{11}$/km in 2017/18
- Real World Driving Emissions (RDE)
  - On board emission measurement 2017/18
- CO_2/Fuel Economy Targets
  - Hybridisation, plug in, less waste heat
- LEV III forces lower fleet average emissions
  - More SULEV 20 and SULEV 30 vehicles in US
- Tightening legislation in emerging markets *e.g.* Brazil, India, China
  - Robust systems required if fuel quality variable

New Product Opportunities

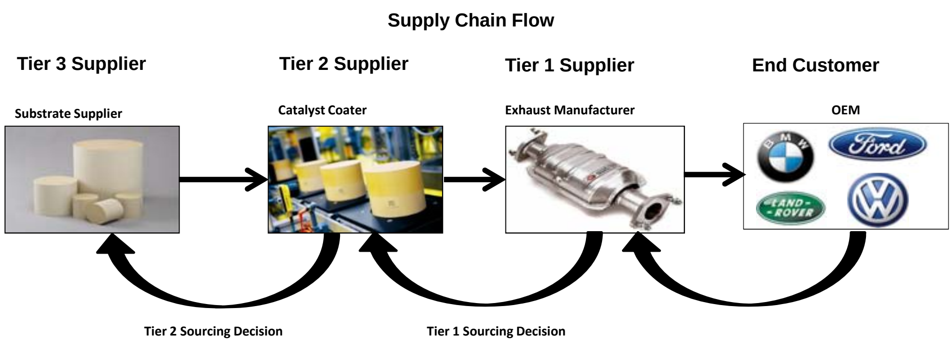
- Diesel NOx control
  - Widespread adoption of SCR and LNT
  - Integration onto particulate filter – SCRF®
  - Combined trap/reduction systems
  - Multifunctional filters – ammonia (NH_3) slip, hydrogen sulfide (H_2S) attenuation
- Gasoline particulate number
  - Introduction of coated gasoline particulate filters: Three Way Filters (TWF™)
- More robust catalyst systems for real world emissions control
  - Increased thermal durability
  - Emissions control at low temperatures and at high speed / high exhaust gas flow

JM Diesel Roadmap to Euro 7

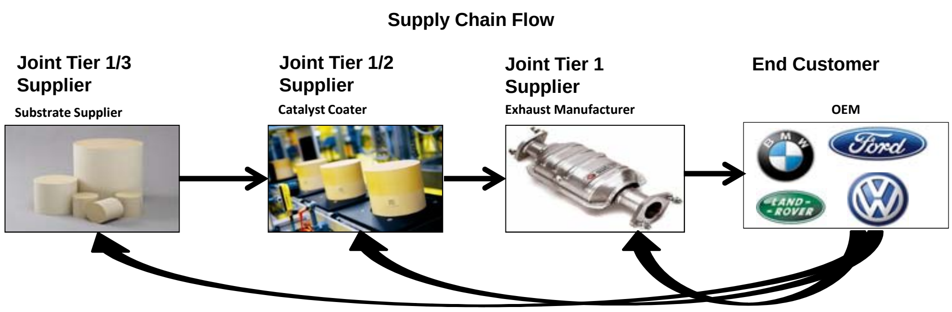
Increasing diversity and complexity of catalyst systems



Traditional Supply Chain Flow



Automotive Catalyst Supply Chain Decisions



Substrate Supplier sourcing and prices agreed with OEM, and catalyst dimensions built into vehicle architecture.

Catalyst manufacturing supplier and pricing sourced by end user. Research and development also direct interaction with OEM.

Coaters have no sourcing decision on substrate supplier or canner

Exhaust manufacture supplier sourced and pricing agreed with OEM.

Canners have no/little sourcing decision on coating supplier

OEM sourcing decision through full supply chain.

OEM has full transparency on each suppliers cost in final product delivered.

Supply Chain Strategy

Key thrusts developed with IfM

Customer Collaboration
NPI to gain flexibility in supply chain and risk reduction
S+OP global roll out
Network Optimisation
Procurement Focus
Freight Cost Reduction
KPIs
Organisational Development

Collaboration in Supply Chain

Areas for Consideration

Collaborative Relationships

Key to Supply Chain Transformation

Flexibility in capacity and materials from product introduction

Enabler of Contingency to avoid Risk in supply through multisite approval

Standardisation in process and equipment to ensure consistency

Four step supply chain demand visibility, from substrate to vehicle

Enabling lean through the entire supply chain, packaging, marking, inventory, batch sizes, etc

EU NPI group created:
high risk project management

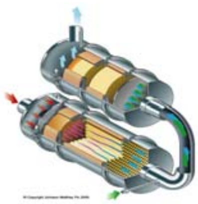
Innovation through the supply chain at each stage

Fit for Market supply chains

Collaboration in Supply Chain

Flexibility in Capacity and Materials in New Product Introduction

Significant testing involved in new product introduction



Testing in technology centres and with OEMs.

Traditional approach was single manufacturing
and material sources

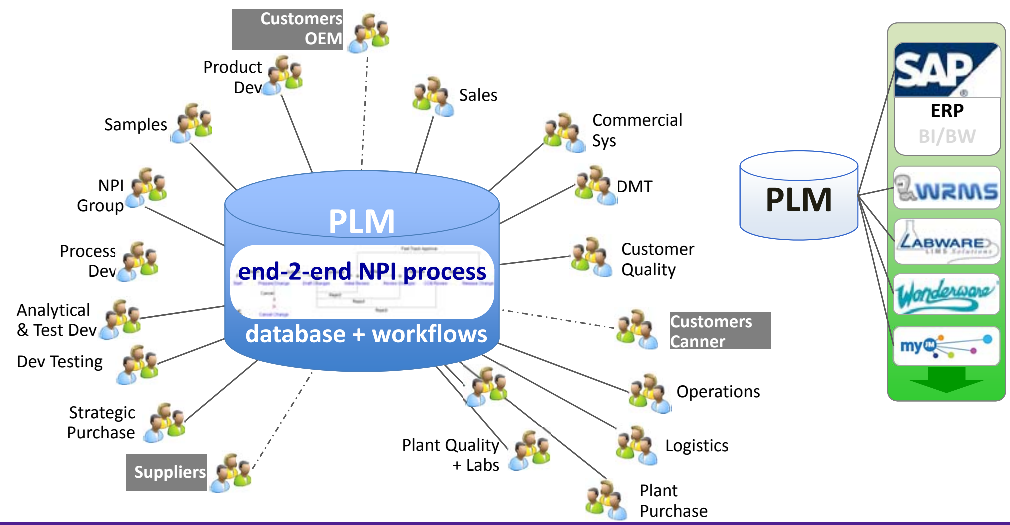
Creates business risk in event of production interruption at plant or supplier locations.

Focus on testing new products for multisite approvals and alternate raw materials sources.

Drive for standardisation at plants and through testing to ensure identical performance.

NPI – Target Situation

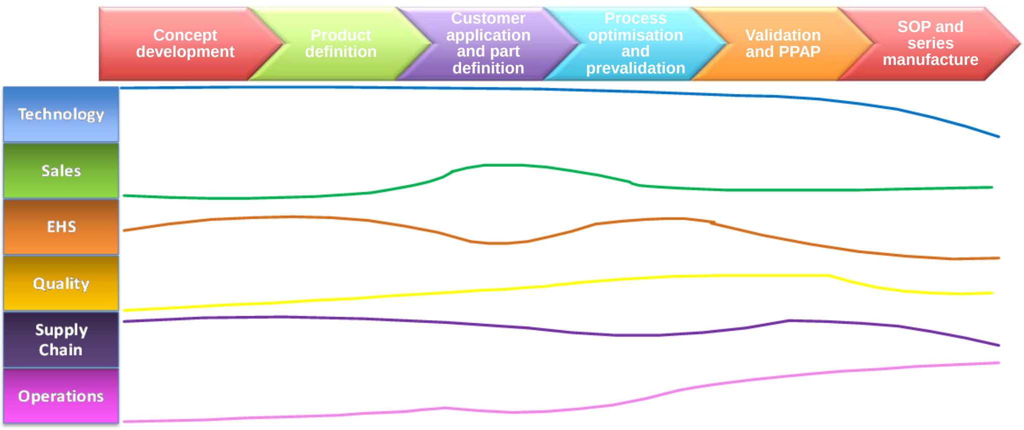
- *Data Analysis & Governance*
- *Workflow Mgt & Process Automation*



Product Master Data →"Single Source of Truth" + Cascading Data

Developing a Global NPI Process

Visualising contributions to raw materials sub-process (swimlane)



Functional contribution is equivalent globally

Collaborative Relationships

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Fit for Market supply chains

Collaboration in Supply Chain

Four step supply chain demand visibility from substrate to vehicle

In each supply chain four main companies are involved

Substrates, Coaters, Canners, OEMs.

In each chain different companies may be involved from amongst three substrate manufacturers, three coaters, and three main canners, each chosen by the OEM

Lead times substrate-coater can be 2-12 weeks

Lead times coater to canner can be 2-5 days

Lead times canner to OEM, daily

Collaboration in Supply Chain

Four step supply chain demand visibility from substrate to vehicle

Currently lack of visibility of demand signal from OEM to the canner to rest of the chain

Differing batch sizes at each step, and differing supply lead times, creates bullwhip effect and inventory holding policies to reflect disjointed scenario.

Pilot ongoing in one collaborative relationship to share vehicle production schedules with all parties in the chain.

Inventory visibility at all stages being shared

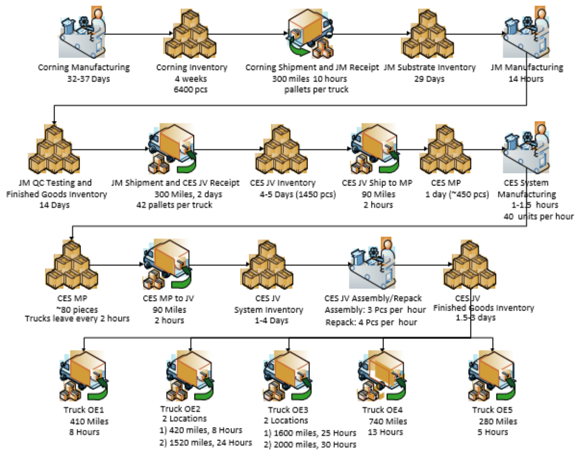
Expectation for low overall inventory in the chain, and opportunities for VMI and smoother flow throughout.

Collaboration

Through Supply Chain Visibility

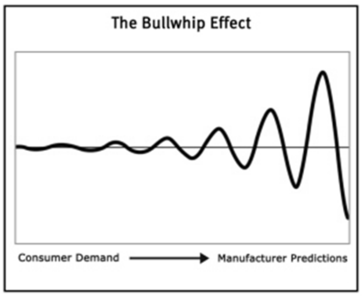
End to end visibility

Inventory, Demand Variability and Lead Time at each step,



Supply chain collaboration

Bullwhip effect,



Collaborative Relationships

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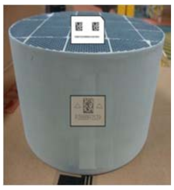
Fit for Market supply chains

Supply Chain Collaboration

Enabling lean through the supply chain

Packaging; Cartons with substrates inside from manufacturers are re-used during coating, and then for delivery to canners. Investigating removal of cartons totally.

Labelling of substrates takes place at each step, reviewing options to use original label at all steps in the chain.



Reviewing batch sizes at each step to equalise flows.

Collaborative Relationships

Key to Supply Chain Transformation

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Fit for Market supply chains

Collaborative Relationships

Fit for Market Supply Chains

Different markets operate against various stages of legislation

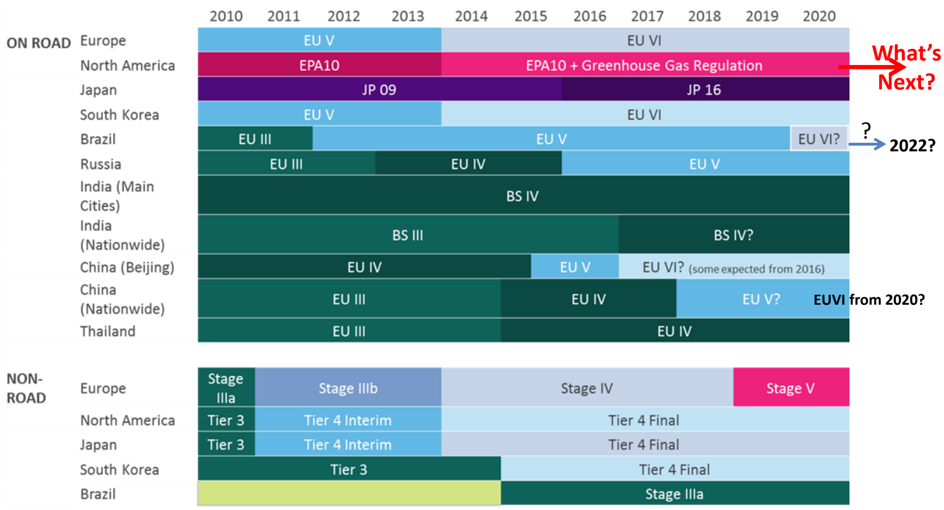
BRIC markets are still evolving regulation and set varying expectations of catalytic performance and costs

Specific markets such as China and India will see differing product standards between ‘Western’ OEMs and local manufacturers

Need to run two supply chains side by side, based on customer expectations, and at varying cost levels

Cost is main driver in India and with local Chinese manufacturers, with basic levels of performance meeting local legislation

Global HDD Regulations: On Road and Non Road



Supply Chain
Future Challenges

Global based supply chain rather than country specific
Flexible locations
Standardisation of equipment and processes
Customers expect global standards
Diversification of legislation and customer product ranges

Collaboration in Supply Chain
Conclusion

In a constantly evolving market, where legislation and product differentiation are growing, it is essential to achieve collaboration in the supply chain to control costs and reduce complexity.

A growing awareness of this is allowing more parties to work together, with greater transparency and urgency.

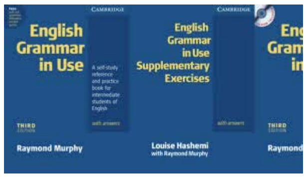
Johnson Matthey is driving this initiative in our sector, where differing tier suppliers all work for the same customer, and already enjoys a significant number of such relationships.

Q + A

Cambridge University Press

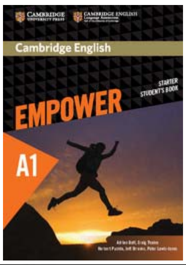
Ensuring Supply Chain functions keep pace with massive industry and organisational change

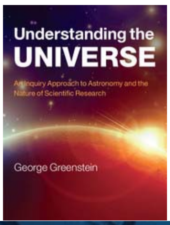
24th, 25th September2015

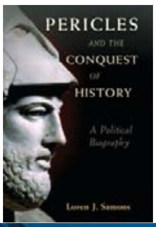


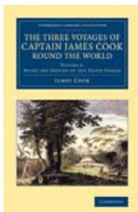
Agenda

1. Overview
2. The Changing face of the Industry, Sales and Organisation
3. How the Press is adapting
4. What else needs to happen
5. Summary



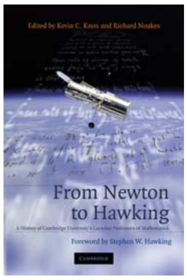






CUP overview.

- Dating back to 1534, is part of the University of Cambridge and is the oldest Publishing house in the world
- Notable Authors include Stephen Hawking and Isaac Newton
- £270 million turnover
- 2,500 employees
- 3 main business areas
  - Academic Books, Journals and Bibles
  - English Language Teaching
  - Education
- 50 country footprint, distribution across over100 countries



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Overview (cont'd)

- 100% Outsourced Manufacturing; 80% Outsourced Supply Chain Logistics activities
- Size of 3 publishing segments relevant to Sales:
  - Academic Books and Journals 40%
  - English Language Teaching (ELT) 40%
  - Education 20%
- Academic Sales – US, UK, Australia, India
- ELT Sales – Europe, Central America, South America, Asia
- Education Sales – India, Australia, UK, Africa,
- Global Business but little global coordination until very recently

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Overview (cont'd) – world view

The Changing face of the Industry, Sales and Organisation

- Digital Online Sales now account for around 25% of all Sales
- Blended products are a key product and Sales share is increasing robustly
- Fast growing Sales in new or growth markets – new branches – 90% of CUP Sales are now outside the UK
- Customer demands are becoming stronger globally
- Need for global joined up operations is more important than ever before, due to growing global footprint, increased focus on compliance and diversity of Sales
- Change of all back office systems globally

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How the Press is Adapting and keeping pace

Historical Press Global Structure vs how we are now adapting

- Focus on UK and US business – hangover from pre 2010 when majority of business was in the UK and US and other regions smaller
- Other regions autonomous operationally and made their own decisions, often to the detriment of the global cost base
- No global joined up manufacturing plan / manufacturing only recently outsourced
- No global inventory or warehousing control (US and UK only)
- Global freight managed locally
- No overall Supply Chain Management
- No Procurement Policy or structure

→

- Focus on all regions as a global business
- No regions are autonomous – operations globally joined up
- Global reviews on manufacturing – global planning
- Global views of inventory and global inventory control
- Global reviews of warehousing
- Global freight becoming controlled centrally
- Global freight managed locally
- Global Supply Chain and Procurement Management is in place

How the Press is Adapting

Future Proofing Supply Chains and Getting the cost and control base right

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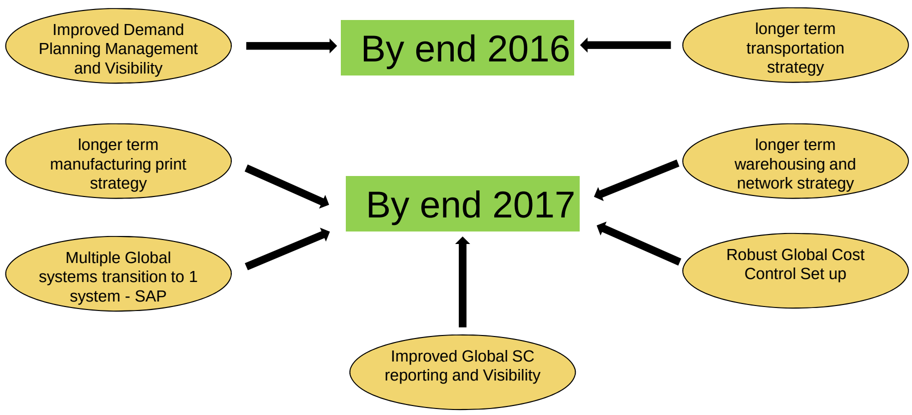
What else needs to happen

Keeping pace with change



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Summary

- The industry is going through fast paced change and so too is the Press, for similar and differing reasons
- Getting the Operation to think globally and be set up globally has been the 1st phase and has been achieved
- Getting the cost and control base right is the 2nd phase
- Getting the longer term operations/end to end supply chain strategy fully in place is the 3rd phase
- Alongside all this is the global transition to SAP
- All the above will enable the Press to have true visibility and be in a robust position to keep pace, be agile and be able to adapt more easily to further change

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A literature-based reference process for global sourcing

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Abstract
A well designed process may be considered a microfoundation of global sourcing capability. The aim of this conceptual paper is to propose a literature-based reference process for global sourcing, drawing on the extant literature on the topic, and by integrating relevant purchasing and supply decision making frameworks to the process. The proposed process comprises both strategic and tactical elements and is structured to include such phases as ‘diagnosis’, formulation of ‘guiding policies’, as well as taking ‘coherent action’. Further, the process addresses saliently both the coordination and the configuration design problems, suggested to be key dimensions of global sourcing, and establishes the dominant role of supply market research and intelligence as an enabler for knowledge-intensive global sourcing.

Keywords: global sourcing, process model, strategy, tactics

1. Introduction

In their influential five level framework, Trent and Monczka (2003; also Monczka and Trent 1991), distinguish international sourcing from the more advanced form of global sourcing, which integrates and coordinates sourcing strategies across worldwide locations and other functional groups, and brings with it higher level of supply performance. Petersen et al. (2000) conclude on the critical role of global sourcing business capabilities in realizing effective global sourcing strategies. Essentially, appropriate (1) structures, (2) processes, and (3) individual level elements, may be suggested to be the microfoundations that contribute positively to global sourcing capability (cf. Felin et al. 2012).

In this conceptual paper, the focus lies firmly on the process microfoundation of global sourcing capability. Whereas extant research does suggest models for global sourcing process, most of them do not cover the critical elements of global sourcing adequately. To make such a bold statement, we must understand what these elements are. Drawing on the summarising work of Quintens et al. (2006), as well as on Porter’s (1986) configuration and coordination dimensions for international strategy, we state that global sourcing domain includes: (1) decisions on the internal *coordination* of the PSM function (i.e. allocation of category responsibility; e.g. Arnold 1999) for achieving the three global sourcing synergies (Trautmann et al. 2009a); and (2) decisions on the geographic *configuration* (location) of supply and PSM function, ranging e.g. from local to international (e.g. Smith 1999), and from dispersed to concentrated (Porter 1986).

In order to demonstrate that such elements are widely accepted in the extant literature on global sourcing, at least implicitly, we examine definitions used for global sourcing. It is observed that the most widely used definition for global sourcing (used e.g. in Gelderman and Semeijn 2006; Schneider et al. 2013; Trautmann et al. 2009a), is based on the work of e.g. Trent and Monczka (2005; 2003), combining both coordination and configuration, with for example Monczka and Trent (1991, 3) stating as follows: "the integration and coordination of procurement requirements across worldwide business units, looking at common items, processes, technologies and suppliers". Kusaba et al. (2011, 74), build on this and define low cost country sourcing as "a specific case of global sourcing with a focus on countries with relatively lower production costs and a culturally and/or geographically substantial distance from the buyer's location", essentially combining coordination and configuration perspectives. Others use a more configuration focused definition (e.g. Kumar et al. 2010; Holweg et al. 2011), such as for example the following: "Global sourcing – here defined as the purchasing of goods outside the geographical area to which the company belongs" (Golini and Kalchschmidt 2011, 86).

The aim of this paper, therefore, is to propose a literature-based reference process for global sourcing, drawing on the extant literature on this topic, and by integrating relevant decision making frameworks to the process as well. The guideline for the design of the reference process is to have an outcome, which enables practitioners to make informed decisions consistently about global sourcing, considering both the dimensions of coordination and configuration. The proposed reference process is based on literature alone (much of it drawing on case studies and action research), and it has not been subjected to empirical testing. Motivation for this research is the lack of up to date process in global sourcing (Alard et al. 2007; Zeng (2003). Research problem of this study is related to the reference process building, which could be described with following questions: is there possibility to build reference process to global sourcing through existing literature in the field, and how division to strategic and tactics issues should be considered?

2. Review of selected normative and process oriented research on global sourcing

Trent and Monczka (2003) suggest that companies can develop global sourcing processes that demonstrate the characteristics and conditions of any of the five levels in their stage-model. In other words, 'internationalization of the sourcing process' may take place, or a company may engage in 'the development of a Level V global sourcing process' (Trent and Monczka 2003, 29, 30). Further, Zeng (2003) suggests global sourcing to be a special case of outsourcing, and include such stages as (1) investigation and tendering, (2) supplier evaluation, (3) supplier selection and development, (4) implementation, and finally, (5) performance measurement and continuous improvement. However, the critical element of coordination, i.e. the key condition of the 'global sourcing process' by Trent and Monczka (2003) is not explicitly taken into consideration.

This practical problem of allocating the lead responsibility for sourcing of categories in a multi-unit organisation, or in other words *coordination*, is addressed by Trautmann et al. (2009a), who suggest a purchasing portfolio model that is specified by (1) the strategic importance of category and (2) its global sourcing synergy potential, assessed in three dimensions (cf. Rozemeijer et al. 2003). The case study validated model informs coordination of category management in MNEs' integrated PSM functions, furthering the work of e.g.

Arnold (1999). It is noted that the coordination dimension should be included in any rigorously designed global sourcing process.

Addressing sourcing location or *configuration* oriented decision making (proposed to be another key distinguishing phase in an international and global sourcing processes from the spatial perspective; cf. Trent and Monczka 2003), Smith (1999) suggests a model for the identification of items for local, national, within trade area or international sourcing (sourcing approaches in terms of location). Key factors for the decision making are proposed, and include product specification and its rate of change, level of product technology and its rate of change, risk of production process failure and the ease of correction, product availability and volatility/criticality of demand, and finally, intrinsic product cost and the cost of delivery. Smith's (1999) work offers the first prescriptive and general level tool for geographically configuring the supply base. Later, Kamann and van Nieulande (2010) suggest a structured four-filter process that includes the assessment of items or categories, then countries and the general approach to configuration, including the decision on using middlemen (based on the decision matrix of Smith 1999), and finally the total cost of ownership. Their approach is specifically designed for low cost country sourcing arrangements; however, it informs the configuration dimension further. It is noted that the configuration dimension should also be included in any rigorously designed global sourcing process.

Considering the state-of-the-art in terms of global sourcing processes, it is important to to cover the work of Alard et al. (2007), who suggest a reference process for global sourcing, designed in cooperation with industrial partners. Their process includes the following 14 elements: (1) definition of the supply demand, (2) definition of make-or-buy strategy, (3) analysis and classification of the supply demand, (4) make-or-buy decision, (5) definition of global production and sourcing network strategy, (6) definition of the structure of the global production and sourcing network, (7) procurement market research, (8) supplier evaluation, (9) contract agreement, (10) organisational design of the supplier relationship management, (11) design adaptation, (12) prototype manufacturing and ramp up production, (13) operative procurement, and (14) risk management. Alard et al. (2007) point out several important properties for a generic global sourcing process, such as the international scope and strategic alignment. Alard et al. (2007) also incorporate the configuration dimension in their process; however, the coordination dimension is less explicitly considered. The global sourcing research has advanced significantly since the work of Alard et al. (2007) was published, and thus it does not incorporate comprehensively the new frameworks and tools from the literature, which offer valuable insight on making the highly strategic global sourcing decisions. By presenting a literature-based and updated reference process for global sourcing, we address the deficiencies and hope to inspire new research efforts on the topic.

3. Literature-based reference process for global sourcing

The proposed reference model for global sourcing process is literature based, and as such is informed by the work of Alard et al. (2007) and Zeng (2003) for its general features, and on the other hand on other PSM literature for its specific features and any normative elements (Figure 1), aimed at facilitating decision making particularly in terms of coordination and configuration. Furthermore, we separate strategic level steps from tactical steps in the process, and similarly to Alard et al. (2007), we suggest the importance of initial make-or-buy considerations and a handover to operative buying as the final step in our model. Finally, for the purposes of ensuring alignment with current thinking on strategizing, we structure the process by using such managerially appealing elements as diagnosis, formulation of guiding policies, and coherent action (Rumelt 2011).

3.1. Strategic level global sourcing process

Step 0 - Depending on the context, the global sourcing process may start with analysis and decision in terms of make-or-buy (step 0; cf. Alard et al. 2007). Global sourcing literature informs this phase by for example pointing out the possibility of competence destruction in outsourcing (Kotabe et al. 2008) and higher probability of recalls in cases where outsourcing is coupled with offshoring (Steven et al., 2014). In many cases, a given position on make-or-buy has been taken by top management or the internal customer; however, PSM function should be capable in discussing the implications of such a position or proposing a reconsideration of such a position (cf. Tassabehji and Moorhouse, 2008).

Step 1 - In case of initial buy-decisions, PSM receives the sourcing task and the process starts with step 1, in which discussion between PSM and internal stakeholders should cover the requirement, for example in terms of forecasted demand (Alard et al. 2007), the nature and specifications of the sourced product or service (Jensen and Petersen 2012), as well as the challenging of any a priori assumptions on supply process (service levels, replenishment) and supply market (existing vs. new supplier, domestic vs. foreign supply market). The extent of this discussion depends on the complexity of the sourcing task, varying from new-buy situation to modified rebuy (van Weele 2010). At this point, the company's manufacturing footprint strategy (Srai and Christodoulou 2014), as well as any strategic imperatives and competitive priorities, should also be identified, which may influence sourcing decisions. This may include planned product allocations to manufacturing sites, the maintenance of innovative capacity (Dankbaar 2007) or achievement of cost savings through for example increased share of LCC sourcing (Horn et al. 2013). Such considerations essentially ensure strategic alignment (Baier et al. 2008).

Step 2 - In step 2, PSM considers the initial specification of the requirement and makes a check on possible category responsibility in the organisation. If a category authority can be identified, the task is handed over to corporate level or to the appropriate authority at the local level (step 2.1). As global sourcing should seek to achieve corporate level synergies in terms of (1) economies of scale, (2) economies of information and learning, and (3) economies of process (Rozemeijer et al. 2003; Trautmann et al. 2009a), requirement specifications should be discussed also from the point of view of standardization and achieving pooling as a result. In essence, if the requirement specification is aligned with existing specification of similar products or services, the requirement can then be sourced at corporate level from global suppliers, potentially with savings (cf. Smart and Dudas 2007). The reference process in Figure 1 depicts the loop between steps 1 and 2, reflecting this possibly iterative specification alignment process.

Step 3 - The above described steps, potentially with iteration, are part of a broader 'diagnosis phase', (steps 1 through 5) which then commences with the internal and parallel assessments of requirement in terms of its possible role in the core competence of the firm and any technical / knowledge advantages (Trautmann et al. 2009a; step 3.1), and its projected spend volume, value added or profit impact (step 3.2; as e.g. in the vertical dimension of the purchasing portfolio model; Kraljic 1983). Further, requirement's other characteristics are assessed, along such dimensions as the level of customization, rate of change in specification, level and rate of change in product technology, risk of failure and ease of correction, product availability, criticality and volatility of demand, as well as the intrinsic and delivery costs of the product (step 3.3; Smith 1999, also Kamann and van Nieulande 2010). It is noted, that in step 3.1, the outcome may suggest reconsideration of the make-or-buy decision, as significant role in core competence of the firm and high levels of other advantages may suggest in-house production (McIvor et al. 1997).

Step 4 - The diagnosis phase then concludes with external assessment, i.e. in step 4, supply market research is conducted (cf. Alard et al. 2007), aiming to identify answers to such questions as from where and from whom the item or service may be sourced. This step may also address prices, capacities and capabilities, market demand and segmentation, technology trends, as well as clusters (Schiele 2008; Steinle and Schiele 2008) and geography of competencies (Tokatli 2008). With several links to latter steps in the process, the critical role of supply market research underscores the knowledge intensity of sourcing in general and global sourcing in particular. Here the results of research may also suggest lack of supplier capabilities, leading again to the reconsideration of the make-or-buy decision in step 0 (McIvor et al. 1997).

Step 5 – The next step takes input from step 4, and considers the supply market complexity and risk (as in the purchasing portfolio model; Kraljic 1983), and the determinants and boundaries of the 'relevant supply market' (Trautmann et al. 2009a), with added complexity from the potential international context (Hu and Motwani 2014; Sen and Zhang 2009).

Step 6 - The process then moves on to classification of the requirement, for the purpose of formulating 'guiding policies' for global sourcing. The next step depends on whether sourcing decisions are being made in a single or multi-unit organisation, as based on the diagnosis, responsibility for sourcing the requirement may be allocated at this point to corporate or local levels in step 6 (for the case of multi-unit). Here the decision making approach for global sourcing coordination by Trautmann et al. (2009) can be used. Input for this decision is taken from steps 3.1, 3.2 and 5. Outcome of the analysis may suggest a move to either step 2.1 or step 7, depending on whether analysis is conducted at HQ or at a business unit. In the case of single unit organisation, the process moves directly to step 7.

Step 7 - In this step a classic portfolio analysis should be conducted (step 7, drawing on steps 3.2 and 5), along for example Kraljic (1983), and planning for any strategic moves by the means of for example reducing supply risk (Gelderman and van Weele 2003). This step also takes input from step 1, and aligns purchasing and supply strategy with company strategy and competitive priorities (cf. Quintens et al. 2006; Alard et al., 2007). The outcome of this exercise (guiding policies) should influence configuration decisions in step 8 (e.g. mainly leverage products should be considered for LCC sourcing; Kamann and van Nieulande 2010), as well as some of the steps in the tactical phase of the global sourcing process (steps 11, 12 and 13).

Step 8 - The next step then draws on the assessment conducted in step 3.3, as well as the where-oriented and possibly constraining results from step 4, and by using the approach by Smith (1999; see also Kamann and van Nieulande 2010), it suggests a guiding policy for sourcing configuration: local sourcing (near), source from trade-area, source globally and buy locally, or global sourcing with direct relationship. This decision may be further informed by the work on sourcing intermediaries (Vedel and Ellegaard 2009), multi-tiered supply chains (Mena et al. 2013), IPOs (Jia et al. 2014), and the implications on supply base density for risk (Deane et al. 2009). This step concludes the strategic level global sourcing process, with guiding policies for coordination (local vs. corporate responsibility), configuration (direct vs. indirect chain; near vs. global) and tactical sourcing as the outcome.

3.2. Tactical level global sourcing process

Step 9 - Tactical level global sourcing process starts with step 9, which seeks to enable the refinement of configuration by identifying, short-listing, assessing and deciding on supply countries and regions, and the resultant trade logistics pipelines, possibly revisiting step 4 for more refined information. This step is informed by the process described by Kamann and van Nieulande (2010), and the work Carter et al. (2008, 2010), suggesting managerial biases in country selection, and the importance and precedence of it in relation to supplier selection (step 12; also Jin and Farr 2010). Country selection should also consider the possible effects from country-of-origin (Chu et al. 2010; Ganesan et al. 2009) and foreign trade regulation (Mann, 2012). Finally, the alternative designs for logistics pipelines may be considered for linking source with point of consumption (Creazza et al. 2010).

Step 10 - The process then proceeds to step 10 in order to analyse any required design adaptations to products or services, as informed by Lanza et al. (2010; see also Alard et al. 2007). Lanza et al. (2010) essentially suggest that product or item designs need to be tailored to fit with the characteristics of low cost countries. Basic adaptation principles (e.g. material substitution by labour), which if implemented, drive additional costs for low cost country sourcing, but make success more probable.

Step 11 - Furthermore, guided by policy from step 6, step 11 involves standard preceding tasks to supplier selection, namely identification and short-listing with RFIs/RFQs, once the souring country or region has been determined (Carter et al. 2010).

Step 12 - Here supplier selection takes place (Inemek and Tuna 2009), often involving some form of TCO analysis (Weiler et al. 2009; Kamann and van Nieulande 2010; Kumar et al. 2010; Platts and Song 2010; Holweg et al. 2011; Kumar et al. 2011), and by taking into consideration any quality or security related requirements (Chen and Deng 2013; Voss 2013).

Step 13 - The process continues to the next step where continued management of the supply arrangement is defined, including roles and policies. In terms of relationship management, the global sourcing process is informed by research on cross-cultural issues (Andersen et al. 2009; Abbott et al. 2013; Jia and Zsidisin 2014), as well as on supplier relationship governance decisions (e.g. Enderwick 2009; Schneider et al. 2013). Furthermore, operative level inventory and replenishment policy decisions are informed by Colicchia et al. (2010), Colicchia et al. (2011), and Son and Orchard (2013).

Step 14 - Finally, in step 13, the supply arrangement is handed over to operative buying, with follow-up plan in place e.g. in terms of performance and compliance (cf. Alard et al. 2007).

Importantly, it emerges from the extant global sourcing literature that the process must necessarily involve risk management (Christopher et al. 2011; Hu and Motwani 2014; Sen and Zhang, 2009) and sustainability management (Goworek 2011; Goebel et al. 2012; Thornton et al., 2013) as overarching themes and sources of additional guiding policies for all the steps in the process. While the former is included in the process of Alard et al. (2007), we add to it by suggesting the relevance of sustainability in many cases, particularly when LCCs are considered (Joo et al. 2010).

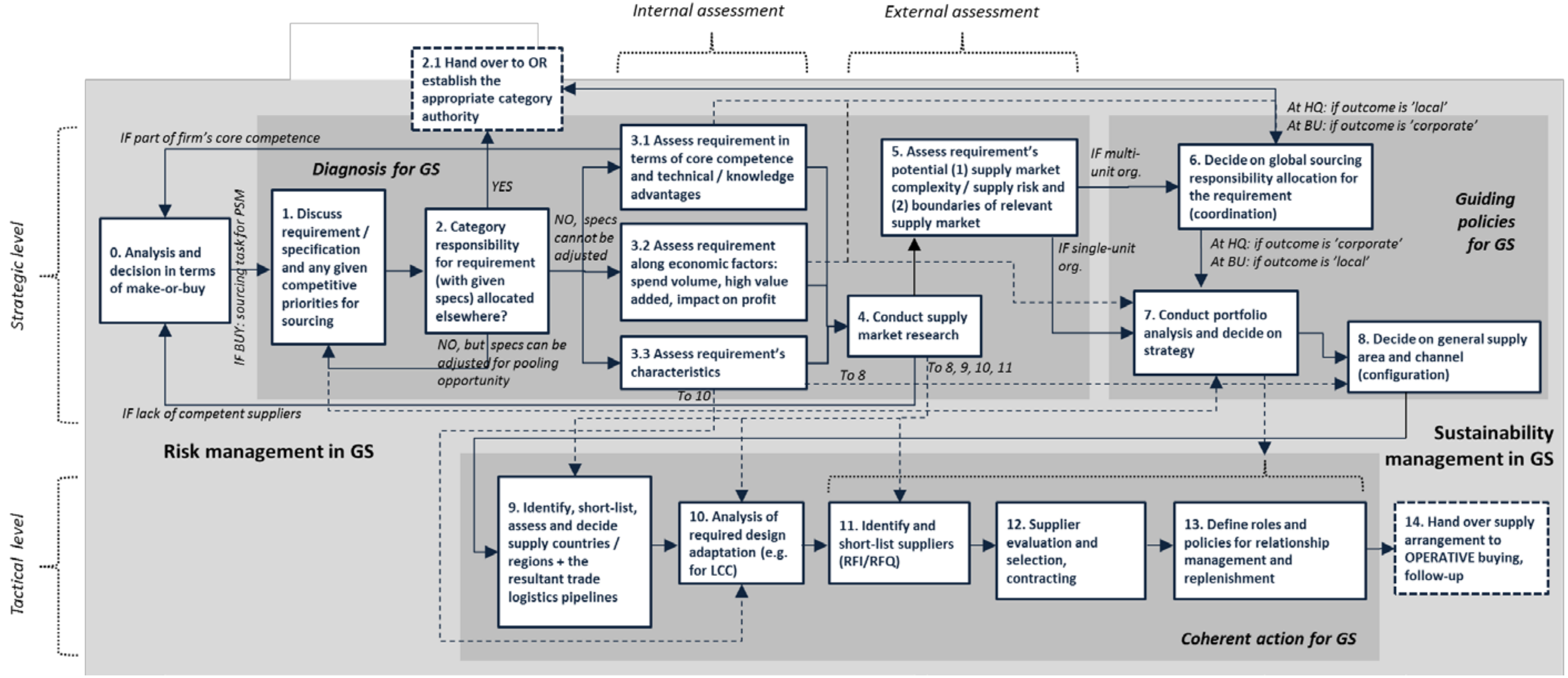

Figure 1 **Literature-based reference process for global sourcing** (dashed lines indicate information/knowledge input)

4. Conclusions and further research

This conceptual paper has proposed a reference model for global sourcing processes, informed specifically by the work of Alard et al. (2007) and Zeng (2003), and incorporating insights from the PSM literature in general, as well as contributions from earlier normative work on global sourcing in particular. The proposed process comprises both strategic and tactical elements and is structured to include ‘diagnosis’, formulation of ‘guiding policies’, as well as ‘coherent action’ (Rumelt 2011). We are confident that global sourcing could be seen as a process and it could be divided to strategy and tactics. Although, operative issues are not dealt here, we believe that this lowest level could be developed in the future with further research within the area.

The proposed process takes into account any coordinating global sourcing structures that allocate category responsibilities, and addresses saliently both the coordination and the configuration design problems in new-task and modified rebuy situations (van Weele 2010). The process establishes the dominant role of supply market research and intelligence as an enabler for global sourcing. By explicitly incorporating coordination and configuration, we also hope to emphasise the importance of covering both dimensions in any further research on global sourcing, as the literature appears to suffer from diversity in definitions and scope.

Further research may drill down in to the identified steps, and further develop relevant approaches and tools. The process and its elements should be tested in refined through iterative action research. Particularly, the mentioned area of supply market research would benefit from further elaboration, and linking with e.g. such related areas as market and technology intelligence, as with the function’s more strategic role in managing external resources, PSM and global sourcing is and necessarily becomes increasingly knowledge-based. In addition, important details and daily decisions of operative level should be incorporated in the further research – sometimes daily issues arise or develop as tactical or strategic, if e.g. unknown issues take place and risks materialize after decisions have been made (Carter 2000; Razzaque and Whee 2002; New 2010).

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Supply Chain Network Design Considerations for Pharmaceutical Companies that Implement Continuous Manufacturing Processes

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Abstract

Recently, pharmaceutical companies have been operating in very challenging environment and this has forced them to investigate innovative manufacturing technologies that will allow more efficient production processes. There is a growing interest in the opportunities that continuous manufacturing can offer for the industry compared to the traditional and far from perfect batch processes that are currently used. Strategic supply chain planning efforts are extremely important when companies consider changes in their business strategy rather than allowing supply chains to evolve organically. In this research the author attempts to identify the impact that continuous manufacturing will have on the supply chain network design by establishing links between supply chain design planning process, pharmaceutical industry trends and continuous manufacturing system characteristics. At the end, conceptual model is suggested for supply chain structure of the current pharmaceutical manufacturing system and the new continuous manufacturing system.

Key words: Pharmaceutical industry, Continuous Manufacturing, Supply Chain Design

Introduction

This research investigates pharmaceutical industry and the implications that the innovative continuous flow processes would have on supply chain design decisions. The article will review the current challenges that pharma companies are facing. Then brief overview of continuous manufacturing will be given, followed by analysis of industry supply chain status. Next, the author attempts to establish links between strategic supply chain design planning process, industry trends and continuous manufacturing system opportunities. At the end a conceptual model for supply chain structure of the current and the new continuous manufacturing system is developed to illustrate the impact of adoption of the different manufacturing mode.

Pharmaceutical industry – the changing environment

Pharmaceutical industry can be defined as a network of organisations, resources, processes involved in the discovery, development and manufacturing of drugs and medications (Shah, 2004). According to the World Health Organisation data pharmaceutical market is worth 300 billion USD a year with an expectation this figure to increase to 400 billion USD in a 3 years span (WHO, 2014).

Shah (2004) defines five major groups of key actors in pharmaceutical industry are 1.) research and development-based companies; 2.) generic manufacturers who produce out-of-patent drugs and over-the-counter products; 3.) local manufacturers that produce both generic drugs and branded medicines under licence or contract and serve the local market; 4.) Contract manufacturer that provide outsourcing services for production of APIs or final products for other companies, but don't have their own portfolio, and 5.) drug discovery and biotechnology companies, which are often start-ups with small manufacturing capacity.
The interest of this research is the first group - large pharmaceutical R&D companies, which dominate the market. The 10 biggest R&D pharmaceutical companies control more than 30% of the overall pharmaceutical market (WHO, 2014).

In the recent past the R&D pharmaceutical companies used to have very good position in the market. The typical strategy for companies was high investment in "blockbuster drugs". The R&D phase had a good productivity and the patents had long and effective life. The industry had very high entry barriers and limited number of product substitutes. The industry used to benefit of high profit margins and the attention was focused on new product discovery and development while the operations efficiency stayed behind.

In the past few decades the operating environment of the research-based pharmaceutical companies has become more challenging. The pharmaceutical industry has reached its maturity and this has led to decrease of productivity of R&D phase and increase of the costs and time for developing new drugs.

The time when the industry used to benefit of high returns on their investment in R&D and long and effective patent lives has passed. The recent circumstances are much more challenging. To take a new drug to market becomes more difficult, more expensive and more time-consuming than ever. Meanwhile, R&D pharma companies are facing huge patent expiration wave known as "patent cliff". Lost patents of key drugs after 2001 resulted in unprecedented negative impact on companies' revenues (Shah, 2004; Patricia, 2011). For example, for the first quarter after Pfizer's Lipitor (cholesterol-lowering treatment) patent expired, the global sales of the drug dropped by 42% and Pfizer’s total profit decreased by 19% (Loftus, 2012).

The combination of these factors is leading to growth of generic companies and financial pressure caused by generic drug invasion. Competition within the industry has become more aggressive than ever. Homeopathic and biological companies also become powerful players in the market with the increasing popularity of bio products and homeopathic treatments. Additional price pressure is coming from the healthcare authorities. The demographic structure is changing with aging population and the healthcare costs per capita are constantly increasing leading to the encouragement of the use of cheaper generic substitutes where possible.

Further challenges for the pharma companies are the increasing expectations of the patients. The society is becoming more demanding in terms of safety, affordability and availability of drugs. Patients are becoming customers with higher expectations for products and services. This brings the attention towards development of pharmaceutical products for unmet medical needs, orphan drugs and specialised and personalised drugs.

The challenges discussed above lead to change of the key success factors in the industry. Historically, R&D pharma companies have been concentrating most efforts and resources on ‘blockbuster’ drugs research and development, but now in the current environment companies pay much more attention on the opportunities for process efficiency improvements, new technology adoption and supply chain optimisation. There is an urge for cost control and efficiency within the manufacturing units. These were not top priority before, but now when the R&D activities are not giving the best results, for pharma companies, operations efficiency is essential requirement to stay competitive in the market.

Continuous manufacturing – the new opportunity

Traditionally the pharmaceutical industry is dominated by batch manufacturing to such extend that naturally continuous and semi-continuous processes are modified in order to fit into the batch concept (Plumb, 2005). In the recent years there is growing interest within the pharmaceutical industry in streamlining of the manufacturing processes. However, continuous manufacturing still has very limited implementation in pharmaceutical plants unlike industries such as food and petrochemical industries where continuous processes are well-established and proven for operational and cost efficiency (Vervaet and Remon, 2005).

The reasons for the late interest in continuous processing of pharmaceutical companies are quite complex. Generally, pharmaceutical industry benefits of higher profit margins on their products whereas low profit margins have stimulated other industries to look towards continuous manufacturing techniques as means to improve operational effectiveness and economic performance much earlier (Vervaet and Remon, 2005). Over the years limited efforts have been made to investigate the opportunities of continuous-flow process in pharma.

As previously stated, the driving force in pharmaceutical industry has always been research and development of new drugs and this is where the most investments for innovations and improvements are made. While launching a new drug in the market brings huge potential for making good profits, pharmaceutical companies seem reluctant to investigate new opportunities in manufacturing processes (Gernaey et al., 2012; Plumb, 2005).

In addition, pharmaceutical companies operate in highly regulated environment. To bring a drug to market is complex, time-consuming and expensive process. Plumb (2005) points out that licensing could be considered as one of the major factors restraining the switch from traditional batch processes to continuous manufacturing as once the process of production is licensed any changes in the way the drug is manufactured will cause the necessity of revision of the license. This will be economically unfavourable for the manufacturer because it is related to more time and funds to be spent.

Another reason for pharma companies to stay within the guidelines of batch manufacturing, authors find in the flexibility that this concept can offer (Plumb, 2005; Gernaey et al., 2012; Singh et al., 2013). Flexibility is an important factor when annual demands are not that high and the production facilities have to allow the switch from one product to another. However, ongoing research and attempts for designing flexibility in continuous processes are on the way to change the mind-set that only batch manufacturing concept can offer this advantage (Singh et al., 2013).

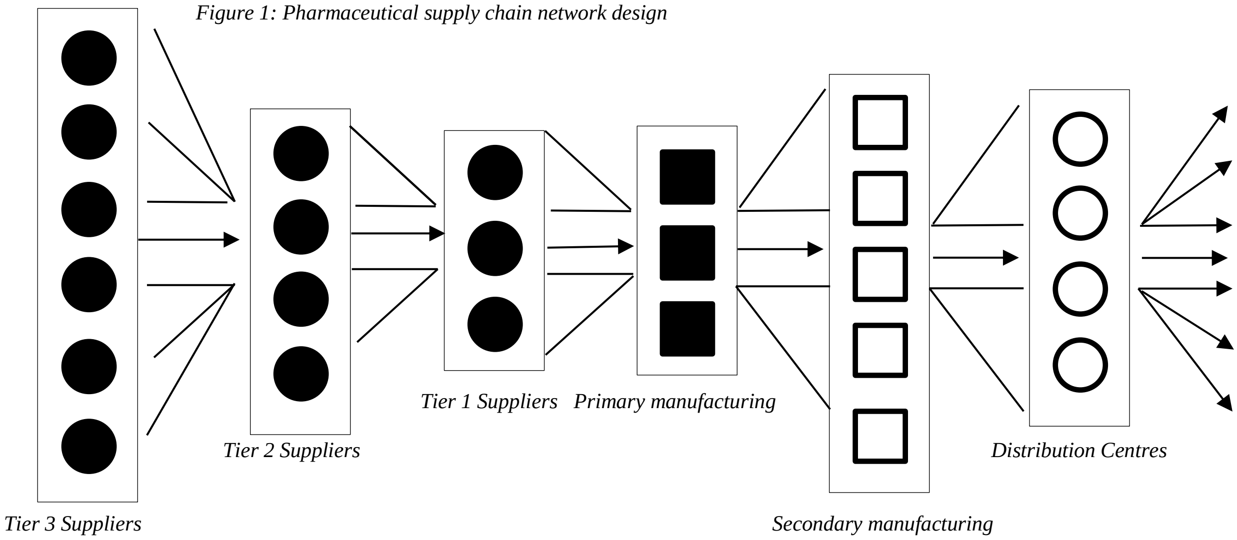
In the recent years there is growing interest in the investigation of opportunities that this innovative for the pharmaceutical industry manufacturing concept can offer. Most of the driving forces that have paved the way towards more efficient production processes have already been introduced above. On one hand, the costs for research and development are continually increasing, while operational performance is decreasing (Plumb, 2005; Vervaet and Remon, 2005). Lonardi (2004) points out that productivity in the industry is very low and the average pharmaceutical company manage to obtain typically only 30% overall equipment effectiveness (OEE). On the other hand, patent lifetime is limited. Plumb (2005) states that more than half of the patent life is lost even before the new product is launched on the market. According to Leuenberger (2001) the patented drugs time-to-market is the most important issue and launch one day earlier of “blockbuster” product on the market is associated with US$1 million of sales, vice versa any time waste means huge financial losses. In line with Plumb (2005) up to 90% of the market share could be lost within the first one year after the patent expires in favour of generic drug manufacturers. In this situation the companies are forced more than ever to research for new opportunities for reducing time-to-market and increasing the operational productivity. The work that has been done in the field so far show promising results that continuous manufacturing could offer such opportunities for significant improvements.

Pharmaceutical Supply Chain – current state and challenges

Handfield and Nichols (1999) define pharmaceutical supply chain as “the integration of all activities associated with the flow and transformation of drugs from raw materials through to the end user, as well as associated information flows, through improved supply chain relationships to achieve a sustainable competitive advantage’’. A typical pharmaceutical supply chain would consist of a number of tiers of suppliers of raw materials, primary and secondary manufacturing units, including contractors’ sites, if any, distribution centres, wholesalers and retailers (Shah, 2004).

Figure 1 represents the typical structure of pharmaceutical supply chain.

Figure 1: Pharmaceutical supply chain network design



Primary manufacturing units are engaged with the production of Active pharmaceutical ingredients (API). They transform the raw materials into APIs and transport them to the secondary plants for the production of finished products. Sousa et al. (2011) argue that due to the low volumes of production, the logistics costs for transportation to the secondary facilities are not high and they can be placed distant from each other. Therefore, localisation decisions for the primary sites are based on cost for production, economic and political stability of the area and availability of work force. The primary manufacturing plants can be dedicated or multipurpose, depending on whether one or more products are produced in the site. Most of the primary plants are multipurpose due to the low volumes of products and with the idea to spread capital and fixed costs between different products and increase the equipment utilisation. The primary manufacturing plants production is often associated with long lead-times, huge inventory requirements and delays. Demand fluctuations in the customer-facing supply chain end amplify when they are moving toward the upstream causing Bullwhip effect. Shah (2004) argues that the batch manufacturing processes that are dominant mode of operations in the primary plants do not ensure good supply chain responsiveness in the industry and contribute significantly to the poor supply chain performance results.

Secondary manufacturing supply APIs and different excipients and transform them through various processes into finished goods in consumable form that can vary in type: solid (tablets), semi solid (paste, cream, gel) or liquid (syrups). Secondary plants can be placed together with the primary ones, but it is more common that they are localised in different parts of the world. The reason for this is different localisation criteria. Important factors for localisation of primary manufacturing sites are mainly related to the distance from suppliers, transportation costs, labour costs, and other manufacturing costs. While for the secondary manufacturing plants the factors that matter are linked to the closeness to the target markets, local governments tax regulations and legislation.

Distribution centres and wholesalers are the right extreme end of pharmaceutical supply chain, but they play very important role in the industry. Usually they are just few, but most of the demand goes through them. One of the today’s biggest challenges for the supply chain in pharma is ensuring traceability and secure supply chain for all the products that reach the end customers.

Such supply chain structure requires regular flow of materials and information across numerous facilities around the globe and that is associated with enormous strategic, operational and tactical efforts as well as huge amounts of money moving through the chain.
Supply chain of pharmaceutical industry is very complex, slow and usually difficult to manage and difficult to respond to market dynamics. In the same time it is very sensitive and carries high responsibility. If the right product does not reach the right customers at the right time and at the right price that can have direct negative impact on the health and safety of the population (Uthayakumar and Priyan, 2013). The industry has to maintain customer service level near 100% and often the solution lies behind keeping huge inventory in stock. Typical for pharma industry is the high level of high-valued inventory which in practice is frozen capital (Susarla and Karimi, 2012). Uthayakumar and Priyan (2013) argue that companies cannot achieve the required customer service level at optimal cost unless they streamline their supply chain processes.

Another costly issue for the industry is products perishability (Masoumi, et al., 2012; Uthayakumar and Priyami, 2013). Every year pharmaceutical products for millions of pounds remain unsold before their expiration date. It is crucial for companies to know the level of inventory that is hold at various points of the supply chain. However, after the products leave the distribution centres the inventory visibility becomes very limited due to the structure of the downstream supply chain and the manufacturers become aware about expired products only once they reach the reverse logistic channel at the distribution centres (HDMA, 2009).
In contrast, it is not an isolated case drugs to be reported in shortage. FDA (FDA News Release, 31 Oct 2013) reported pick of 251 shortages in U.S. in 2011 followed by regulative actions to reduce this number resulting in 134 shortages less in 2012. Amongst the drugs that went in shortage were cancer treatment, anaesthetic and surgery products. Pharmaceuticals shortages are serious thread for public health that can cause delays of critical care or treatments with less effective or more expensive products. Masoumi, et al. (2012) identify the reasons for shortages as mainly manufacturers' decisions to stop production initiated by financial challenges such as very low profit margins.

Counterfeit products entering pharmaceutical supply chain at various points is another major issue that not only possesses high risk for public health and safety, but also for profitability, reputation and brand trust of companies. Securing pharma supply chain, ensuring traceability and supply chain integrity is of crucial importance to fight the problem with falsified medicines.

Other important supply chain challenges facing pharmaceutical industry:

- High inventory levels and material handling;
- Alignment of capacity with demand;
- Outsourcing planning and outsourcing capabilities;
- Ensuring responsiveness;
- Quality processes and products, waste reduction;
- Meeting increasing global market needs;
- Environmental impact

The majority of these challenges are related to the specifics of the manufacturing processes. These are pull-driven multistage processes that require long lead times and therefore it is difficult to ensure responsiveness to changes in demand. Hence, large stocks of inventory have to be kept as a buffer in order to ensure responsiveness and high service level which is a must in the industry. Shah (2004) points out that with the explained production model it is impossible for the pharma companies to benefit from short-term opportunities like epidemics, shortage of a competitor's product, etc. Pharmaceutical companies should make a step towards innovations in the processes that would be able to improve the problems in supply chain and improve supply chain performance indicators. Lainez (2012) states that effective supply chain lies in lean operations which minimise the working capital associated with inventory. Such an opportunity has been explored to be continuous manufacturing.

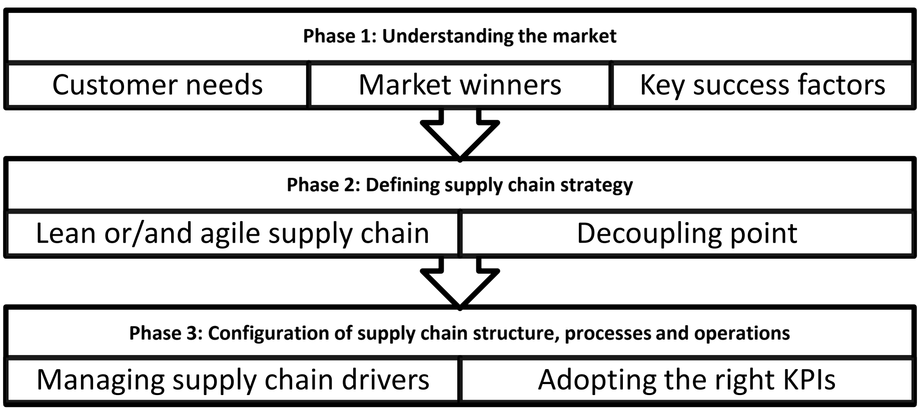
Strategic supply chain planning and continuous manufacturing considerations

There is an agreement within practitioners and researchers that there is an emerging need for improved, more efficient and integrated supply chain in the pharmaceutical industry. This need arises from the current challenges and technological developments in the pharmaceutical industry, in particular continuous processing. Recently there is an increasing attention placed on the performance, design and analysis of SCs in pharma. As already explained in the previous sections this attention is a result of various factors. Manufacturing costs are progressively increasing, but operational effectiveness is continuously declining. In the past production costs used to be just a little percentage of the final value of the drug, but nowadays they can absorb between 10-20% of the total value (Papageorgiou, et al, 2001). The reasons are the more complex manufacturing paths, the high level of inventory and waste. Recently, managers become more aware of keeping costs low by optimising the processes, investigating the opportunities of new technologies and re-designing their supply chain.

Supply chain design is a vital part of supply chain management and commonly it is described as the structure of the supply chain. The right design of supply chain is a core capability that can improve the effectiveness and become a key source of competitive advantage. However, if companies do not align their supply chain design with the business strategies, this can limit their performance. Often decisions regarding supply chain design are crucial for the business. However, it is still a common case for organisations to allow their supply chains to evolve organically instead of making strategic planning efforts. Strategic supply chain planning is extremely important when companies consider changes in their business strategy. The processes related to implementation of new technology, process optimisation, change in business strategy and supply chain design should be performed simultaneously in organisations in order to achieve best results. Therefore, this research attempts to establish links between strategic supply chain design planning processes, current trends and challenges in pharmaceutical industry and continuous manufacturing system opportunities. The author makes an effort to answer the question: What considerations should be taken into account related to the strategic supply chain planning processes for pharmaceutical companies that are looking to implement continuous processes?

Figure 2 represents typical supply chain design process (adopted from Badenhorst-Weiss and Nel, 2011).

Figure 2: Supply Chain Design Process



Identifying and developing of core competences is crucial for companies' competitive position in the market The first phase of strategic supply chain process is related to understanding customer needs, identifying the key success requirements and ensuring that products and/or services offered will create value for the customers (core competences). It was already discussed in previous parts that pharmaceutical market trends have become more challenging in terms of increased customer demand and expectations. Continuous manufacturing can be recognised as a driver for success in key areas in pharmaceutical manufacturing according to Technological Strategic Board (2012) such as manufacturing of tailor-made therapies and personalised medicines, new methods of administration of drugs and new developments in formulation design to minimise the waste and maximise the shelf life. Continuous manufacturing allows combining of different processing units into a single production line, so that the raw materials could be processed into finished goods without interruptions in considerably more compact facilities. There is a true potential that implementation of continuous processes in pharmaceutical production will allow cheaper and more efficient manufacturing with much shorter cycle times. Additionally, the significant reduction of plant footprint requirements may allow localisation of production facilities in multiple locations close to customers. These factors are expected to have major positive impact on the responsiveness of organisations to the market demands.

The second phase of supply chain network planning is related to defining the right supply chain strategy for the business/the product. It is crucial task for business to match their supply chain strategy to the market needs. Agile strategy which offers more flexibility is a profitable strategy for volatile markets, while for more stable demand efficiency and waste elimination that are core principle of the lean strategy will give best results on performance. Leagile is a hybrid strategy that is defined as "the combination of the lean and agile paradigms within a total supply chain strategy by positioning the decoupling point so as to best suit the need for responding to a volatile demand downstream yet providing level scheduling upstream from the marketplace" (Naylor et al., 1997). Decoupling point is the point to which customer orders penetrate the supply chain or in other words, the point where the product is linked to a specific customer. Hoekstra and Romme (1992) define the decoupling point as "the point in the material flow streams to which the customer's order penetrates. It is here where order-driven and the forecast- driven activities meet. As a rule, the decoupling point coincides with an important stock point - in control terms a main stock point - from which the customer has to be supplied." It is a norm that businesses select lean strategy for the processes upstream of the decoupling point and agile strategy downstream. Upstream of decoupling point is forecast driven (push) and downstream is driven by real customer orders (pull). Olhager (2012) argues that pharmaceutical industry takes position in an "untypical" decoupling point zone with high profit margins and relatively high volume MTS operations. However, that is possible for industries that build value mainly on R&D and brand name. Currently the decoupling point in pharma industry is outside the manufacturing towards the customer-end of the supply chain (in the distribution centres). "Ultra lean" manufacturing, flexible production schedule, shorter cycle times and close-to-market production localisation - continuous manufacturing has the potential to shift the decoupling point to the left and transform the push operations to more pull-driven and real demand-orientated.

The last phase of supply chain design process is configuration of supply chain network, processes and operations. Organisations should design their supply chains in a way that supports the best supply chain objectives in order to achieve good performance and competitive advantages. To do this they have to plan strategically the supply chain drivers and set the right performance indicators. There are three logistical drivers – facilities, inventory and transportation and three cross-functional – information, sourcing and planning (Chopra and Meindl, 2006). Following, the author will look at implications of continuous manufacturing on each of these drivers.

1.) Facilities

Supply chain design decisions related to the facilities are associated with location, function and capacity of the facilities within the supply chain. These decisions have significant impact on the performance of the supply chain. The facilities network structure in pharmaceutical industry is very complex with many players in the supply chain. Continuous manufacturing has the potential to transform radically the current configuration. First of all, the new manufacturing system is expected to be capable to transform raw materials into finished goods eliminating the need of two separate production sites for APIs and secondary processing. Second, it requires significantly less plant footprint and production can be placed in more compact almost "container-size" facility. The factory footprint is related to high expenses. Plumb (2005) reports that the average cost for $1m^2$ of secondary pharmaceutical manufacturing space is around US$ 3000. Hence, significant capital cost savings could be expected in continuous production, because the size of continuous plants is suggested to be much smaller than the size of batch plants on equal productivity (Tomba et al., 2013). Third, facilities can be located close to market, because the new production system is less labour intensive, much more compact and efficient. Such decentralised network suggests higher responsiveness to customer demand without compromising on efficiency. Forth, capacity planning will improve. In current plant often the equipment utilisation is very low. It was already stated that the typical overall equipment effectiveness within the industry is about 30% (Lonardi, 2004). But in supply chains unutilised equipment and excess capacity cost money. Continuous flow processes are much more efficient in terms of equipment utilisation.

2.) Inventory

Inventory in supply chain is in form of raw materials, work in progress (unfinished goods) and finished goods. Inventory has a significant impact on the responsiveness of organisations. The more inventory is stocked, the more responsive supply chain is to changes in demand. However, inventory is also a major source of cost. Lean supply chain main issue is reducing inventory and waste. In pharmaceutical industry huge inventory levels are held in the supply chain. Implementation of continuous processes will change the inventory management. Processes are streamlined and this will reflect into less inventory handling and the associated costs. To big extend the WIP inventory in between processes will be eliminated. If primary and secondary manufacturing is combined into singe production, the intermediates handling will be minimised. Inventory reduction will result in higher efficiency.

3.) Transportation

Design of transportation network is another important driver of performance and also an element of the supply chain that is expected to be considerably affected by adoption of more continuous processes in pharma industry. It was already pointed out that combined primary and secondary facilities in singe compact plants near local markets is real opportunity that arises from continuous manufacturing. This new opportunity suggests cut of the costs related to transportation of APIs to secondary plants and minimises the transportation costs for delivering of finished goods to customers.

4.) Information

Information and coordination is one of the most important and in the same time probably the most difficult to manage supply chain driver. It is important that every party of supply chain works towards achieving the strategic supply chain objectives and constantly shares appropriate information with all other parties. However, in complex supply chain structures this is not really the case. Lack of coordination and on time information flow result in operations disruptions and loss of profit. Information flow management could improve with continuous manufacturing system, because production in singe facility with ultra-lean operations requires less coordination, compared to the current multi-stage processes and separated primary and secondary production.

5.) Sourcing

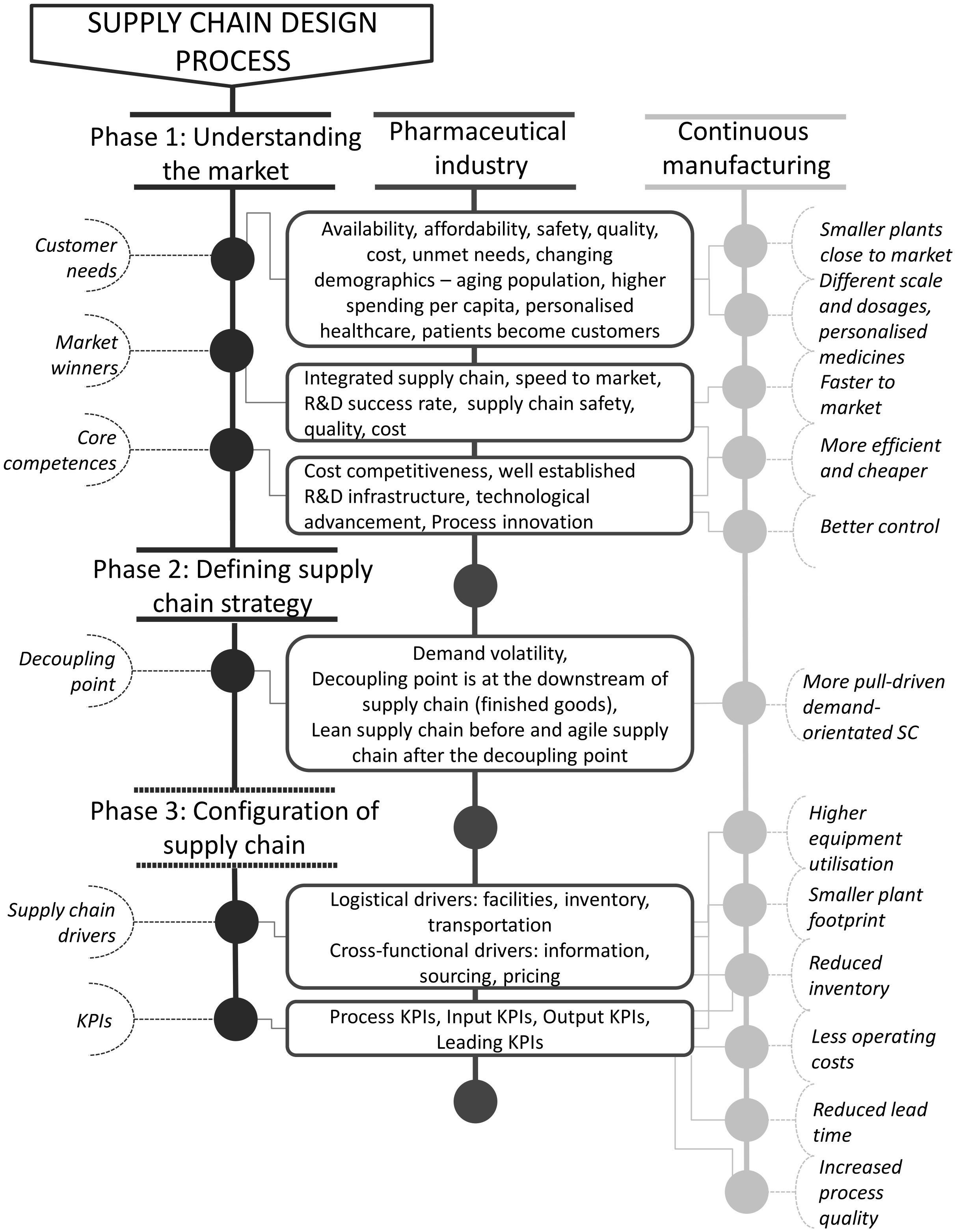
Sourcing is supplying with goods and services. This supply chain driver is related to strategic decision whether to perform tasks in-house or to outsource them. In pharmaceutical industry APIs remain strong outsourcing focus. Contract Pharma's Tenth Annual Outsourcing Survey in 2014 showed that 54% of the respondents outsource more than half of their APIs and 37% respondents outsource more than half of their secondary processes (Contract Pharma, May 2014). The main reason for outsourcing is seeking for efficiency that companies cannot achieve by themselves. The opposite case is a rare event – seeking for responsiveness that company supply chain cannot achieve. Usually pharma companies make outsourcing decisions driven by the global objective for high performance and profitability of supply chain. Contracting is orientated towards firms that can offer significant economies of scale or have lower cost structure for different reason. However, Contract Pharma's survey reveals that outsourcing is not without challenges. One of the issues raised is the lack of transparency and lack of contractors' motivation for improvement. Additionally, contractors' flexibility and responsiveness is low and the lead times are often long. Continuous manufacturing will affect the manufacturing capabilities and the level of efficiency and responsiveness of pharma companies and that will have an impact on the outsourcing decisions.

6.) Pricing

Success of supply chains networks lie behind careful tracking and planning of pricing-related metrics. Profit margins in pharmaceutical industry remain high to offset the high R&D related costs before the launch of the products to the market. However, for the past decade the R&D and operating costs are constantly increasing. One of the most important pricing performance metric is profit margin. Industry has to maintain healthy profit margin, but in current environment this is becoming a challenging task. Continuous flow processes are more efficient, less labour intensive, more controllable and proven to reduce inventory and waste and related to them variable costs. New processes will also impact the fixed cost, mainly due to the smaller plant footprint. The characteristics of continuous manufacturing suggest new more favourable cost structure for the pharmaceutical products.

The summary of the analysis and considerations is presented in the Figure 3 below:

Figure 3: Links between supply chain design planning, pharmaceutical industry trends and continuous manufacturing system characteristics



The following conclusions can be derived regarding the impact of implementation of continuous processes on strategic supply chain deign planning:

- Continuous manufacturing has the potential to strengthen companies' abilities to follow market trends and meet market needs;
- Continuous manufacturing is likely to improve efficiency and responsiveness of companies' supply chains;
- Continuous manufacturing could allow more pull-driven supply chain;
- Implementation of fully continuous plants will lead to transformation of the facility location and allocation network and transportation network structure;
- Continuous manufacturing has the potential to reduce fixed and variable operating costs and improve inventory management;
- Continuous manufacturing will improve coordination and information flows.

Each of these opportunities has to be investigated further in order to assess correctly the impact. It must be noted that in this research the author does not explore the challenges of adoption of more continuous processes in pharma industry. Full evaluation of new manufacturing processes would require comprehensive analysis of both enablers and barriers.

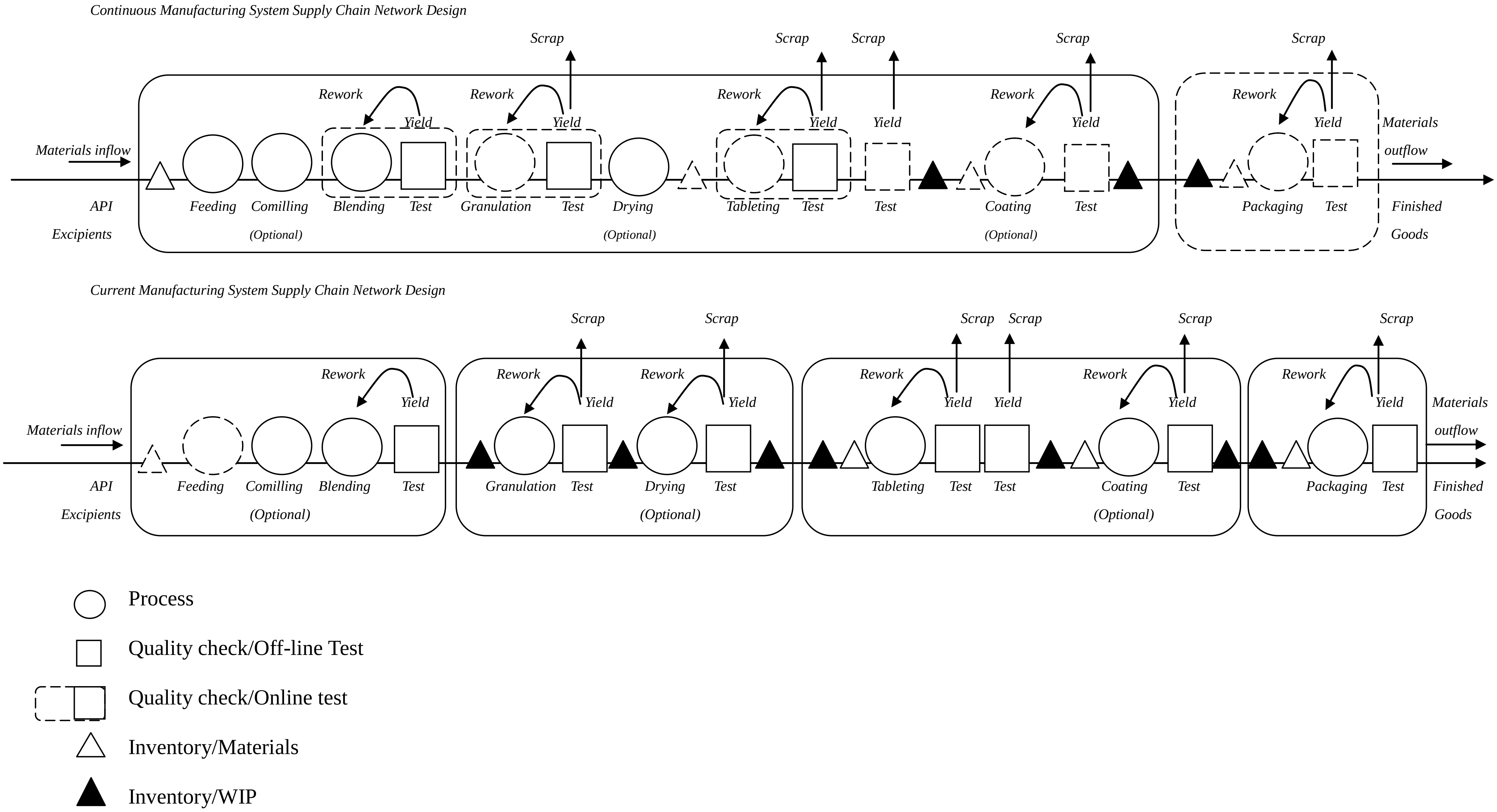
Conceptual models for supply chain design of current secondary manufacturing system and continuous manufacturing system

Next the author makes an attempt to illustrate the impact of continuous manufacturing on part of pharmaceutical supply chain by developing conceptual models of the supply chain design of the current manufacturing system and a continuous one for secondary production facility (Figure 4).

The concepts represent typical secondary manufacturing processes. They start with inflow of APIs and excipients in the system and in this particular case go through 8 different production steps until they leave the system as finished products. One of the main differences between the two systems is that in continuous manufacturing processes are performed without interruption. The current manufacturing requires completion of one process and then transfer to the next one and inventory keeping between the different processes. The innovative manufacturing system suggests significant reduction of work-in-progress in between different production steps and the costs associated with keeping and handling this inventory.

The two conceptual models show also the quality checks/tests that a typical product has to go through. At every quality check it is decided according to the results whether the unfinished products that are tested will move downstream towards the system's exit, or they will be returned for rework, or they will go out of the system as scrap. In the continuous manufacturing conceptual model half of the tests are performed online which allows better process control. In contrast, the current manufacturing requires quality tests to be performed off the line.

Figure 3: Continuous and current manufacturing system supply chain design for secondary pharmaceutical production



Limitation for these conceptual models is that they are developed not for a specific product, but for a general one, Different products may not include all 8 production steps or may have additional ones. Moreover, the full potential of continuous manufacturing may not be captured with a general conceptual model. For example, it is suggested that continuous manufacturing in some cases will allow reduction of production steps or change in the raw materials requirements (for example elimination of solvent). Investigation of such cases will reveal the real potential of continuous manufacturing in pharmaceutical industry.

Future research aims and objective are related to developing and validation for a similar conceptual model, but for an actual pharmaceutical product, and not only for the secondary production, but also for primary and combination of both. These will suggest alternative supply chain scenarios that are going to be explored and evaluated against different performance indicators in accordance to the specific strategic objectives using simulation modelling.

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Supply Network Resilience: A Review and a Critique of Recent Research[1]

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ABSTRACT

Recent years have seen considerable growth in research on supply network resilience. This has been in part driven by the tragedy of the 2011 Tohoku earthquake and tsunami, and also by increasing concerns with the vulnerability of global supply chains to threats from international terrorism. Many researchers have sought to establish the connection between supply network morphology and resilience, asking the question: are some network structures more resilient than others? In this review, we present a critique of some of this work, focusing on recent contributions by Kim et al (2015), Simchi-Levi et al (2014), Fujimoto and Park (2014) and Olcott and Oliver (2014). We conclude with reflections on the role of the state and the need for participatory planning.

KEYWORDS: Supply chain resilience; robustness; risk

1. INTRODUCTION

The idea of resilience and robustness (and the corresponding ideas of fragility, vulnerability and risk) in supply chain have attracted a great deal of interest in recent years. For example, the number of papers in the Elsevier *Science Direct*™ database using ‘supply chain’, ‘supply network’ or ‘supply base’ in combination with ‘resilience’, "resilient’ or ‘robust’ in title, abstract or keywords has risen from 16 in 2008 to 72 to 2014[2]. This rise has been driven, among other things, by aftermath of the 2011 Tohoku earthquake and tsunami, and in part by increasing concerns with the vulnerability of global supply chains to threats from international terrorism. However, despite this growth of interest, the field remains plagued by definitional and methodological problems. Many authors are at pains to distinguish robustness from resilience (broadly, taking the first to mean the ability to continue uninterrupted in the face of problems, the second being the ability to recover after a disruption – see Read 2005; Monti 2011); however, these distinctions are not applied consistently across papers and some authors make one concept a subheading of the other (Ponomarov and Holcomb 2009; Scholten et al 2014; Durach et al 2015). Furthermore, the conceptual discussions are frequently merged with broader headings such as supply chain risk and vulnerability (Leat and Revoredo-Giha 2013; Rangel et al 2014; Ho et al 2015; Qazi et al 2015; Heckmann et al

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[2] Of course, during this period the total number of supply chain-related papers also increased; however, ‘resilience/resilient/robust’ papers rose from 3.0% to 5.6% of all supply chain papers (defined as those using ‘supply chain’, ‘supply network’ or ‘supply base’ in title, abstract or keyword).

2015), and it is common for different scales of problems (earthquakes at one end, 'glitches' and small-scale stock-outs at the other) to be rolled-together (Sodhi et al 2012).

These conceptual problems exacerbate the methodological problems faced by researchers. For research interested in major catastrophes, one difficulty is that the number of available examples is relatively small, and each is highly determined by a great deal of specific, contingent circumstances: for example, a supply chain disruption associated with a natural disaster may differ in many important ways from disruption arising from war or terrorism or an industrial accident. Generalising to an abstract problem becomes difficult, and research has struggled to find ways of formulating generic theory. Further, supply chain resilience is an important and sensitive issue: firms are unlikely to wish the full extent of their potential problems to be aired in public, making access to research data problematic.

This paper explores supply chain resilience by considering of some of the current literature in the field. It does not attempt a systematic review, but instead picks out four recent contributions for discussion and comparison. The discussion then moves on to offer some tentative ideas about possible future research directions.

2. RESEARCH CHALLENGES IN SUPPLY CHAIN RESILIENCE

One way to think about resilience is to think in terms of a single firm's operations and policies. Examples of studies which have focused at the firm level include Wieland and Wallenburg (2012) and Brandon-Jones et al (2014) and Ambulakar et al (2015). These studies have attempted to use survey data to develop structural equation models (SEMs) showing how abstract concepts interact, for example how a firm's 'agility' interacts with 'robustness' or 'business performance'. Despite being carefully executed and reported, these studies illustrate three fundamental weaknesses. Firstly, they share the problems of all such SEM-driven survey research, relying on the reification of abstract forces or characteristics that are assumed to be universal, stable, meaningful and measurable constructs. Secondly, they are usually based on small samples from often ill-defined populations, normally with data obtained from single organisational respondents. These are generic problems that apply to a large body of management research, but these limitations become particularly acute in settings of great contingency; firms' challenges in respect of supply chain resilience are unlikely to be uniform across industries and geographies, so trying to address the issue with generic theoretical models may be overly ambitious.

Furthermore, such surveys are reliant on the perceptions and understandings of the respondents: if managers have, for example, a false sense of security about the situation of their firm, or a misapprehension about the likelihood of a problem, then opinion surveys of managers are unlikely to penetrate this. In other words, if the interesting thing about supply chain resilience is that it needs information and insights that are not currently prevalent, then there is a natural limit on what insights might be wrung from opinion surveys.

Crucially, the problem with studies at the firm level is that the issue of supply chain resilience is fundamentally an inter-company issue. For example, a firm's agility or robustness is unlikely to be a characteristic of the single firm itself, but is more likely to be a feature of its supply base (and, indeed, downstream customers, and political/economic context).

Some studies have sought to examine the problem from a broader perspective than the individual company; Section Two of this paper examines examples of four different approaches that seek to understand the question of resilience from a multi-firm perspective. Kim et al (2015) provide an analysis that emphasises the morphology of the supply network, framed in the techniques and metrics of network science. Simchi-Levi et al (2014) explore an approach developed to evaluate the supply base of the Ford Motor Company. Fujimoto and Park (2014) provide a conceptual, semi-normative exploration of the way in which manufacturing network design can find an appropriate balance between flexibility and efficiency. Olcott and Oliver (2014) use a qualitative, descriptive account of the aftermath of the Tohoku disaster to draw out managerial lessons for firms. In the next section these studies are briefly summarized and reviewed.

2.1 The Structural/Topological Approach: Kim et al (2015)

Kim et al's paper represents a growing stream of interest in research which seeks to describe supply chain networks using the paradigm of network science (see Wiendahl and Lutz 2002; Battini et al 2007; Borgatti and Li 2009; Bellamy and Basole 2013; Choi et al 2001; Choi and Hong 2002; Choi and Wu 2009; Pathak et al 2009; Kim et al 2011; Hearnshaw and Wilson 2013; Li et al 2013; Sofitra et al 2014; Xu et al 2014; Zeng and Xiao 2014; Kito and Ueda 2014; Kito et al 2015). This approach entails the characterisation of the supply network as a collection of nodes and arcs. In terms of resilience, this kind of approach generally focusses on those nodes and arcs which might be deemed 'critical'; the network elements which, if disrupted, could have the largest adverse effect on the operation of the wider system. This approach has a long heritage and goes back at least to Wollmer's (1963) early work on railways, and has parallels with the network planning techniques used in project management (PERT/CPM – see Kelley 1961). How this criticality is determined broadly divides into two: those approaches in which purely morphological/topological features of the network are used to determine vulnerability, or those in which other (non-morphological) data is invoked.

In the first of these paradigms, it is generally assumed that scale-free networks (in which the distribution of links follows a power law) will have the property of being resilient to random node failures, but vulnerable to failures at key nodes. This property is independent of any other information about the nodes themselves. For example, Watts (2004) uses the case of the Aisin fire (Nishiguchi and Beaudet 1998) as an argument that the resilience of the network is at least in part a function of the topological structure of the network. The general idea is that some network topologies are inherently more resilient/robust than others, an idea explored in a variety of other network contexts (for example Reis et al 2014; Valverde et al).

The paper by Kim et al (2015) is a good example of this stream of research: they offer a proposition that, ceteris paribus, "the structure of a supply network affects the resilience of the supply network". The authors define a network disruption in terms of graph theory, "a situation where there no longer exists a walk between the source(s) and sink node as a consequence of a disruption(s) in nodes or arcs." Following Rivkin and Siggelkow (2007), they use a series of 'toy' models of 12 nodes to illustrate the consequence of different types of disruption. They use this approach to devise a metric for resilience which is given by:

$$Supply\ network\ resilience = \left[\frac{\begin{array}{c}total\ number\ of node\ or\ arc\ disruptions\\ not\ resulting\ in\ network\ disruption\end{array}}{total\ number\ of\ node/arc\ disruptions}\right]$$

In their simulations of the ‘toy’ networks, they show that the small network which most resembles the ‘scale-free’ model is indeed the most resilient, and this leads them to develop the general proposition that “The more closely a supply network follows a power-law for the degree distribution of the nodes, the more resilient the supply network will become.” Indeed, the authors go so far as to suggest that managers could apply a rule of thumb:

> *“Do 20% of the facilities (nodes) have transportation connections (arcs) with 80% of the other facilities (nodes) in the network?” If so, the network structure should lead to higher resilience since it follows the power-law distribution.”*

The paper eloquently argues for the need for a network view of supply chain resilience, and its conclusions are framed with intelligent caveats and qualifications. Nevertheless, four main criticisms can be made of the approach.

Firstly, the approach to resilience is one which interprets the network only in terms of topological configuration; what the nodes and arcs do exactly, or what risks they face, is left out of the analysis. As with other research in this paradigm, some kind of homogeneity of ‘flow’ in the network is assumed. It could be argued that there is a kind of paradox here: Ghosh and Rosenkopf (2014) discuss how one of the purposes of network explanations – in contrast to those that see organizations merely at the atomistic level – is to take a more contextualised view. However, in practice, the ‘structuralist’ view often risks putting too much weight on the topology of network structure and so ends up, ironically, imposing an excessive reductionism. Even when the purity of the network model is augmented with other features (for example, inventory transfers in Fridgen et al’s (2014) Petri-Net approach), the models achieve their mathematical tractability by stripping out contextual information that presumably would be essential for real-life application.

The second criticism is more technical, and concerns the over-simplistic application of the ‘scale-free’ description. In other disciplines, doubts have been raised about the applicability of the concept, often driven by the fact that real networks are too small (or the information sampled from them is too small) for the scale-free label to be particularly meaningful (Khanin and Wit2006; Lima-Mendez and van Helden 2009).

Thirdly, there is the problem that these models tend to reflect a relatively static view of a supply network. In Kim et al’s approach, flow can be redirected down existing arcs in response to a problem, but new links cannot be made. Such models generally fail to take into account the potential for dynamic reconfiguration of the network. This point is explored in more detail in New et al (2013).

Finally, the approach only considers what happens when there is a problem, and assesses how resilient a particular structure is. It says nothing about how the system might recover, which is the focus of the approach taken by Simchi-Levi et al (2014), to which we now turn.

2.2 The Recovery-Window Approach: Simchi-Levi et al (2014)

Simchi-Levi et al's approach is shown a celebrated project which has won multiple awards, including the prestigious 2014 INFORMS *Daniel H. Wagner Prize for Excellence in Operations Research Practice*, and the 2015 *Ford Engineering Excellence Award*. The work resulted from concern within the Ford Motor Company about its supply chain following the experience of the Tohoku tragedy. The model is distinctive in several ways; firstly, it avoids the needs for estimating risks of failure of elements of the chain; secondly, it relies on an adaptive model of the supply network which includes information about how production for particular products could be shuffled around between suppliers in the event of a major difficulty. Central to the model is the idea of TTR (time-to-recovery), which is an estimate of how long it would take for a node in the chain to return to full functionality following a disruption. The model is complex and extensive, and includes product (i.e. simplified bill-of-material information), capacity information and cost estimates.

The analysis proceeds assuming a disruption with a specified TTR, and then removing each node in the model, one at a time, for the duration of the TTR period. In each case, the model then invokes mathematical optimization methods to calculate the optimal response (which could be using up inventory, or moving production to alternative site), and then assesses the overall supply chain performance impact of these optimal changes. The performance impact (PI) can be measured in a variety of ways, including lost production or impact on profits. This PI figure is then allocated to the node, and when the analysis has been completed for all nodes, the results can be scaled so that each node has a score between 0 and 1. The idea is that managers can then focus their attention on those nodes which have a high PI, which may not be major suppliers as measured by volume of spend.

According to Schmidt et al (2014), the model has been useful to Ford; whereas it used to monitor 1,500 supplier sites as part of its supply chain risk monitoring activity, the model showed a total of 2,600 sites requiring extra scrutiny, less than half of which were currently in the monitored group.

The account of the model is very impressive, but there would appear to be some limitations to the approach. Along with other approaches like that of Soni et al (2014), the model works by consolidating a great deal of information into simple quantitative scores. There is a risk that this might occlude more subtle information, such as different types of problems (e.g. impact on quality) that might result from a disruption. Also, despite the sophistication of the optimization in the model, it is inevitable that some simplifications are required in the model formulation; it could be that these simplifications could undermine the validity of the model. Because the model does not attempt to deal with the relative probabilities of failure, it is possible that the model throws up as 'vulnerable' sites which in practice are very unlikely to be a problem. The model, being data hungry and complex, is likely to be expensive to maintain and operate, and so it is also likely that this approach is going to be always limited to large and powerful companies like Ford.

A further limitation of the approach is its focus on evaluating a single type of disruption (a plant that stops operating for a specified time period); it lacks the more holistic risk approach advocated by some other writers (e.g. Faisal et al 2007). Finally, the approach serves to point out nodes in the system that require monitoring and attention, but does not necessarily point to other ways in which systems can be configured for resilience. One approach that does attempt this is that of Fujimoto and Park (2014) which is described in the next section.

2.3 Virtual Dual Sourcing: Fujimoto and Park (2014)

One of the key decisions in sourcing policy is the extent of single sourcing; a strategy that has been extensively analysed in the literature from both normative and theoretical perspectives (Treleven and Schweikhart 1988; Ramsay 1990; Tullous and Lee Utrecht 1992; Hong and Hayya 1992; Berger and Zeng 2006); Burke et al 2007; Inderst 2008; Blome and Henke 2009; Yu et al 2009). In practice, it is commonly found that, in some industries, firms practice a hybrid approach called 'parallel sourcing' (Richardson 1993; Richardson and Roumasset 1995). Using the example of the automotive industry, Richardson highlights that although a single supplier might be used for an item on a particular model, other suppliers are used to supply similar items for other models: this means that it is possible for the customer to shift production from one supplier to another at relatively low cost, reaping many of the operational advantages of single sourcing whilst retaining negotiating leverage over the suppliers.

In some senses, Fujimoto and Park's paper is straight-forward development of this idea, but what is striking about the treatment is that the conception of a manufacturing network offered is much richer than a simple collection of nodes and arcs:

> *"…the supply chain of a given product-as-artefact can be reinterpreted as a chain of value-carrying design information between Thompson's "technical core" processes (Thompson 1967) or between Penrose's "productive resources" (Penrose 1959), each of which is a combination of design information and its medium." (430)*

This focus on a supply chain as a flow of design information rather than physical inventory means that the key challenge presented by a supply chain disruption is seen reallocating capability. Indeed, Fujimoto and Park argue that resilience is about investing in the capacity for rapid capability transfer rather than investing in slack resources (such as inventory or the duplication of production resources). For major disasters, the task is not immediate recovery – so carrying extra inventory is irrelevant to the challenge:

> *"..no matter how much inventory is maintained by some suppliers or how many multiple production lines are in place, they will not ensure the reasonably quick recovery of the whole supply chain of a particular product if the disaster disrupts the production of other parts from other suppliers… it is meaningless to set a goal of 'same-day supply of our part only'. It is more important to set a realistic goal of*

'working together to resume production of all the necessary components for this product in, say, two weeks…" (433)

In concentrating on what happens of the recovery period, Fujimoto and Park's approach is consistent with Simchi-Levy et al's (and some other writers, including Sheffi and Rice 2005 and Melnyk et al 2009), but what is distinctive is the discussion of what policies should be followed to make the actions needed in this period possible. The logic proposed is essentially in keeping with the logic of mixed-model scheduling in the Toyota Production System (Yavuz and Akçali (2007); the increased cost of dynamic flexibility are better than the costs of holding inventory or building in buffers to systems. The arguments of the paper are supported by those in Whitney et al (2014), who argue that (in the absence of the approach suggested by Fujimoto and Park) temporary sourcing diversification is not necessarily an effective solution to supply chain disruption.

Fujimoto and Park's model is derived from interviews and visits to firms in Japan following the 2011 earthquake, and that incident is also the basis of the paper by Olcott and Oliver discussed in the next section.

2.3 Resilience as Collective Response: Olcott and Oliver (2014)

One of the seminal papers on supply chain resilience - Nishiguchi and Beaudet's (1998) account of a fire at a Toyota single source supplier – shows how firms in and beyond Toyota's supply base rallied to support the firm's production after a fire at a single-source supplier. Production of missing parts was rapidly switched to new sites, but only by collective effort of many suppliers responding in a proactive and cooperative way. Olcott and Oliver's paper explores the extent to which a similar pattern of behaviour emerged after the 2011 earthquake, and is based on extensive interviews with affected firms.

The paper is distinctive in bringing an explicitly sociological element to the analysis; the authors explore how the concepts of social capital and Weick-ian 'sensemaking (Weick) can be used to explain how the inter-company collaboration was possible. The authors derive five major lessons:

- *Mitigation of supply chain vulnerability*: here, the authors effectively endorse the approach implied by Fujimoto and Park.
- *Social capital and business continuity planning*: the authors point out the significance of firms being able to reconceptualise themselves as partners in the light of the catastrophe
- *Preparing for co-operation in a crisis*: recommendations are made for firms to undertake Business Continuity Planning as a collective endeavour.
- *The role of industry associations*: the authors emphasise the role played by industry associations as brokers and 'bridges' between firms
- *Rapid sensemaking and development of situational awareness*. The authors use the particular example of the electronics firm Renesas to show how problem solving and information transfer was structured during the crisis.

The importance of collective, collaborative processes in recovery from supply chain disruptions is explored by Brüning et al (2015), who make a series of propositions for further research.

3. DISCUSSION

These recent papers show some of the diversity of current supply chain resilience research, but also point to a growing consensus about some of the issues. Certainly, in all cases, there is an argument for greater knowledge: firms need to know more about their supply networks to be able to both plan for problems and then respond to disruptions when they arise. Further, there is broad agreement that the question of supply chain resilience is a collective problem, and responses need to be formulated in terms of broad participation across supply chain actors.

This brief review has only covered a fraction of the current academic literature on the topic, and the papers do not reflect a complete view of the state of the art. However, it is still sensible to reflect on what might be missing in the approaches described, and to reflect on how work in this field may be taken forward.

In Lim's (2012) review of the aftermath of the 2011 earthquake (an unpublished Masters thesis) one of the key issues that emerges is the extent to which the supply chain recovery process was hampered by situations that extend beyond the traditional orbit of supply chain management. For example, a major constraint on the speed with which production was resumed was problems associated with electricity supply (particularly following the problems at the Fukushima nuclear plant, and in part dependent on controversial government decisions about when and how electricity supplies should be restored; plants faced great uncertainty in knowing when electricity would be resumed.) Similarly, some recover activities were constrained by congestion on roads and ports, which also introduced substantial uncertainty. This raises the question of how indirect, broader issues affect supply chain resilience, and this theme is picked up in a variety of reports on supply chain resilience (for example a 2013 report from the World Economic Forum (Bhatia et al 2013). This refers to the need for public sector/state action, for example in regulation, standard setting and emergency planning. It is probably true to say that for much of supply chain resilience research, the role of governments, the dependence on critical infrastructure, and role of the wider community is relatively neglected.

There may also be something to be learned from some work from other disciplinary perspectives. For example, the work of Lasker et al (2009) has focussed on the need for genuine community participation for disaster planning; the analogy for supply chains could be the need for genuine participation from smaller suppliers. Much of the perspective in the extant work on supply chain perspective is from the view of the large firm (Simchi-Levi et al 2014 being the most acute example of this. Lasker's observations are that planning which does not draw on the knowledge and insights of citizens is likely to produce plans that are highly dysfunctional. Indeed, it is easy to imagine that large firms' approaches for information from smaller suppliers is likely to produce information that would be distorted by the power imbalances between the firms ("Yes, of course we'd prioritise your needs above other customers…") .

It seems unlikely that the issue of supply chain resilience will irecede as an issue for research, and the current explosion of interest has provided a wide range of fertile directions for future investigation.

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Risk and Resilience of Global Supply Networks: ***Identifying and Mitigating the Water Stress Risk of the Californian Wine Industry Supply Chain***

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Keywords: Supply Chain Configuration, External Resources and Water Stress

Topics: (1) Supply Chain Configuration, (2) Risk and Resilience, (3) Natural Capital Theory

Abstract

This paper explores natural capitals (Water, Biodiversity and Eco-system services) in supply chain design from the perspective of water stress. This research builds upon natural capital theory and supply chain configuration analysis approach. Three bodies of literature have been reviewed: water stress, risk management and supply chain. A case study research approach was adopted drawing upon exemplar supply network partners within the Californian Wine Industry supply chain where currently water stress risk exists. A key finding of this research includes an observation that supply chain design needs to include natural capitals usage and stakeholder collaboration. This study advances the supply chain configuration approach by illustrating the significance of internalising natural capitals for supply chain configuration from a risk perspective. This study suggests that natural capitals are significant resources in the supply chain, and supply chain design needs to incorporate collaboration across an extended network of stakeholders. .

Introduction

The Intergovernmental Panel on Climate Change (IPCC) report concluded that *"human interference with the climate system is occurring and climate change poses risks for human and natural systems"* (IPCC AR5 WG2, 2014). Within this context, one of the sustainable development challenges facing the world is meeting the rapidly increasing demands for water (Postel, 2000). This paper focuses on natural capitals and supply chain design from a risk perspective. This research builds upon natural capital theory and supply chain configuration analysis approach.

This paper argues that key industrial sectors have to date taken a narrow view and, at best only understand their internal resources and primary supply chains. Furthermore, this paper suggests that natural capitals are increasingly important to supply chain performance. Instances, such as Coca-Cola's experience in India (Morrison and Gleick, 2004), and Nestlé in Michigan, USA (Barton and Morgan-Knott, 2010), highlights issues in natural resource provisioning such as water. An argument exists that supply chain design should internalise natural capitals, and broaden the notion of network structure to integrate non-traditional supply chain partners. It is within this context that the research question: *How can water stress risk be identified and mitigated within the supply chain?* is defined.

This paper is structured as follows: *Theoretical Foundation*: defines the theoretical arguments which link natural capital efficiency to supply chain performance. *Approach*: describes the research design, conceptual and methodological frameworks, and case study results. *Discussion*: presents an analysis of the findings; and *Conclusion*: describes the implications, the theoretical contribution to theory, and informs future research direction.

Theoretical Foundation

Theoretical concepts and key arguments in the research are drawn from indirect linkages established between the theoretical domains of natural capital and supply chain design. The theory on natural capital defines three types of natural capital stock or flow: 1) resources, 2) sinks and 3) services (Porritt, 2007). This paper uses the provisioning of water as the natural capital resource stock or flow upon which to base the theoretical argument.

Supply chain theory advances the notion of organizational performance as a function of resource-based efficiency across a supply network (Chandra and Grabis, 2007). Three bodies of literature were reviewed: water stress, risk management and supply chain. Water scarcity and water stress have been defined in the literature as a volumetric abundance, or lack thereof, of water supply, and as the ability, or lack thereof, to meet human and ecological demand for water respectively. Compared to scarcity, "water stress" is a more inclusive and broader concept. It considers several physical aspects related to water as a natural capital asset, including water scarcity, but also water quality, environmental flows, and the accessibility of water (i.e., whether people are able to make use of physically-available water supplies). That notwithstanding, many water-related conditions, such as water scarcity, pollution, poor governance, inadequate infrastructure and climate change, create risk for many different sectors and organizations simultaneously. This reality underpins the notion of "shared water risk" or "basin risk", which suggests that different sectors of society have a common interest in understanding and addressing shared water-related challenges.

Much of the theoretical work on supply chain design has been related to internal resource-based efficiency from the perspective of a focal firm across a narrow network structure. Supply chain theory informs our understanding that network structure, value structure, process flow and product characteristics are all resource-based supply chain design considerations. Natural capitals based efficiency has been less explored. Traditionally, supply chain design has not been linked to managing natural capital risk or in collaborating across a broader definition of supply chain partners.

It is observed that conditions of increasing water stress cause supply chain risk. Water risk from the perspective of a supply chain network entity has been commonly categorized into three inter-related types: *Physical Risk:* Having too little, too much, or water that is unfit for use, or inaccessible. *Regulatory:* Changing, ineffective, or poorly-implemented public water policy regulations. *Reputational:* Stakeholder perceptions that a company does not conduct business in a sustainable or responsible manner with respect to water (Sarni, 2011). The notion of water risk vulnerability within the context of supply chain design has been identified as a characteristic impacting performance. Hence the theoretical argument to internalise natural capitals within supply chain design, and to broaden the notion of network structure, value structure, process flow and product characteristics, and to integrate non-traditional supply chain partners.

Given this theoretical argument, four sub-questions are defined: 1) in what way are supply chain partners and their relationships defined? 2) What characteristics of natural capitals are significant to the supply chain? 3) What supply chain risks and vulnerabilities exist? and 4) How should businesses and stakeholders within the supply chain respond?

Approach

This paper used a case study approach to explore this new phenomenon of natural capitals in supply chain design and to answer the question: *How can water stress risk be identified and mitigated within the supply chain?* This type of research question is consistent with the conditions outlined by Yin 2003 as appropriate for a case study based research methodology. The case selection was determined based on regional and industry characteristics. The US State of California was selected as the focal region given its population and hydrological trends. The Californian agriculture sector, specifically wine growing and production, was selected as the focal industry given its economic contribution and reliance upon water. The detailed criterion taken into consideration in company case selection is defined in Table 1.

	Business Model	*Independent Grower*	*Winery Only*	*Integrated Production and Distribution*	*Grower and Winery*
Category	Selection Criteria / Organization	Company A	Company B	Company C	Company D
Supply Chain Activity	Grower	√		√	√
	Grape Procurement		√	√	√
	Producer		√	√	√
	Packaging			√	√
	Bottling				√
	Warehousing				√
	Distribution				√

Table 1 Company Selection Criteria

Furthermore, the research design included the following four steps and techniques: (1) A semi-structured interview consisting of sixteen leading questions was conducted to explore the relationship between external (water) resource usage and the Californian wine industry supply chain. (2) Secondary data gathering was conducted to determine the water stress challenges and preliminary insights into the resulting supply chain vulnerabilities. (3) Plant tours were conducted at each participating company to validate the relationships between external (water) resource usage and supply chain vulnerabilities. This facilitated an enhanced understanding of the supply chain process flows, and supply chain network, product and value structure relative to water intensive processes. (4) Finally, a supply chain mapping was completed to establish an understanding of the key challenges, operational differences and supply chain vulnerabilities. To effectively assess the supply chain vulnerabilities and risks, the supply network risk and resilience framework was used as the conceptual model (Kumar and Srai, 2014). The methodological framework advanced by Srai and Gregory (2008) and extended by Kumar and Srai (2015) was used in this analysis. The data was analysed and is presented in the summary Tables 2 – 5.

Supply Chain Mapping of the Californian Wine Industry					
	Network Structure	**Company A**	**Company B**	**Company C**	**Company D**
Strategic Level (Supply Network Configuration	Supply Network – Vertical Complexity	Tier 1 Suppliers – Seed, Feed / Fertilizer, Herbicide / Pesticides, Fuel, Water, Electricity, Wine Additives, Transportation Companies. Tier 1 Customers – Producers (McGrail Vineyards/ Cabernet, Darcie Kent Vineyards/Petite Sirah); Concannon Vineyards.	Tier 1 Suppliers – Water, Electricity, Wine Additives, Transportation Companies, Wood Barrel Manufactures. Tier 1 Customers – Wine Retailers, Consumers; Tier 2 Customers – Consumers.	Tier 1 Suppliers – Seed, Feed / Fertilizer, Herbicide / Pesticides, Fuel, Water, Electricity, Wine Additives, Transportation Companies, Wood Barrel Manufactures, Bottle Manufacturers, Cork Suppliers, Capsules / Caps Suppliers, Labelling and Cardboard Broker / Printer Tier 2 Suppliers – Glass Manufacturers, Agribusinesses, Cork Growers, Pulp & Paper Mill Manufacturers; Tier 3 Suppliers – Forest & Pulp Mill. Tier 1 Customers – Wholesalers, Distributors, Consumers, Bulk Wine Customers, Private Label Businesses, and Wine Club Members; Tier 2 Customers – Wine Retailers, Restaurants & Resorts; Tier3 Customers – Consumers.	Tier 1 Suppliers – Growers, Seed, Feed / Fertilizer, Fuel, Water, Electricity, Wine Additives, Transportation Companies, Steel Barrel Manufactures, Bottle Manufacturers, Cork Suppliers, Capsules / Caps Suppliers, Labelling and Cardboard Broker / Printer; Tier 2 Suppliers – Glass Manufacturers, Agribusinesses, Cork Growers, Pulp & Paper Mill Manufacturers; Tier 3 Suppliers – Forest & Pulp Mill. Tier 1 Customers – Wholesalers, Distributors; Tier 2 Customers – Wine Retailers, Restaurants & Resorts; Tier3 Customers – Consumers.

	Network Structure	Company A	Company B	Company C	Company D
	Supply Network – Horizontal Complexity	Tier 1 Suppliers – 1 Wente Vineyards Seed Supplies; 1 Municipal Water Supplier	Tier 1 Suppliers – 1 Estate Zinfandel Vineyard, 1 Barrel Supplier, 1 Municipal Water Supplier	Tier 1 Suppliers: 8-10 total of which 2-3 Glass Suppliers (Gallo), 2 cork suppliers, 2 pesticide and 3 irrigation equipment suppliers, 2 packaging suppliers. Tier 2 Suppliers: ink suppliers (water based)	Tier 1 Suppliers – 30 Growers (local); 2 Glass Suppliers (Owens-Illinois), 1 cork (Corticeira Amorim) Tier 2 Suppliers – raw materials, energy, logistics, packaging and capital goods Tier 3 Suppliers - municipal/city systems, wells & surface for water supply
	Supply Network – Spatial Complexity	Tier 1 Suppliers to Focal Company: 5 miles Focal Company to Tier 1 Customers: Bay Area Distribution (50 mile radius)	Tier 1 Suppliers to Focal Company: Sonoma County (75 miles) Focal Company to Tier 1 Customers: Inter-State Distribution (250 mile radius)	Tier 3 to Tier 2 Suppliers: Tier 2 to Tier 1 Suppliers: Tier 1 Suppliers to Focal Company: Glass supplier (50miles); cork supplier (Portugal); Focal Company to Tier 1 Customers: 70 countries including Brazil, Canada, China, Japan, Germany and the Caribbean. Tier 1 to Tier 2 Customers: Domestic and worldwide	Tier 3 to Tier 2 Suppliers: Tier 2 to Tier 1 Suppliers: Tier 1 Suppliers to Focal Company: Glass supplier (2,000 miles); Multiple in CA (Oakland, LA, Tracy & Fairfield); cork supplier (Portugal) Focal Company to Tier 1 Customers: Domestic
	Process Flow (water sensitive)	• Landscape Irrigation, Misters, Harvest Activities, Stormwater residue, Wastewater residue	• Hopper Rinse, Bin Rinse, Crush, Press, Sanitation, Wastewater residue	• Fermentation, Cellar, Tank, Barrel Processing, Centrifuge, Aging, Sanitation, Line Cleaning, Bottling, Laboratory, Tasting Room, Chillers, Bathroom and Break rooms, Transportation, Wastewater, Recycling	• Fermentation, Cellar, Tank, Barrel Processing, Centrifuge, Aging, Sanitation, Line Cleaning, Bottling, Laboratory, Tasting Room, Chillers, Bathroom and Break rooms, Transportation, Wastewater, Recycling

	Network Structure	Company A	Company B	Company C	Company D
	Value Structure	Terroir Grape Variety Grape Quality Grape Yield	Terroir Varietals Aging Assemblage	Terroir Grape Variety Grape Quality Grape Yield Varietals Aging Assemblage Packaging Brand	Terroir Grape Variety Grape Quality Grape Yield Varietals Aging Assemblage Packaging Brand
	Product Characteristics	Fruit Only: Cabernet (clone 337 and clone 8); Petite Sirah	Varietals produced: 10 Zinfandel Chardonnay Syrah Tempranillo Cabernet Sauvignon Barbera Blended Wines	Vine varietals grown: 30 Varietals produced: 20 Estate Grown - Cabernet Sauvignon - Sauvignon Blanc - Chardonnay - Riesling - Merlot Single Vineyard - Chardonnay - Pinot Noir Small Lot - Brut - Cabernet Franc - Muscat - Petite Sirah - Petite Sirah Port - Pinot Blanc - Pinot Noir Rose - Blended Wines Nth Degree - Cabernet Sauvignon - Chardonnay - Merlot - Pinot Noir	Varietals produced: 13 Chardonnay Sauvignon Blanc Pinot Grigio Riesling Gewürztraminer Moscato Cabernet Sauvignon Merlot Pinot Noir Shiraz Zinfandel White Zinfandel Malbec

Table 2 Within-case Summary – Supply network configuration analysis

Organization Name	Farmed Acers	Varietals	Product Structure	Network Relationship	Network Role / Governance	Distribution
Company A	62	3	Make-to-Specification	Strong, Transactional	Principle Supplier	Regional
Company B	N/A	10	Seasonal	Transactional	Principle Customer	Inter-State
Company C	960	13	Traditional	Integrated	Leader	Domestic
Company D	3,000	30	Innovative	Strong, Integrated	Leader	International

Table 3 Cross-case analysis – Supply network configuration

Process Flow	Metric	Metric Usage Benefits	Data Elements	Data Sources
Vineyard – Water Use	Water Use Efficiency = Acre-inches Applied / Acre = Acre-inches Applied / Ton of Grapes	Environmental and societal benefits: reducing water use can reduce GHG emissions and enhance water availability for multiple uses. Economic benefits: reducing water use can save money and potentially reduce future regulatory compliance costs.	• Applied water (including for frost protection) • Acreage • Yield (total tons)	Utility records; Flow meter readings
Winery – Water Use	Water Use Efficiency = Gallons Used / Gallon of Wine = Gallons Used / Case of Wine	Environmental and societal benefits: reducing water use can reduce GHG emissions and enhance water availability for multiple uses. Economic benefits: reducing water use can save money and potentially reduce future regulatory compliance costs.	• Water usage • Gallons and cases produced	Utility records; Flow meter readings

Table 4 Vineyard and Winery Water Use Efficiency Metrics

	Company A	Company B	Company C	Company D
Vineyard Efficiency	2.5	N/A	3.0 - 3.5*	2.1
Winery Efficiency	N/A	Unknown		

*calculation based on only estate grown grapes.

Table 5 Vineyard and Winery Water Use Efficiency Metrics – Case Study Organizations

Discussion

Supply Chain Mapping of the Californian Wine Industry

The Californian wine industry supply network structure (tables 2-3) highlights that significant operational diversity exists in terms of vertical, horizontal and spatial complexity. In 2014, global Californian wine shipments were 269 million cases, with an estimated retail value of over $24.6 billion (Wine Institute, 2014). From the perspective of network structure and specifically vertical complexity, the supply chain can be viewed as two processes, 1) the cultivation of grapes for wine (*viniculture*) and 2) the wine making process (*oenology*). Figure-1.

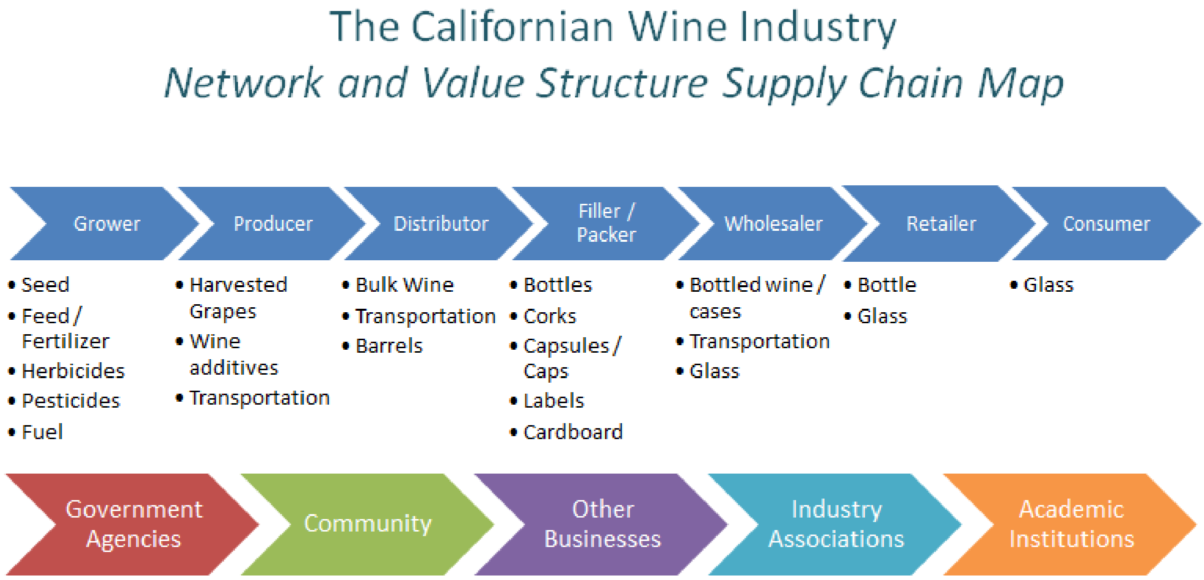

Figure 1: The California Wine Industry Supply Chain Map

From the perspective of spatial complexity, the research findings suggests that the Californian wine supply chain is global in scope, as evidenced by the sourcing of oak barrels from France and cork from Portugal to international wholesale, retail and consumer markets. Furthermore, in the drought stricken US State of California the notion of “shared water risk” or “basin risk” was observed.

The implication of this observation to the relationship between natural capitals and supply chain design is that additional non-traditional supply chain partners such as water districts, other business and residents emerge as stakeholders.

Supply Chain Natural Capitals (Water) Usage within the Californian Wine Industry

A key relationship observed relating to water usage is that the demand for water varies seasonally. “50-60% of a facilities annual water use occurs during the 60-90 day harvest period”, (Company D). It was also observed that the spike in water use during the harvest season was attributable to the facts that: 1) wineries are at their peak operation, generally working twenty-four hours per day / seven-days per week, 2) The operations performed during this period include cleaning and sanitation which is extremely water intense, and 3) These activities coincide with the generally hotter and warmer California weather and the resulting need keep the grapes cool to arrest fermentation.

Water is used extensively for sanitation, and cleaning, cooling and for moving grapes through the production process. The product characteristics are an expression of the number and type of grape varietals grown and produced, for instance, Company C grow thirty grape varietals from which they produce twenty types of wine. Based on the case study findings, a relationship exists between the type of grape varietal and the associated water usage. There is also a significant indirect costs associated with waste water discharge; these costs are incurred in large part due to requirements relating to waste water pre-treatment, permitting licenses and associated effort to monitor and report metrics relating to water discharge (Company D). Figure 2 highlights the natural capitals (Water) usage observed at the case study companies.

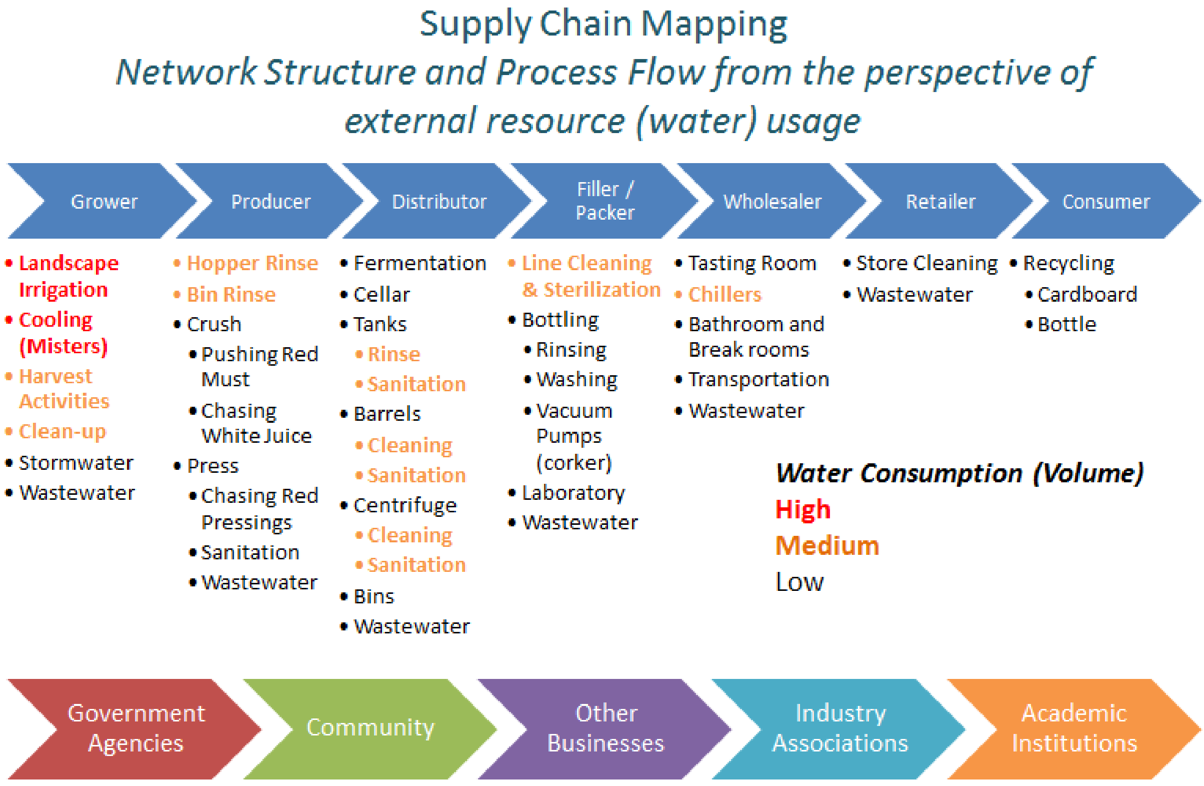

Figure 2: Supply Chain Natural Capitals (Water) Usage Map

Supply Chain Risks Imposed by Natural Capitals Utilization within the Californian Wine Industry

The research has identified particular supply chain risks and vulnerabilities imposed by water stress. An applied configuration approach to supply chain risk management has proved effective in highlighting vulnerabilities and mitigations. Four supply chain risks imposed by water stress have been observed, these are: 1) water scarcity and resulting impact on landscape irrigation, grape quality and yield, 2) water quality and resulting impact on cleaning and sanitation, 3) water quantity and resulting impact on cooling and wine production and 4) water discharge and resulting impact on pre-treatment costs and soil quality.

Three of the four case study companies mitigate water scarcity risk by process flow adjustments enabled by new technology. "For example, at a basic level some wineries use flood irrigation, others use drip irrigation, some deploy high-tech sensors and weather stations while other do not. There is a lot of technological variability across the processes"

(Company A). According to data collected by the Wine Institute, an association of Californian wineries and affiliated businesses; 85% of their grower membership is now using drip irrigation (Wine Institute, 2015). The adoption of water metering technology and product characteristic choices such as white vs. red wine production has been observed as favourably influencing water quantity. Another observation of alternative process flows is a movement away from water for frost protection towards wind technology (Company D). At Company C adjustments to value and network structure was observed as evidenced by their movement into dry farming.

From the perspective of product structure, Company C grows thirty grape varietals from which they produce twenty types of wine. A relationship was observed between the type of grape varietal, and the resulting water quality and quantity risk. For instance, grapes used in the production of white wines such as chardonnay, pinot grigio, riesling and gewürztraminer utilize water significantly for the purposes of tank cooling. Grapes used in the production of red wines, such as cabernet sauvignon, merlot, tempranillo and barbera, varietals of which Company B and Company C feature, while do not have the same cooling demands, do utilize water significantly more when it comes to cleaning and sanitation.

In conclusion, it has been observed that the case study companies have all used elements of network structure (Company C), alternative process flows (Company A, B, C and D), adjusted value structure (Company C) and product redesign (Company C) to mitigate natural capitals risk across the core industrial supply chain.

Californian Wine Industry Supply Chain Response

A key observation that emerges is the influence of non-traditional supply chain partners in mitigating the "basin risk". This perhaps leads us to consider that the scope of supply chain collaboration needs to be broader than the traditional product – supplier relationship. An argument can be presented that supply chain configuration should be extended to examine other industrial partners that operate within a shared water basin or stress zone, such as other businesses, regulatory agencies and community residents.

This perhaps leads us to the following theoretical contribution, that when natural capitals are a factor in supply chain performance, supply chain design needs to incorporate collaboration across an extended network of stakeholders. The following four step framework has been adapted to identify, evaluate and mitigate natural capitals (water) stress with supply chain design is suggested. 1) Map the supply chain from the perspective of network, process, value structure and product characteristics, and to include extended supply chain partners beyond the traditional product – supplier relationship, 2) Define the characteristics of the natural capitals (water) resource stress, 3) Identify natural capitals (water) risks and vulnerabilities, with consideration towards the extended supply chain partners, and 4) Define mitigations that include non-traditional supply chain partner collaboration.

Conclusion

This research focused on the relationship between natural capitals and supply chain design by posing the research question: *How can water stress risk be identified and mitigated within the supply chain?* The case study findings suggest supply chain water stress risk can be identified and mitigated by extending supply chain collaboration beyond the traditional product-supplier relationship to include a broadened set of stakeholders which share “basin risk”. The key findings of this research include:

1) An observation that supply chain network, process, value and product configuration variations exist, and that the extent of natural capitals (water) risk is influenced by supply chain design choices in process flow, value structure and product characteristics.

2) Supply chain collaboration is one of the tools that can applied to manage natural capitals supply chain risk, however the definition of supply chain collaboration needs to be extended to include a broadened set of stakeholders which share “basin risk” such as businesses, regulatory agencies and community residents.

3) A prototype framework for identifying, evaluating and managing natural capitals (water) risk within a supply chain.

4) A theoretical contribution that suggests whenever natural capitals are a factor in supply chain performance, supply chain design needs to incorporate collaboration across an extended network of stakeholders.

Further research is required to explore additional natural capitals risks beyond water stress and across more case study companies. Sector-level differences also need to be further explored to further develop our understanding natural capital and supply chain theory.

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Title: An Expanded Supply Chain Risk Framework: Incorporating the Complexities of Services, Emerging Industries and Large Scale Systems

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Abstract:
Over the last two decades firms, governmental agencies, and non-governmental organizations ("FGNs") have been seeking improved understanding of supply chain management and supply chain risk. In this study we extended the traditional focus of supply chain risk research to additional areas of focus that are of concern to FGN executives, including emerging supply chains, governmental agencies, quasi-governmental agencies, non-governmental agencies, and large scale systems engineering projects that cope with complex technical challenges and multi-year development cycles.

We developed a more comprehensive and more generalized framework of supply chain risk to encompass a broader range of risks and challenges that FGNs must manage. The framework includes traditional areas such as customers, management, operations, sourcing, and logistics and couples them with risks associated with mission and strategy, technological disruptions and discontinuities, sustainability, service supply chains, emerging industries, lean practices and fragility, product development and innovation, economic effects, legal and regulatory challenges, supply chain disruptions, and supply chain design.

In this study we worked with several research partners involved in traditional industries, services, emerging industries, and governmental, quasi-governmental and not-for-profit sectors to review and enhance insights from the study. These and many other industries will be illustrated in the paper. To our knowledge, the framework in this study is the most comprehensive supply chain risk framework to date.

The study and the resulting extended supply chain risk framework were well received by the research partners, which was significantly improved due to their participation. In the paper summarize some of their concerns and insights, prior to drawing conclusions and discussing limitations and future research that arose from the study.

Market Expansion and Firm Value Creation through International Joint Ventures and Strategic Alliances

An Empirical Analysis of Emerging Market Multinationals

Abstract:

The aim of this paper is to examine the impact of internationalization activities of Emerging Market Multinational Corporations (EMCs) on firm performance. We provide an empirical analysis of the value implications of non-equity strategic alliances and joint venture activities that took place during the period of 1991-2012 by using an event study framework and cross-sectional regression analysis. We analyze 538 international expansion announcements entailing 376 joint ventures and 162 strategic alliances associated with 66 Emerging Market Multinationals that originate in Southeast Asia, Latin America and Eastern Europe. Overall, the results of this event study suggest that the market, on average, market reacts negatively to EMC international expansion activities.

1. Introduction

Internationalization of corporations from the emerging markets (EMCs) has been in existence since the 1970s. During that time both the internationalization activities and the size of EMCs were relatively small. However, the internationalization trends that have taken place since the 1970s show indication of their growth over the years. In the 1970s, the total capital investment by EMCs was very small, amounting merely to $120 million. Total foreign sales amounted to $137 billion in 1996, compared to $120 billion in 1995. Although international expansion of EMCs seemed to be sojourned in 1998 with the aftermath of the financial crisis in Asia, EMCs quickly recovered from this setback. The median foreign assets holdings increased slightly from 1.5 billion in 1998 to about 1.6 billion in 1999. In 2012 foreign assets grew by 21 percent and foreign sales by 56 percent.[1]

In the early stages, geographic preferences and expansion strategies of EMCs depended on the interventionist or inward looking policies of home country governments. Since firms affected foreign exchange earnings of their home countries, governments considered their expansions as an instrument of export promotion and motivated EMCs to expand.[2] In recent years, however, outward looking policies of home and host country governments accelerated international activities and expansions of EMCs. The recent increase in international expansions of EMCs is mainly motivated by the changing attitudes and policy regimes of home and host country government, as in the 1990s, most emerging markets and developing countries experienced a shift towards market-oriented economies.

In response to these changes and with the opening of new markets, the scope and the mode of doing business have also been altered dramatically in recent years. In the 1980s, manufacturing was chosen to be the most prominent industry for operations among the EMCs. To pursue their manufacturing operations, a large number of EMCs explored such

[1] UNCTAD, World Investment Report (1995; 1996; 1997; 1998; 2001; 2002).

[2] See R.B. Lall (1986) and Agrawal (1985).

factors as securing and /or accessing a stable supply of raw materials and capital goods, better utilization of capital, gaining new markets, and manpower through economies of scale, as well as obtaining technical know-how and transferring technology.[3] Later, EMCs developed their competitive advantage by matching their competencies, and resources to the environments they operated in. As EMCs accumulated knowledge in managing international operations, they gradually built additional facilities in other countries. Thus, market uncertainty was reduced when firms gained experience and knowledge from other markets with similar conditions and risk was diversified in unstable political and financial systems. As interaction and integration with different market environments increased, EMCs gradually internalized their comparative advantages by investing production facilities in developed countries and established their own subsidiaries in these major markets.[4]

These changes also triggered changes in the modes of international expansions of EMCs. In the early years of expansions, exports were favored for international operations. Especially, Asian and Latin American EMCs carried out trade-related export strategies and/or export led growth strategies and thereby established export businesses as incremental commitments throughout the 1980s.[5] In the early 1990s, however, joint ventures and strategic alliances began to dominate the expansion scene. Besides these activities, the operations of EMCs have come to include, cooperative arrangements, and firm networks.[6] Due to these changes, EMCs have begun modifying their internal operations at intra- and inter-firm levels in a wider geographic access. Today, these multinational corporations hold offices and subsidiaries in more than one developed, developing and/or emerging country. Consequently, EMCs operate and organize their business activities in different international locations in line with their overall firm strategies and relate their technologies according to the environments they operate in.

[3] See, for example, Wells (1977), Agrawal (1981), Jo (1981), White (1981), Ting and Schive (1981), and Agrawal (1985).
[4] See Khan (1986), Lau (1992) and Lim and Moon (2001).
[5] Wells (1977) Chen (1981), and Diaz-Alejandro (1977).
[6] See Kogut (1988), Hennart (1991), Buckley and Casson (1996), and Calantone and Zhao (2001).

Their increasing growth shows that these firms generate efficient allocation of capital and labor, and create various inputs and skills wherever their operations take place.[7]

However, although over the years EMCs signified an increasing growth due to the acceleration of their international activities, our knowledge of various attributes of these firms is limited. In this study, we focus on the internationalization of these firms through cross-border joint ventures and non-equity strategic alliances. We are particularly interested in the value implications of these expansion strategies. More specifically, we analyze the impact of each form of cross-border expansion on the firm value.

To better understand the predictors of wealth creation for EMCs in the international markets, we primarily examine market reaction to cross-border expansion announcements of EMCs. We organize these determinants into three categories: 1) Firm Factors; 2) Industry Factors; and 3) Country Factors (specifically of the target nation). Each category is also divided into subcategories to make sense of the importance of the proposed-determinants. Each category is examined separately within the given length of the event windows.

Our sample includes 66 emerging market multinational firms drawn from the Top 50 non-financial Emerging Market Transnational Corporations list and Top 25 non-financial Transition Economy Transnational Corporations list published in various issues of UNCTAD's World Investment Report. We compiled a total 558 cross-border expansion announcements made by these 66 firms between 1991 and 2012 from Securities Data Corporation's Joint Ventures and Strategic Alliances databases. These transaction announcements entailed 376 joint ventures and 162 non-equity strategic alliances. We used standard event study methodology to capture the impact of each announcement on the firm value around the announcement date. Our results indicate that there is an average

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[7] See Lecraw (1977), Wells (1977;1981), Kumar (1981), Thee (1981), White (1981), Akinnusi (1981), Agrawal (1981), S. Lall (1981), R.B. Lall (1986), and Lau (1992) .

negative abnormal return associated with the cross-border expansion announcement immediately around the announcement date.

The remainder of the paper is organized as follows. In section 2, we provide a brief theoretical-conceptual background for our inquiry and review the evidence in the relevant literature; in section 3, we discuss our data and methodology; in section 4, we present our results, and in section 5, we conclude the study with final remarks.

2. International Expansion through Joint Ventures and Strategic Alliances and Firm Value: Theoretical Implications

In the following section we discuss the value implications of international expansions through joint ventures and non-equity strategic alliances in turn.

Previous studies state that international joint ventures and strategic alliances are strategic tools for firms operating in international markets. They are also a growing phenomenon in cross-border expansion activities of EMCs with which firms respond to globalization of various industries and a rapidly changing international business environment. According to the behavioral view, JVs are also preferred since they are more lenient towards transferring knowledge attaining efficiency, and competitiveness that cannot be acquired through licensing agreements in respective markets (Hanvanich and Cavusgil, 2002).

The impact of strategic interaction in explaining international expansion goes back to the influential work of Knickerbocker (1973). From a transaction cost perspective, JV and SAs offer viable alternatives to acquisitions as hybrids between internalization and arm's length transactions when uncertainty is low and asset specificity is intermediate. Hence, transaction cost theory states that joint ventures can be considered as a trade-off between costs and advantages (Williamson, 1975). Therefore, JVs can be considered as a value creation mechanisms.

Internationalization through JVs and SAs are also seen as risk reducing formations. For example, strategic option theory considers joint ventures as substantially risk reducing mechanisms. This theory also establishes that JVs and SAs can be interpreted as links between the option to wait and the option to invest (Kogut, 1991). Hanvanich and Cavusgil (2000), show that these variations and their risk may be avoided with cross-border expansion activities through international joint ventures. But, firms also consider non-equity strategic alliances, rather than committing to full investment since strategic alliances reduce risk and promote firm value creation as SAs can be efficient for hedging risk since no one partner endures the full risk of the joint project.[8]

The Multinational Network Hypothesis**,** one of the contemporaneous theories that can explain EMC activities postulates that foreign investment decisions improve the expanding firm's ability to benefit from the systemic advantages inherent in a multinational network. The valuation effects of strategic actions leading to creation of a multinational network stem from the firm's ability to arbitrage institutional, and the informational externalities captured by the firm. The cost savings gained by economies of scale in production, marketing and finance also have a role – to the extent that these options can be exercised by the acquiring firm and cannot be traded and acquired by other investors because the value of the firm should increase to reflect the incremental value of these options.[9] For instance, a multinational production network allows shifting of production in response to any large-scale changes in relative prices that can occur globally. The cost structure flexibility helps reduce the average marginal cost of worldwide production relative to that of purely domestic production and results in higher profit margins or greater market share. A similar argument can be made for average output prices in international markets when demand shocks are not perfectly correlated - provided that the costs of creating and maintaining such a diversified corporate network are not excessive. Such a network can add additional value to the firm because of its ability to exploit a larger variety of market conditions.

[8] Porter and Fuller (1986), and Chang and Kuo (2001).
[9] Errunza and Senbet (1981, 1984), and Doukas and Travlos (1998).

Hence, joint ventures and strategic alliances entail interactions and network systems. Today strategic networks and interactions are significant incentives for EMCs since they have a great impact upon value creation. More recent work in this area speculates that strategic linkage theory displays a reason for expansion and value creation of Taiwanese firms (Chen and Chen, 1998). Strategic linkage theory views FDI as an attempt to link some strategic resources that the firm is deficient of, and which are available in a foreign country. Within the network relations international interactions may also increase the operational flexibility of the firm by giving the firm the opportunity to exploit market conditions (Kogut, 1983). This is also true for most firms that originate in Asia, which is illustrated through an examination of Hong Kong firms whose transnational operations are entrenched in networks of relationships today (Yeung, 1997). Hong Kong firms that were once seeking economies of scale in the use of equipment and capital goods and internalizing the use of technology and capital goods (Chen, 1981) are now attempting to minimize risk through international diversification and strategic network linkages.

In some cases firms create flexible and focused organizational formations through strategic alliances. Specifically, in non-equity strategic alliances mutual commitment entails less impact on operations of the affiliating firms than joint ventures (Chan, Kensinger, Keown and Martin, 1997). Since with the formation of a non-equity alliance a new organization is not created, it has been preferred by many EMCs. In this way they can generate new links and disperse quickly when they experience changing demands in the market place. Moreover, strategic alliances can create value for partnering firms and provide flexibility for accomplishing strategic objectives as well as preventing agency costs.[10]

However, agency cost framework also suggests that managers may have the incentives to adopt and maintain value reducing diversification strategies which may not be entirely

[10] Jensen (1986), Mody (1993), and Chan, Kensinger, Keown and Martin (1997).

consistent with shareholder wealth creation. In other words, they may pursue international expansion strategies even if doing so reduces shareholder wealth. Dennis et al (2001) suggest that there may be three factors that motivate managers to expand internationally. First, managing a large, multinational, corporation provides greater power and prestige on the manager as articulated by Jensen's managerial hubris hypothesis and Stulz's empire building motives [see, e.g., Jensen (1986) and Stulz (1990)]. Second motivation stems from the link between the firm size and managerial compensation as established by Jensen and Murphy (1990). Third motivation is related to the manager's risk reduction incentives. As argued by Amihud and Lev (1981), to the extent that the cash flows of global segments are imperfectly correlated, global diversification reduces the risk of the manager's relatively undiversified personal portfolio. If these private benefits exceed the manager's private costs, the firm may pursue global diversification that is not consistent with shareholder value creation.

On the other side of the coin, collaborations initiated through JVs and SAs remain difficult to manage, particularly because of the potential mismatches in the goals and aspirations of organizations domiciled in two or more countries. Despite the initial good intentions and rational motivations behind them, JVs and SAs may not prove compatible with the strategic objectives of companies involved. Consequently, international joint ventures and SAs often prove to be unstable and unsuccessful.

These modalities have been increasingly used in international expansion activities of EMCs. Certainly, the increased use of joint ventures and strategic alliances by EMCs over the years contributed to their increased international market penetration and configuration of their multinational network. However, as previous literature indicates that value creation is interdependent with a variety of factors that can be generally classified as firm-specific, industry-specific and target country specific factors. We evaluate the influence and implications of these factors on the value attained by internationally expanding EMCs.

According to the extant literature, industry specification of a firm does indeed affect the expansion decision and the type of expansion activity (Brouthers and Brouther, 2000;

Shimizu et al, 2004). In this study, we see the importance of industry activities of EMMs in their international expansion patterns. Thus, we examine the market reaction to firm expansion by including two categories - hi-tech and manufacturing (non hi-tech), as most EMMs are now involving more hi-tech related activities and not just manufacturing interests as once they used to.

Here, market reaction to pre-expansion announcements reveals the following:

3. Data and Methodology

Data

The cross-border announcements analyzed in this study are associated with 66 emerging market multinationals which are compiled from Top 50 non-financial Emerging Market Transnational Corporations list and Top 25 non-financial Transition Economy Transnationals list published in UNCTAD's annual publication World Investment Report. Non-equity strategic alliances and joint ventures announcements data for 1991-2012 period are extracted from the Securities and Data Corp.'s (SDC) Worldwide Mergers and Acquisitions database. Equity returns and company accounts data are compiled from DataStream International. .

We identify a total 558 cross-border expansion announcements made by the 66 firms included in our sample between 1991 and 2013. These transaction announcements entailed 376 joint ventures and 162 non-equity strategic alliances. Our sample firms originate from diverse regions, mainly from the emerging market economies, such as Latin America, Asia Pacific, South Asia, Central and Eastern Europe, and South Africa. The also operate in a range of industries

Methodology

Method One: Event Study

We utilized standard event study methodology to evaluate the impact of each expansion announcement on the firm value. The event-study methodology is inspired by the efficient market hypothesis (Fama, Fisher, and Jensen, 1969) that capital markets are efficient instruments to evaluate and process the impact of new information available on firms. The principal logic of the hypothesis is the credence that investors in the capital markets oversee publicly available information on firm to assess the impact of firm activities, not just on current performance but the performance of the firm in the future as well. Furthermore, an event study discloses the impact of firm strategic decisions on shareholder value, and captures the firm's performance on market share. In addition, it makes a benchmark available to compare outcomes of these strategic decisions across firms, industry, and other firm and market characteristics.

Traditionally, the market model is assumed to be the underlying return process. The market model assumes a linear relationship between the return of any security and the return of the market portfolio. For each security i market model assumes that returns are given by:

$$R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_t \text{, where} \qquad (1)$$

$E[ei]=0$ and $Var[eit]=\sigma^2 ei$

and where Rit is the return on security i at time t. The subscript t indicates the time, the subscript i indicates a specific security, and the subscript m indicates the market. Rmt is the return on the market portfolio during period t. The model's linear condition arises from the assumed normality of returns. The ε_t is a random error term for security i at the time of t, and the βs are firm specific coefficients to be estimated.

Equation (1) is estimates a 255 - day estimation period from t = -11 to t = -265 where t = 0 is the event day. In this study, the window is defined as the period between 10 days prior to the event to 10 days after the event. By the estimated regression parameters, α and β from equation (1), a normal return during the event window is predicted. The estimated model is used to predict returns for the security during the event window (t = -10..10). The abnormal return (AR) due to the announcement on any given day of the event window is therefore equal to the actual return minus the predicted normal return, given by the prediction error:

$$AR_{it} = R_{it} - \alpha_i + \beta_i R_{mt} \tag{2}$$

Daily abnormal returns are then computed within the particular event window for each expansion. To obtain a general insight of the abnormal return observations of each expansion announcement, the abnormal returns for a sample of *N* firms a daily average abnormal return (AR) for each day *t* is calculated as the following:

$$AR_t = \frac{1}{N}\sum_{i=1}^{n} AR_{it} \tag{3}$$

Assuming that the returns on each day are independent, the standard errors are cumulative; therefore, the proper standard error is the cumulative standard error. This is due to the fact that adding independent normal variables requires adding the cumulative standard errors. Thus to précis the abnormal returns over the entire 21-day-event window yields the Cumulative Abnormal Returns (CARs):

$$CARt = \sum_{i=1}^{n} ARit \tag{4}$$

To further test for the impact of each expansion during the event window (T_1, T_2), the abnormal returns can be added together to find the cumulative abnormal returns $(CAR_i(T_1, T_2))$ for firm *i* over the period (T_1, T_2):

$$CARt(T1, T2) = \sum_{t=T1}^{T1} ARit \tag{5}$$

According to previous researchers suggest that that abnormal performance measures such as cumulative abnormal returns (CARs) are less likely to generate false rejections of market efficiency. In addition, distributional properties and test statistics for cumulative abnormal returns are better understood.[11] However, this study utilizes standardized cumulative abnormal returns (SCARs) to determine whether an international expansion decision taken by an EMC has a material effect on the firm value. Therefore, the following procedure is applied.

To determine whether the abnormal returns are significant, they are standardized where they are divided by the estimated deviations (S). This is done to examine whether the abnormal return is statistically different from zero. The standardized abnormal return (SAR) is calculated as

$$SARt = \frac{1}{N}\sum_{t=1}^{N} \frac{ARit}{Sit} \tag{6}$$

$$SARit = ARit / Sit \tag{7}$$

where residual standard deviation is multiplied by *AR* for each day for each event. In other words, *Si* is the square root of firm $i's$ estimated forecast variance computed as

$$Sit = \left[S_i^2 \left[1 + \frac{1}{N} + \frac{(Rm - \bar{R}m)^2}{\sum_{t=1}^{N}(Rmt - \bar{R}m)^2} \right] \right]^{1/2} \tag{8}$$

where S_i^2 is the residual variance for security i from the market-model regression, *N* is the number of observations during the estimation period, Rm is the return on the market portfolio for the Kth day of the estimation period, Rmt is the return on the market portfolio for day *t*, and $\bar{R}m$ is the average return of the market portfolio for the estimation period - assuming that individual abnormal returns are normal and independent across firms.

In order to test the null hypothesis the study constructs a test statistic using the standardized abnormal returns, which are averaged across the EMCs and summed across

[11] Fama (1998), and Mitchell and Stafford (1998).

the event window to find the standardized cumulative average abnormal returns (SCAR). $SCARi$ for days is given by:

$$SCARi(T1,T2) = \frac{CARi(T1,T2)}{\sigma(T1,T2)} \tag{9}$$

$SCARi$ is obtained by multiplying $CARi$ with $\frac{1}{stdv}$ and then multiplying it by number of days.

The residual variance from the event study is used as the estimated forecast variance for firm *i*. Therefore, SCARs for a range of event windows spanning around the expansion announcement are examined. This examination begins with the standardized cumulative abnormal returns of day –10 through 0, SCAR (-10, 0), and reduce the event window to SCAR (-1, 0), and finally to day 0 through day +1, SCAR (0, +1). Specifically, the study examines the following intervals SCAR (-10, +10), SCAR (-5, +5), SCAR (-10, +5), SCAR (-5, +1), SCAR (-2, +1), SCAR (-1, +1), and SCAR (-1, 0). The SCARs employed in the event study are also utilized as dependent variables in the second (cross-sectional regression analysis) and third (logistic regression analysis) empirical models of this study.

Method Two: Cross – Sectional Regression Analysis

In the past, econometric issues in evaluating abnormal returns have been given vast attention; yet, residuals in cross-sectional regression analysis have been discounted for many years. Recently, different tecniques are being used to identify reasonable conditions that may have inference with abnormal returns.[12] Therefore, in order to examine the impact of activities mentioned throughout the study on performance of EMCs Cross-Regression analysis is utilized.

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[12] B.Espen Eckbo, Vojislav Maksimovic and Joseph Williams. "Consistent Estimation of Cross-Sectional Models in Event Studies." *The Review of Financial Studies* 3 (1990): 343-365.

However, in order to see the differences between expansion types, i.e. JVs *(EXP1)* and SAs *(EXP2),* one way ANOVA is utilized prior to conducting cross-regression analysis. Once the differences are observed cross- regression analysis is applied accordingly. The same procedure is also conducted for the regions, i.e. Asia *(REGION1)*, Eastern Europe *(REGION2),* and Latin America *(REGION3).*

In the cross-sectional regression analysis SCARs by each interval are utilized as the dependent variables (this is true for equations 10, 11, and 12) and in the first analysis regressed against the expansion types in order to observe whether the expansion types have any impact on value creation, meaning creation of positive or negative standardized cumulative abnormal returns (SCARs). This is calculated as follows:

$$SCAR(-1,0) = \beta_0 + \beta_1 FS/TS_1 + \beta_2 EXP1_2 + \beta_3 EXP2_3 + \varepsilon \qquad (10)$$

where, *EXP1*, *EXP2* and *ECOPOLFREE* are dummy variables. This is followed by a similar equation for to test the impact of the regions that the EMCs originate from:

$$SCAR(-1,0) = \beta_0 + \beta_1 REGION1_1 + \beta_2 REGION2_2 + \varepsilon \qquad (11)$$

where, *REGION1* and *REGION2* are dummy variables. The procedure is exercised in order to see if there are any value creation effects of EMCs' country of origin.

In the next cross-sectional regression analysis *SCARs* are dependent variables once more *(SCARs* for the seven intervals utilized in the event study are tested individually) as in the first two analyses and regressed against a predictor variable *FS/TS* (foreign sales to total sales ratio) and thirteen dummy variables. These dummy variables are the same ones that are employed for the event study. They are included here to make further inference with the results from the event study and also to observe whether there is consistency in the findings. The variables that had no previous significance are extracted from the regression. The equation for the cross-sectional regression analysis is as follows:

$$SCAR(-1,0) = \beta_0 + \beta_1 GEOCULPROX_1 + \beta_2 ECOPOLFREE_2 + \beta_3 RELATEDINDSTRY_3 + \beta_4 HITECH_4 + \beta_5 DEVELOPED_5 + \beta_6 FS/TS_6 + \beta_7 INVESTSIZE_7 + \beta_8 LEVELCONTROL_8 + \beta_9 REGION1_9 + \beta_{10} REGION2_{10} + \beta_{11} NOADR_{11} + \beta_{12} 144A_{12} + \beta_{13} LEV1_{13} + \beta_{14} LEV2_{14} + \beta_{15} BID_{15} \beta_{16} PRIOPRES_{16} + \beta_{17} PREVINTEXP_{17} + \varepsilon \quad (12)$$

The next step is to examine whether the expansion activities of EMCs impact on firm performance. In order to have a sound examination several performance measures are utilized as the dependent variables. These performance measures are: *ROA, and ROE*, , where Δ (change in -1 year to 1year, 2 year and 3 year are included in the dependent variables. (-1) year is 1 year prior to the announcement. In order to see if there is any improvement or decrease in the performance measures, post 1, post 2 and post 3 years of the announcement of the expansion are also examined. Here, the *FS/TS, TA* and *TS* are used as the predictor and control variables. The performance equations are as follows:

$$\Delta_1 ROA = \beta_0 + \beta_1 FS/TS_1 + \beta_2 TA_2 + \beta_3 TS_3 + \varepsilon \quad (13)$$

where, *ROA* (Return on Assets) is the dependent variable, Δ_1 is the change in *ROA* post 1 year of the expansion announcement.

$$\Delta_2 ROA = \beta_0 + \beta_1 FS/TS_1 + \beta_2 TA_2 + \beta_3 TS_3 + \varepsilon \quad (14)$$

where, *ROA* is the dependent variable, Δ_2 is the change in *ROA* post 2 year of the expansion announcement.

$$\Delta_3 ROA = \beta_0 + \beta_1 FS/TS_1 + \beta_2 TA_2 + \beta_3 TS_3 + \varepsilon \quad (15)$$

where, *ROA* is, once more, the dependent variable, Δ_3 is the change in *ROA* post 3 year of the expansion announcement. The same procedure is repeated for all the other performance measures utilized in this study.

$$\Delta_1 ROE = \beta_0 + \beta_1 FS/TS_1 + \beta_2 TA_2 + \beta_3 TS_3 + \varepsilon \quad (16)$$

where, *ROE* (Return on Equity) is the dependent variable, Δ_1 is the change in *ROE* post 1 year of the expansion announcement. This process is repeated for post 2 and post 3 year of the expansion announcement.

Method Three:Logistic Regression Analysis

To proceed with the Logit Transformation, negative SCARs are separated from the positive ones and the variables with significance are utilized in the analysis. Where $(Li) = a + bX\text{I}$ is the transformation procedure.

$$a + \beta x = \ln\left(\frac{P}{1-P}\right)$$

where, (22)

$$Li = Logit = \ln\left(\frac{P}{1-P}\right)$$

(23)

and where, ln = log = natural logarithm; P is the proportion of subjects in a group effected; a is the constant; β is the Logit regression coefficient; and Xi is the Level of the independent variable . Instead of the slope coefficients (β) being the rate of change in Y (the dependent variables) as X changes, the slope coefficient is interpreted as the rate of change in the "log odds" as X changes. If x increases by 1, $\ln\left(\frac{P}{1-P}\right)$ changes by β. β is used to predict P. If $P \geq .5$ it is put into 1, and if *P*< .5, it is put into 0.
In the Logit analyses, the dependent variables are *SCARs* at the seven intervals, which the study utilizes throughout.

The logistic regression model can be obtained under a large variety of alternative distributional assumptions whereas the multivariate linear approach is only applicable when the assumptions are the set of the independent variables is distributed multivariate normally with a common variance-covariance matrix. Therefore, logistic regression approach performs better when the process departs from multivariate normality, especially in the case that there are dichotomous or zero variables. Consequently, logistic regression can be considered more robust than linear analysis.[13]

Adorning the results and robustness are the main reason for this study to include logistic regression analysis. One other reason for this attempt comes from the advice of Gomes and Ramaswamy (1999) indicating that previous studies assumed a linear relationship between multinationality and performance, but this may not be the case. They also suggest that the stability of the multinationality and performance relationship have not been examined. Therefore, in their study they utilize a curvilinear model, which addresses both the costs and benefits associated with multinationality. [14] Deriving from their work, this study also addresses multinationality, yet it includes logistic regression approach in order to observe the stability of the relationship between multinationality and value creation.

Hence, in this study foreign to total sales (FSTS) ratio is taken into account. The dependent variable is the log of the odds ratio, meaning (SCAR- Interval) - defined as when the odds of (probability of) (FSTS) being positive increases the odds of (probability of) the dependent variable being positive decreases or vice-versa. The reason for the inclusion of the (FSTS) ratio as an explanatory variable is that since it defines the international involvement vigorously and unambiguously, it is the most extensively used and accepted measure of multinationality.[15] Hence, (FSTS) ratio is used as one of the variables in this study to capture the degree of international experience of EMCs and logistic regression approach is included to have sounder results.

4. Descriptive Results

[13] G. Hayden Green, Betsy V. Boze, Askar H. Choudhury and Simon Power. Using Logistic Regression in Classification. *Marketing Research* (1998).
[14] Gomes and Ramaswamy (1999) "An Empirical Examination of the form of the relationship between Multinationality and Performance."
[15] Sullivan (1994), and Aybar, Kan and Milman (2002),

4. a. Firm-Specific Factors

All Expansion Activities/ Expansion Type:

SCARs JV Expansions. Total number of events considered 387. When JVs are considered, positive means outweigh the negative ones. However, the mean values are not statistically significant except during the interval (-5, +5) where the z value for the positives/negatives test is significant at 10 percent level and where market reacts positively to 46.51 percent of JV expansions. Positive market reaction to JV announcements at (-10, +10) interval is 45.74, which is significant at 10 percent level. However, mean value for SCARs is negative. The mean values suggest some value creation at the intervals, (-10, +5), (-5, +5), (-5, +1), (-2, +1) and (-1, +1), 50.65 percent, 46.51 percent, 49.61 percent, 47.80 percent and 49.61 percent positive market reaction respectively. However, median significance levels tested by Wilcoxon signed-rank test and positives/negatives significance levels tested by Doukas' *z* test are mostly negative and not statistically significant. Especially, around the announcement day mean and median values are negative and not statistically significant. Significant response the announcement is captured only during the intervals (-10, +10) and (-5, +5). (See Table 1, Panel 1, Appendix A)

SCARs SA Expansions. Total number events considered 159. SA announcements show some value creation for EMCs since the mean and positives/negatives test, and most medians are positive in two windows. The market also reacts positively to most announcements where overall average for intervals is 52 percent. Positive market reaction to SA announcements are significant at (-10, +10) 52.83 percent and (-10, +5), 53.46 percent at 5 percent and 10 percent levels respectively. The rest of the intervals also show positive market reaction at (-5, +5), (-5, +1), (-2, +1), (-1, +1) and (-1, 0), however, no statistical significance is indicated. Overall, results imply that cross-border expansion through SAs may create positive market reaction and value for EMCs. However, this is only apparent within the long windows. (See Table 1, Panel 1, Appendix A)

Overall, the results of ANOVA and the cross-sectional regression analysis are consistent with the findings of the event study. ANOVA results indicate that SA type of expansions positively impact on value creation as all mean values of SAs are positive at all intervals. JVs seem to impact at a lesser level on value creation, but indicate that there is value creation in general. JVs have some positive impact on value creation at various intervals and negative on the others; however, the positive impact is much less than that of SAs. This is consistent with the Event Study results. (See Table 1, Appendix B)

This is also confirmed by the cross-sectional regression analysis, meaning, SAs impact positively on value creation. JVs also denote positive correlation with abnormal returns and value creation, but the value creation is less than that of SAs. These results are consistent with the results of ANOVA and event-study analysis. These results are indicated by the following descriptive analysis. When JVs are examined, there is some value creation. This is indicative of the following. Value creation is apparent at the interval (-10, +5) as the values show coefficient is [1.5053], *t* value is [1.73] and the *p* value is [0.087] statistically significant at 5 percent level. Drawing from the results, it can be assumed that SAs impact on value creation more positively as opposed to JVs However, as SAs show positive impact on value creation, the FSTS ratio increases at longer intervals. For example, at (-10, +10) where *t* value is 1.39 significant at 10 percent level and (-5, +5), with a *t* value of 1.64 significant at 5 percent level – therefore, indicating positive correlation with multinationality in the long run. (See Table 2, Appendix B)

Regions:

SCARs – EMCs' Region Asia (JVs). A total of 360 events are examined in order to make sense of the JV cross-border expansions of EMCs that originate in Asia. The statistically significant values are at (-10, +5) and (-10, +10). At the interval (-5, +5), the market reacts positively to 46.11 percent of all events where mean SCARs are positive, but median SCARs are negative. At this interval, the only statistically significant value is the z value for positives/negatives, which is at 10 percent significance level and it is negative. At the interval (-10, +10), the positive market reaction is 45.28 percent and the negative median z value is at 10 percent significance level. Here, the z value of for the positives/negatives is at 5 percent significance level and it is also negative. Therefore, it can be assumed that value creation and positive market reaction may not be apparent after the interval (-5, +5). (See Table 2, Panel A1, Appendix A)

SCARs – EMCs' Region Asia (SAs). Total of 149 expansion events considered. When EMCs from Asia expand internationally through SAs, the market seems to react positively to the announcements. Although SCARs are positive at all intervals, the statistically significant ones appear during larger windows. At the interval (-10, +5), the market reacts positively to 53.02 percent of all events where the mean significance level of the z value is at 5 percent. At the interval (-10, +10), the market reacts positively to 51.68 percent of all SA announcements of the Asian EMCs wit the mean z value significance is at 5 percent. Therefore, positive market reaction may not immediate but may appear in the long term. (See Table 2, Panel A2, Appendix A)

SCARs – EMCs' Region Latin America (JVs). Total of 20 events considered. When JV announcements of EMCs from the Latin American region are examined, the results clearly supports value creation and positive market reaction, as most SCAR values are positive and statistically significant except at the interval (-10, +10). The statistical significances of the values are noticeable at the following intervals. At the interval (-2, +1), the market reacts positively to 65.00 percent of all announcements with the significance levels of z values for both the mean and the median are at 5 percent level and the significance level for the z value of positives/negatives is 10 percent. At the interval (-5, +1), positive market reaction is 70.00 percent with the z value significance levels for both the mean and the median at 10 percent and for the positives/negatives at 5 percent.

At the interval (-5, +5), the market reacts positively to 65.00 percent of all events where the z value significance level for both the mean and the median is at 5 percent and the z value significance for positives/negatives is at 10 percent. Finally, at the interval (-10, +5) positive market reaction is 70.00 percent again, with the mean z value, 10 percent, and the median and positives/negatives z value are at 5 percent level of significance. The results indicate that there is definite value creation and positive market reaction, as all statistically significant results are positive. Value creation and positive market reaction are mostly apparent and statistically significant after the intervals (-1, +0) and (-1, +1). Therefore, the value creation and positive market reaction may both show during longer intervals. (See Table 2, Panel B1, Appendix B)

SCARs – EMCs' Region Latin America (SAs). Total of 9 events included. There is a definite evidence of positive market reaction and value creation for EMCs that originate in Latin America and expand internationally through SAs. Results indicate that all SCARs are positive at all intervals and positive market reaction averages around above 60 percent. At the interval (-1, 0), the market reacts positively to 66.67 percent all announcements where the mean significance value is at 10 percent. At the interval (-1, +1), positive market reaction does not change but the mean significance levels increases to 5 percent where the median significance levels is at 10percent. At the interval (-2, +1), the positive market reaction stays the same at 66.67 percent with mean significance at 5 and the median significance level at 10 percent. At the interval (-5, +1), positive market reaction decreases to 55.56 percent where mean significance value is at 5 percent. At the interval (-5, +5), the market, once more, reacts positively to 66.67 percent of all events where the significance level for the mean z value is at 10 percent. At the interval (-10, +10), the market reacts positively to 77.78 percent of all events where the mean and the positives/negative significance values are at 5 percent. Market reaction are both immediate and long term and mostly positive. All SCARs are positive and statistically significant at all intervals. (See Table 2, Panel B2, Appendix A)

SCARs – EMCs' Region Eastern Europe (JVs). Total number of events considered 3. The results show the SCARs of EMCs from the Eastern Europe region and that expand through JVs do not experience value creation, as all SCARs are negative and positive market reaction is minimal. Furthermore, significant values are only at the interval (-1, 0) where the market reacts positively to 0.00 percent of all announcements with z value significance levels of 10 percent for the mean, 10 percent for both the median and the positives/negatives. Therefore, it can be assumed that there may not be any value creation for EMCs that originate in Eastern Europe when they expand through JVs. In addition, market does not receive these announcements positively. (See Table 2, Panel C1, Appendix B)

There were no Eastern European EMCs that expanded internationally through strategic alliances in our data base.

When cross-regression analysis results on EMC regions are observed, it becomes evident that the EMCs from the Eastern European region seem to have very little or no value creation as compared to the EMCs from Asia and Latin America. The mean values of EMCs from the Eastern European region are negative at all intervals. The results also indicate that EMCs from the Latin American region seem to experience more value creation than the EMCs from Asia. (See Table 17.3, Appendix C) Logistic Regression analysis results: The variables Region 1 and Region 2 indicate positive values with *z* value significance levels at 1 percent for both. Therefore, it can be assumed that if the EMMs are from Asia, the odds of SCARs being positive increase. However, if the EMMs are from Latin America this probability increases further. This is inconsistent with the cross-sectional regression analysis. Then again, at the interval (-5, +5) this probability decreases for SCARs of EMMs from Asia. This result is significant at 10 percent level. (See Table 19, Appendix C)

Investment Size:

Highly Valued Transactions (JVs). This examination considers 80 events in order to observe whether large size of investments have any impact on market reaction and firm value creation. SCAR values seem to follow a pattern in which they are all positive. In addition, positive market reaction is also considerably over 50 percent for all announcements. However, the only statistically significant z value is observable at the interval (-10, +5) where the market reacts positively to 60.00 percent of all events and where the z value for the positives/negatives is at 5 percent level. Therefore, it can be concluded that positive market reaction is existent during longer event windows and not on the announcement day for EMCs that invest highly in their joint ventures activities (See Table 3, Panel A1, Appendix A)

Highly Valued Transactions (SAs). In this examination there are only 5 events. When EMCs that expand through SAs invest in highly value business deals, there may be some value creation and positive market reaction; however, positive SCARs are not statistically significant. The only significance is at the interval (-5, +5) for the z value of the positives/negatives, which is at 10 percent. Yet, SCAR values are negative and the positive market reaction is only 20.00 percent. Therefore, higher value investments may induce some value creation or positive market reaction for EMCs that invest through SAs. (See Table 3, Panel A2, Appendix A)

Least Valued Transactions (JVs). There are a total of 78 events to test whether smaller investment sizes have any impact on the JV expansions of EMCs. According to the results, there is an overall value creation and positive market reaction; however, the values are not statistically significant. The results are as follows: At the interval (-5, +1), the market reacts positively to 57.69 percent of all events with the positives/negatives z value significant at 10 percent. At the interval (-10, +5), positive market reaction is 58.69 percent with both the mean and the positives/negatives z values significant 10 percent level. Therefore, it can be assumed that positive market reaction is actualized during longer event windows. (See Table 3, Panel B1, Appendix A)

Least Valued Transactions (SAs). There are only 5 least valued transactions for SAs. There is no value creation when EMCs that expand through SAs take part in low value investments. In addition, positive market reaction does not appear to be higher than 20 percent during the first 5 intervals, which actually reduces to 0.00 percent during the last two intervals. All SCARs are negative and statistically significant at all levels and at all intervals. At the interval (-1, 0) and (-1, +1), the market reacts positively to 20.00 percent of all events where the significance level of mean z value is at 5 percent and the significance level of positives/negatives z value is at 10 percent. At the interval (-2, +1) positive market reaction stays the same with the mean z value significance at 1 percent and the positives/negatives z value significance at 10 percent. Negative market reaction is immediate when EMCs that expand through SAs invest in low value business deals. Overall, there does not seem to be any value creation. (See Table 3, Panel B2, Appendix A)

Cross-sectional regression results on investment size show that this study is consistent with previous research that suggests a negative correlation between the investment size and profitability/value creation.[16] When the investment size is large the abnormal returns seem to take negative values. Investment size at all windows shows significance in the cross- sectional regression analysis, denoting that the smaller size investments create value as opposed to the larger size investments. Therefore, it can also be considered that there is a positive relation with abnormal returns and smaller size of investments. All *t* values for the investment size are negative at all intervals and significant at either the 5 percent level or the 1 percent level. For example, SCARs at (-10, +10), (-10, +5), (-5, +5), (-5, +1), (-2, +1), (-1, +1), and (-1, 0) denote the following *t* values: (-2.22), (-3.15), (-2.87), (-2.29), (-3.26), (-3.72), and (-2.21), respectively with significance levels at 5 percent, 1 percent, 1 percent, 5 percent, 1 percent, 1 percent and 5 percent, correspondingly. Therefore, it can be assumed that investment size – when it is large it is negatively correlated with the abnormal returns. This finding is consistent with event-study results. (See Table 17.1, Appendix C)

Similarly, logistic regression results for the interval (-10, +10) indicate that if the investment size is large, the probability of SCAR being positive decreases. The dummy variable for the investment size (1 for large investments) denotes a *z* value significant at 5 percent level. (See Table 19, Appendix C)

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[16] Somnath Das, Prayot K. Sen and Sanjit Sengupta. “Impact of Strategic Alliances on Firm Valuation.” *Academy of Management Journal* 41(1998): 27-41.

Previous International Experience (JVs). To test the impact of previous international experience in value creation of EMCs that expand through JVs and the market reaction towards these expansion announcements, 354 events are employed. The results indicate that there is value creation in general as all SCARs are positive at all intervals except the interval (-10, +10). However, none of the values are statistically significant except the previously mentioned interval. At this interval (-10, +10), the market reacts positively to 46.05 percent of all events and the statistical significance is only visible for the z values of the median and the positives/negatives, which are at both at 10 percent level. As a result, it can be assumed that positive market reaction and value creation may be at intervals close to the announcement date. Therefore, market reaction is immediate. (See Table 4, A1, Appendix A)

Previous International Experience (SAs). Total number of events 149. The results suggest that value creation and positive market reaction are evident when EMCs that have had previous international experience expand internationally through SAs. All SCARs and market reaction are positive at all intervals. At the interval (-1, +1), (-2, +1), (-5, +1), and (-5, +5), the market reacts positively to 50.34 percent, 51.01 percent, 53.02 percent, and 53.02 percent, respectively of all events where the mean z value significance levels, for all, are at 10 percent. At the interval (-10, +5), the market reacts positively to 54.36 percent of all the events with the mean significance at 5 percent and the median significance level at 10 percent. Finally, at the interval (-10, +10), positive market reaction is 53.69 experience. The SCAR values are significant at this interval since the mean value is at 1 percent and the median is at 5 percent. Both the market reaction and value creation are positive and significant at all intervals, except the (-1, 0) interval. This means that on the announcement day market reaction and value creation are not significant. (See Table 4, A2, Appendix A)

No Previous International Experience (JVs). In order to examine the impact of no previous international experience on value creation of EMCs that expand through JVs, 33 events are employed. However, there does not appear to be value creation, as SCARs at all intervals are negative. In addition, positive market reaction is considerable below the

50 percent level at most intervals. These values are statistically significant at the interval (-5, +1) and (-5, +5) where positive market reaction is 39.39 percent 33.33 percent, respectively and the median significance levels are 10 percent and 5 percent, respectively. The mean z value is significant at 10 percent for the interval (-5, +1). The z value significance level for the positives/negatives test is at 5 percent at the interval (-5, +5). (See Table 4, B1, Appendix A)

No Previous International Experience (SAs). Total number of events is 10. There does not seem to be value creation for EMCs that have not had previous international experience and expand through SAs for the first time. All SCAR values are negative and mostly have no statistical significance. However, they may experience positive market reaction up to a degree as some intervals positive market reaction increases to 50percent. At the significant intervals (-2, +1), and (-5, +5), positive market reaction is 30.00 percent for both. Here, the z value significance level for the positives/negatives is at 10 percent for both. The results show that market reaction is mostly negative and not immediate, and there is no value creation. (See Table 4, B2, Appendix A)

4. b. Industry-Specific Factors

Expansion through Related Industry (JVs) Total number of events considered is 257. Here, the results indicate that when EMCs expand through JVs but operate within the related industry there may be some value creation and positive market reaction to these expansion announcements. However, most SCARs are not statistically significant. The only statistical significance is at the interval (-10, +10) where the market reacts positively to 45.53 percent of all events and where the significance level for the positives/negatives is at 10 percent. Then again, at this interval, SCARs are negative. Therefore, it can be concluded that there may be some value creation. In addition, market reaction is not immediate. (See Table 5, A1, Appendix A)

Expansion through Related Industry (SAs). A total of 124 events considered. It is evident that there is value creation and positive market reaction as all SCARs are positive and statistically significant at intervals. Positive market reaction is over 50 percent at intervals. At the intervals (-1, 0), (-1, +1), (-2, +1) (-5, +1) and (-5, +5) all mean significances are 5 percent level and the positive market reaction is 54.03 percent, 50.81 percent, 51.61 percent , 50.81 percent, and 54.84 percent of all the events, respectively. At the intervals (-10, +5), and (-10, +10), the mean and the median significance levels for both are 1 percent and the positives/negatives significance levels are at 5 percent and 10 percent respectively. At the two abovementioned intervals, positive market reaction is 59.68 percent and 56.45 percent, respectively. Both the value creation and positive market reaction begin immediately following the expansion announcement of non-diversified EMCs that expand through SAs. (See Table 4, A2, Appendix A)

Expansion through Diversified Industry (JVs). For this examination, a total of 129 events are included. Results indicate that there is, nevertheless, some value creation when diversified EMCs expand internationally through JVs. In addition, the market may mostly react positively to the announcements. Then again, most of the SCAR values do not have statistical significance. The only statistical significance is seen at the interval (-10, +10) where the market reacts positively to 46.51 percent of all events and where the mean significance value is at 10 percent level. (See Table 5, B1, Appendix A)

Expansion through Diversified Industry (SAs). Total number of events is 31. There is no value creation when diversified EMCs expand internationally through SAs. However, there is a clear evidence of positive market reaction at various intervals. At the interval (-1, 0), the market reacts positively to 41.94 percent of all events where the mean significance is at 5 percent level and the median significance is at 10 percent level. At the interval (-1, +1), the market reacts positively to 41.94 percent of all events with the mean significance at 10 percent level. At the interval (-2, +1) positive market reaction is 45.16 percent where the mean significance at 5 percent and the median significance is at 10 percent. At the interval (-5, +5), the market reacts positively to 41.94 percent of the events where the mean significance is 5 and the median at 10 percent level. At the interval (-10, +5), positive market reaction decreases to 32.26 percent but both the mean and the median significance levels increase to 1 percent and the positives/negatives test becomes significant at 5 percent level. At the interval (-10, +10), the market reacts positively to 38.71 percent of the announcements where the only significance is the mean value at 10 percent level. Market reaction exists immediately after the announcement of the expansion. (See Table 5, B2, Appendix A)

Similarly, logistic regression analysis shows positive increase in the related industry at (-1, +1) and (-1, 0) intervals with *z* values significant 5 percent and 1 percent respectively, the probability of SCAR being positive increases for the EMCs that operate within the related industry. (See Table 19, Appendix C)

EMC Hi-Tech (JVs). A total of 78 events are observed in order to examine the impact of being a hi-tech EMC on value creation and market reaction when expanding through JVs. Overall, the results indicate that there is unambiguous value creation as all SCARs are positive at all intervals and most are statistically significant. Market reaction is also positive and over 50 percent of all events at all windows. Statistically significant values are observed at various intervals. At the interval (-1, +1), the market reacts positively to 52.56 percent of all announcements. The positive reaction is significant as the mean z value has significance 10 percent level. At the intervals (-2, +1) and (-5, +1), positive market reaction is 53.85 percent in both cases where the significance of the mean z values are 5 percent and 10 percent, respectively. At the following intervals (-10, +5) and (-10, +10), market reacts positively, in both cases, to 57.69 percent of all events, with mean z value significance levels at 5 percent for both and the z value for the mean at 10 during the (-10,+5). The z value for the positives/negatives test is significant at the 10 percent level for both intervals and the z value for the median is significant at 5 percent level for both of the intervals. Overall, the results indicate positive abnormal returns and market reaction. In addition, the positive market reaction is both immediate and long-term. . (See Table 6, A1, Appendix A)

EMC Hi-Tech (SAs). Total number of events is 66. When hi-tech EMCs expand internationally through SAs they experience both the value creation and positive market reaction. The value creation and positive market reaction are immediate. At the interval (-1, 0), the market reacts positively to 57.58 percent of all events where the mean value significance level is at 5 percent and the positives/negatives significance is at 10 percent.

At the interval (-1, +1), the market reacts positively to 50.00 percent of all events where the mean value has significance at 5 percent level. At the interval (-2, +1) positive market reaction is 53.03 percent and the mean value is significant at 10 percent level. Positive market reaction is immediately after the expansion announcement. (See Table 6, A2, Appendix A)

EMC Non - Hi-Tech (JVs). A total of 309 events are included to examine whether non hi-tech EMC that expand through JVs experience value creation and positive market reaction during after the expansion announcements. In general, the results indicate that positive SCARs outweigh the negative ones, but not all have statistical significance. Statistically significant intervals include negative SCARs. At both following the intervals (-2, +1) and (-5, +5), the market reacts positively to 46.28 percent of all events, but the SCARs are negative. In both cases, the z values for the positives/negatives show significance at 10 percent level. At the interval (-10, +10), the market reacts positively to 42.72 percent of all events where the mean z value is significant at 5 percent levels, and the median and the positives/negatives z values are significant 10 percent level. Although there is some evidence for value creation, market reaction does not seem to be positive and immediate to the cross-border announcements of non hi-tech EMCs that expand through JVs. (See Table 6, B1, Appendix A)

EMC Non - Hi-Tech (SAs). Total events included is 93. Value creation and positive market reaction are not experienced immediately during the announcements, but experienced in the longer intervals for non hi-tech EMCs that expand through SAs. At the interval (-10, +5), the market reacts positively to 54.84 percent of all events where the mean value significance level is at 5 percent and the median significance at 10 percent. At the interval (-10, +10), the market reacts positively to 58.06 percent of all events with both the mean and the median significance levels at 5 percent and the positives/negatives significance level at 10 percent. Therefore, it can be concluded that both the positive market reaction and value creation are achieved in the long run. (See Table 6, B2, Appendix A)

In this case, logistic regression results indicate that if EMC is a hi-tech firm, SCARs being positive decreases since the values at the intervals, (-1, +1) and (-1, 0) are negative with *z* values significant at 5 and 10 percent, respectively. (See Table 19, Appendix C)

4.c. Target Country-Specific Factors:

Cultural and Geographic Proximity (JVs). A total of 239 events included. Geographic and cultural proximity of target countries seems to be related to value creation of EMCs that chose to expand through JVs. Positive market reaction is also evident at several intervals. However, the values are mostly not statistically significant. Statistically significant values are at the following intervals; however, all SCARs are negative. At the intervals (-1, 0) the market reacts positively to 45.19 percent of all events. Here, the only statistical significance is for the positive/negatives, which is at 10 percent. At the interval (-5, +5), the market reacts positively to 43.51 percent of all events and the z value for the positives/negatives indicates 5 percent significance level. At the interval (-10, +10), the market reacts positively to 45.61 of all the events where the positives/negatives test is significant at 10 percent. (See Table 7, A1, Appendix A)

Cultural and Geographic Proximity (SAs). Total number of events 52. When EMCs expand through SAs into countries that have geographic and cultural proximity to their home countries, the evidence of value creation and positive market reaction seems to be minimal. According to the results most SCARs have negative values during the earlier intervals. Positive SCARs and market reaction appear after the (-5, +5) interval. At the interval (-1, +1), the market reacts to positively to 40.38 percent of all the events where the statistical significance level for the z value of the positives/negatives is at 10 percent and the SCARs are negative. Positive market reaction is on 36.54 percent at the interval (-2, +1) with the z value significance level for the positives/negatives is at 5 percent; here, again, the SCARs are negative. During these intervals, there is no indication of value creation. However, during the (-10, +5) interval, the positive market reaction increases to 53.85 percent and the SCARs take on positive values where the mean z value is significant at 10 percent. Therefore, it can be assumed that positive market reaction becomes apparent after the initial announcement date. (See Table 7, A2, Appendix A)

No Proximity (JVs). Total number of events 148. EMC expansion into countries with no geographical proximity to their home countries through JVs seem to create value for EMCs as SCARs are positive at all intervals except (-1, 0) and (-10, +10). Market reaction is generally positive over 50 percent at most intervals. However, most of these values are not statistically significant. The only statistical significance is at the interval (-5, +1) where the market reacts positively to 55.61 percent of all events and the z value for positives/negatives is statistically significant at the 10 percent level. (See Table 7, B1, Appendix A)

No Proximity (SAs). Total of 107 events included. When EMCs that internationalize through SAs expand into countries where there is no geographic and cultural proximity to their home countries, do experience value creation and positive market reaction. According to the results all SCARS are positive and positive market reaction is over 50 percent during all intervals. The market reaction is also immediate and long term. At the interval (-1, 0), the market reacts positively to 56.07 percent of all expansions where the z value significance level of the positives/negatives is at the 10 percent level. At the interval (-1, +1) the positive market reaction is 54.21 percent with the mean significance value at 5 percent. At the interval (-2, +1) positive market reaction is 56.07 percent with the mean and the positives/negatives z values both at the 10 percent level. At the interval (-5, +1) the market reacts positively to 54.21 percent of the events where the mean significance value is 10 percent. At the interval (-10, +10) the market reacts positively to 54.21 percent of all the announcements with the z value significance level for the mean at 5 and the median at 10 percent. Therefore, value creation exists. (See Table 7, B2, Appendix A)

Logistic regression results indicates that at the interval (-5, +5), geographic and cultural proximity denotes a *z* value, which is significant at 1 percent level. This may mean that the odds of SCAR being positive increases if the EMCexpands into a country that has geographic and cultural proximity to the EMCs home country. However, this is only true for this interval. Therefore, this may mean that geographic and cultural proximity may not be strongly associated with abnormal returns. (See Table 19, Appendix C)

Expansion into Most Politically and Economically Free Countries (JVs). In examining value creation and market reaction of the JV cross-border expansion of EMCs into most politically and economically free countries, 116 events are considered. The results indicate that most SCARs are positive and the market in general reacts positively to the announcements. However, statistically significant values appear within longer windows. Those intervals are (-5, +1), (-5, +5) and (-10, +5) where the all mean are significant at the 10 percent level and where the market reacts positively to 55.17 percent, 48.28 percent and 53.45 percent, respectively. Therefore, it can be concluded that there is value creation and positive market reaction. However, they may be observable during longer periods. (See Table 8, A1**,** Appendix A)

Expansion into Most Politically and Economically Free Countries (SAs). Total of 52 events considered. Positive market reaction and value creation appear at all intervals. However, the only significance is at the interval (-1, 0), where the market reacts positively to 53.85 percent of all events and the z value significance of the mean is at 10 percent level. Therefore, when EMCs expand through SAs into economically and politically free countries market reaction is immediate. (See Table 8, A2, Appendix A)

Expansion into Least Politically and Economically Free Countries (JVs). When EMC entrance into least politically and economically free countries through JVs examined, 100 events are included. Although most SCARs seem positive and that the market generally reacts positively to the announcements, here again, the positive values are not statistically significant. However, negative SCARs maintain statistically significant values. At the interval (-10, +10) the market reacts positively to 41.28 percent of all events where, the mean significance is at 10 and the positives/negatives significance is at 5 percent. (See Table 8, B1, Appendix A)

Expansion into Least Politically and Economically Free Countries (SAs). Total of 50 events considered. The value creation and positive market reaction appear to be at all intervals when EMCs that expand through SAs enter into countries that have less economic and political freedom. However, the statistical significance begins at the interval (-2, +1) where the market reacts positively to only 38.00 percent of all events with the z value significance level for the positives/negatives at 5 percent. At the interval (-5, +5), however, the positive market reaction increases to 56.00 percent where the mean z value is significant at 5 percent. At the interval (-10, +5) the market reacts positively to 62.00 percent of all events where the mean and the positives/negatives significance values are at 1 percent level for both. At the interval (-10, +10) the market reacts positively to 58.00 percent of all events where both the mean and the median statistical significances are at 5 percent level for both. (-5, +5). (See Table 8, B2, Appendix A)

Results obtained from cross-sectional regression analysis also suggest that the variable of economic and political freedom has positive impact on value creation. The results indicate that if EMCs expand into countries that are economically and politically freer, they experience value creation. The findings are especially significant at SCAR (-2, +1) and (-1, +1) intervals. For the interval (-2, +1), the coefficient is (0.10), *t* value is (2.17) and the *p* value is (0.031) with statistical significance at 5 percent level. At the interval (-1, +1), the coefficient is (0.14), *t* value is (2.92) and the *p* value is 0.004, significant at 1 percent. (See Table, 17.1, Appendix C)

Logistic regression results, in this case indicate that at the interval (-10, +10), the probability of SCAR being positive increases if EMC expands into a developed country (politically and economically free), as the *z* value for developed target country is significant at 10 percent level.

Results on Performance

This study includes performance measures a year prior to the announcement and 1 year, 2 years and 3 years after the announcement in order to infer a constructive result on whether the cross-border expansion patterns of EMCs have any influence on firm performance. Usually, 3 years after the announcement is considered the most sound and reliable time period to show profit. Performance tests display that value creation is mostly attained in the long-run for most EMCs. In most cases, their performance improves with time whether they expand through JVs or SAs. When all three years are examined individually, results, in most cases, show improvement in all years, but performance during the post 3 year seemed to improve more as opposed to post 1 and post 2 years.

Cross –Sectional Regression results indicate that Return on Assets (ROA) improves after the expansion announcement as compared to one year prior to the announcement. The values for the first and the second years after the announcement are positive showing gains for EMCs. However, these values are not statistically significant. In the third year after the announcement, there is a definite increase in the *t* value (2.82), which is statistically significant at 1 percent level. While ROA shows an increase, FSTS ratio decreases in all post three years. This decrease is higher in the third year after the announcement. The decrease is also true for Total Assets (TA) for all three post announcement years with a slight improvement in the third year. However, the values for Total Sales (TS) indicate an increase. The increase is higher in the second and especially in the third year, all values are statistically significant. (See Table 18.1, Appendix C)

The results for Return on Equity (ROE) indicate that there is an increase in all three years after the announcement. The increase is more apparent in the first and the second year after the announcement, but these values are not statistically significant. The improvement declines in the third year as compared to the first and the second year; however, the values are still higher than that of a year before the announcement. The significance level is at 1 percent level. Once again, the FSTS ratio significantly decreases on all post three years. This is also true for TA. However, TS shows increase in all three post announcement years, but lesser in the third year. The results are consistent with the results from the ROA examination. (See Table 18.2, Appendix C)

The results obtained from the logistic regression analysis indicate significance mostly at the (-1, +1) and (-1, 0) intervals; however there some significances at the (-10, +10) and (-5, +5) intervals. At (-1, 0) interval FSTS shows a *t* value of (-1.62) significant at 10 percent level. Since FSTS ratio increases negatively, the odds of SCAR being positive decreases at this interval. Therefore, there is a negative inference between the positive SCAR and the FSTS. (See Table 19, Appendix C)

The results obtained from logistic regression analysis show higher probabilities at the (-1, +1) and (-1, 0) intervals denoting that various variables overlooked by the cross-sectional regression analysis may impact on value creation and that this impact may be mostly positive. The logistic regression analysis further supports the findings from the event study and cross-regression analysis, giving this study the added empirical vigor.

5. Conclusion

The cross-border expansion implications on value creation of EMCs for the period between 1991 and 2003. First, the paper explores the impact of cross-border expansion patterns on firm value creation. Second, it examines market reaction to the announcements of cross-border expansion patterns. Third, it evaluates firm performance in relation to the cross-border expansion activities.

Event-study results indicate that JVs can be associated with some positive SCARs. The mean values suggest some value creation at several intervals. However, statistical significance is not great. When SA announcements are taken into account, however, results indicate value as SCARs are mostly positive. Market reaction to this pattern is mostly positive. However, the differences between JVs and SAs do not seem to be very significant.

When observation is on regions, the results imply that when EMCs from Asia expand through JVs, there is value creation at almost every interval. Similarly, when EMCs from Asia expand internationally through SAs, the market seems to react positively to the announcements. Furthermore, the EMCs seem to be able to create value as all SCARs are positive at all intervals. .

When EMCs from Latin America that expand through JVs are taken into account, there is definite value creation and positive market reaction, but this is only apparent at longer intervals. Value creation and positive market reaction are mostly apparent and statistically significant a day after, and a day before the announcement day. On the other hand, there is definite evidence of positive market reaction and value creation for these EMCs when they expand internationally through SAs. All SCARs are positive at all intervals and positive market reaction is immediate. The results indicate that the value creation and market reaction are both immediate and long term.

The results display that positive market reaction and value creation are more long-term for Asian EMCs and more immediate for the Latin American EMCs that expand through JVs. The results suggest that the three different cross-border expansion patterns experience both the market reaction and value creation differently. Therefore, it can be concluded that the pattern of expansion may make a difference in valuation effects of cross-border expansion activities. Furthermore, the regions that the EMCs originate from also make a difference in the way market reacts and in value creation. Most of the other firm factors, industry factors and country factors analyzed above (i.e. event study results) have influence on both the market reaction and value creation in different manners according to each pattern.

When the effects of corporate governance considered if EMCs are listed as Level III, both the JV and the SA types of announcements seem to attract positive market reaction and value creation (not reported in this paper). All things considered, investment size plays a large role in cross-border expansion patterns of EMCs. Investment size is undeniably associated with abnormal returns. This is specifically the case when JVs are considered. When the investment size is small, there seems to be value creation and positive market reaction at longer event windows.

When the target firm is private, the evidence of value creation and positive market reaction is certain for both the JV and SA patterns of expansion. Especially in the case of SAs. Previous international experience may be associated with abnormal returns of cross-border JV and SA activities encounter value creation and positive market reaction. Once again, JVs and SAs encounter value creation and positive market reaction if they have had prior presence in the target country before the expansion announcement.

Furthermore, industry factors suggest that when JVs operate within the related industry there may be positive market reaction to these expansion announcements. In addition, there may also be some value creation when JV expansion activities are diversified. However, results also indicate that non-diversified activities of SAs experience value creation and considerable positive market reaction as opposed to the diversified SA activities of EMCs.

On the other hand, being hi-tech in JV activities does not seem to be associated with positive abnormal returns, as negative market reaction is strongly exhibited in JV expansions. However, when hi-tech EMCs expand internationally through SAs, they seem to experience both positive abnormal returns.

Country factors, as well, have differing affects in different patterns as in the case with both the firm factors and industry factors. When the target county has geographic and cultural proximity to the EMCs home country, the evidence of positive abnormal returns is minimal for SAs but more for JVs. However, JVs expansions seem to experience better value creation when there is no proximity. Overall, geographic and country factors do not seem to have a large effect on value creation and market reaction. In all cases, the distance does not seem to make a difference as values in none of the intervals utilized in this study are statistically significant.

Finally, international expansion into developed countries may effect in value creation and positive market reaction both for JVs and SAs. However, whether the target is located in developed or developing country is not a large determinant in value creation.

Overall, the results obtained from the event-study display that each factor impacts differently on different patterns (i.e. JVs and SAs) and subsequently on value creation. The patterns themselves are unique in the way they influence both the market reaction and value creation.

The contribution to the field of international business of this research is supported by the following empirical findings. Through a strong conceptual analysis, three robust empirical analyses and three mini case studies, this study finds that most EMMs do not earn significantly positive abnormal returns during the event windows defined in this study. Hence, overall results indicate that on average cross-border expansions of EMMs do not create value and that there is evidence for value destruction in cross-border expansions through M&As. Cumulative abnormal returns for JVs are also on average negative, but statistically insignificant. On the other hand, it is generally evident that there is value creation in cross-border expansions through SAs. It is also indicated that most SA announcements are received by the market positively. However, although these findings are consistent with previous research[17], there is no evidence of statistical significance in this study.

Overall results indicate that market reaction and cross-border activities of EMMs are interlinked with each other. The mostly negative abnormal returns and market reaction may be due to information spillovers and information asymmetry. Furthermore, the SCARs obtained for days immediately around the announcement day indicate the presence of other causal factors. Obtaining negative abnormal returns and little value creation mostly in the case of M&A and some JV announcements may not be within the

[17] Shao-Chi Chang and Nicole L. Kuo. "Equity Participation and the Wealth Effect of Strategic Alliances: Evidence from Taiwan." (2001).

firm's control at all times. Events that occur outside the firm's control may have an affect on the firm's operations in some way. In this case, abnormal returns generated by the event may have been anticipated prior to the announcement date due to information leaks or market anticipation. As a result, investors may have modified their expectations of a firm's future profitability as they grasp new information prior to the announcement.[18]

The finding of a negative association between size of the acquisition and abnormal returns suggests value destructive impact of larger acquisitions. This result can be explained by investors' cautious reaction to large size investments in informationally efficient markets. Since large size investments are associated with capital intensity and that financial advantages may take longer to attain, investors may react negatively in the short-run. Complications in target assessment and misidentification of asset complementarities, informational asymmetries, and high premiums paid for the targets may also have adverse affects on the value of acquiring firms.

Another factor that influences value creation is corporate governance structure of firms. The results suggest that good governance is positively associated with cumulative abnormal returns. This may very well be associated with transparency and information disclosure concerns. Hence, investors may react positively to the cross-border expansions of transparent EMCs as they can speculate company returns and future financial gains in advance. EMCs listed as Level III seem to generate positive abnormal returns; therefore, the influence of Level III listing is most effective on value creation. These results suggest the importance of information disclosure and transparency in EMCs business operations. Therefore, it can be assumed that good corporate governance structures are positively related to value creation of EMCs.

A related firm factor to corporate governance is a target firm's status of being private state-owned (SOE). Similar to the positive effect of good corporate governance structures, when the target company is private EMM value creation is positively impacted. Therefore, value creation may be associated with investing in private firms for EMMs as opposed to the state-owned ones. In general, results suggest that acquisitions of state-owned targets are value destructive. This finding may be attributed the fact that during the privatization processes of SOEs, there are a number of financial and

[18] Campell *et al*., (1997).

governance factors that may be unstable. Hence, investors may not react negatively to instabilities that surround the SOEs. In addition, the governments may still have a stake in these target companies. Therefore, investors may not consider these acquisitions positively and may act vigilantly.

Furthermore, the findings suggest that international experience and familiarity with the target market proved to be insignificant. This can be explained by the accelerating cross-border expansions of EMCs as they are becoming more active actors within the larger international picture and by their formations of network ties with other firms in various regions. Hence, the extent of acquiring firm's experience in executing exapnsionss and its organizational capability to absorb the target may affect the impact of the acquisition on the firm value rather than its prior international presence.

When industry is concerned, findings indicate that diversified EMCs' cross-border acquisitions tend to create minimal value for shareholders. This can be indicative of the factor that EMCs, especially large EMCs may be able to form institutions within themselves and through these institutions may be able to finance their diversified operations, and may not rely on external capital institutions - provided that the costs of creating and maintaining a diversified corporate network are not excessive. Such a network can add additional value to the firm because of its ability to exploit a larger variety of market conditions. This finding is consistent with previous research that state that diversification decreases firm value.[19]

Conversely, results also suggest that hi-tech EMCs' cross-border exapansions are value destructive and expansions of manufacturing firms are value enhancing. Since hi-tech operations are more costly and need better allocation of capital value creation may not be attained in the short run. This may also be due to the considerable experience, knowledge and resources that manufacturing firms may have.

In addition to firm and industry level findings results suggest that some target country characteristics have a significant impact on acquiring firms' value creation. More developed institutional infrastructure and overall level of economic development have positive impact on abnormal returns. When EMMs invest in developing countries with

[19] See, for example, Denis et al. (2002) by employing excess value measure and aggregate data illustrate that both international diversification and industrial diversification decrease shareholder value substantially.

less informationally efficient markets they may be face with winners curse (overpayment for the target company). Hence, this may prolong value creation. Moreover, managers may have the incentives to adopt and maintain value reducing diversification strategies which may not be entirely consistent with shareholder wealth creation. In other words, they may pursue international expansion strategies even if doing so reduces shareholder wealth and creates agency cost. The results also indicate that geographic and cultural proximity proved to be insignificant in value creation.

This study illustrates that expanding EMC performance improves overtime whether these patterns are JVs or SAs. In accordance with the performance tests, value creation is mostly attained in the long-run for most EMCs. For the most part, EMM performance improves with time both for JVs and SAs. The examination that considers a time span of three years (individually) after the expansion announcement shows improvement in all three years, but performance during the third year seem to improve more as opposed to the first and the second years after the announcement as compared to a year prior to the expansion announcement.

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Table 1. Panel 1: EMMs' Daily Abnormal Returns (SCARs) JVs

The table presents the Daily Standardized Abnormal Returns (SCARs) of 386 cross-border JV expansion announcements by Emerging Market Multinationals (EMMs) over the 1991-2012 period. Daily Standardized Abnormal Returns (SCARs) are computed from the market model as prediction errors. Day 0 refers to the announcement day of acquisitions as reported SDC Database. Z-statistics [Wilcoxon Sign-Rank Test] is used to test for the statistical significance of mean [SCARs]. The statistical significance of mean [median] difference between groups is computed by One-Way ANOVA [Mann–Whitney Test for unmatched pairs]. Z statistics (Doukas' test) is used to test for the statistical significance of positives/negatives. ***, **, and * denote statistical significance at the 1%, 5%, 10% levels, respectively.

Interval	Mean	Z-Value Mean	Median	WSR Z-Value	Positive: Negative	Doukas Z	Total Number of Transactions	Positive Market Reaction %
(-10,+10)	-0.05028	-1.1571	-0.08471 *	-1.3821	177:210 **	-1.67748	387	45.74%
(-10,+5)	0.012279	0.273406	0.005991	0.006825	196:191	0.254164	387	50.65%
(-5,+5)	0.010926	0.239458	-0.04806	-0.35855	180:207 *	-1.37249	387	46.51%
(-5,+1)	0.039581	0.800561	-0.00404	-0.10579	192:195	-0.1525	387	49.61%
(-2,+1)	0.034992	0.722084	-0.02909	0.171995	185:202	-0.86416	387	47.80%
(-1,+1)	0.038823	0.738628	-0.0081	0.585147	192:195	-0.1525	387	49.61%
(-1,+0)	-0.00723	-0.13808	-0.01907	-0.32329	187:200	-0.66083	387	48.32%

Table 1. Panel 2: EMMs' Daily Abnormal Returns (SCARs) SAs

The table presents the Daily Standardized Abnormal Returns (SCARs) of 159 cross-border SA expansion announcements by Emerging Market Multinationals (EMMs) over the 1991-2012 period. Daily Standardized Abnormal Returns (SCARs) are computed from the market model as prediction errors. Day 0 refers to the announcement day of acquisitions as reported SDC Database. Z-statistics [Wilcoxon Sign-Rank Test] is used to test for the statistical significance of mean [SCARs]. The statistical significance of mean [median] difference between groups is computed by One-Way ANOVA [Mann–Whitney Test for unmatched pairs]. Z statistics (Doukas' test) is used to test for the statistical significance of positives/negatives. ***, **, and * denote statistical significance at the 1%, 5%, 10% levels, respectively.

Interval	Mean	Z-Value Mean	Median	WSR Z-Value	Positive: Negative	Doukas Z	Total Number of Transactions	Positive Market Reaction %
(-10,+10)	0.128218 *	2.033179	0.080097 **	1.632898	84:75	0.713746	159	52.83%
(-10,+5)	0.145428 *	2.099251	0.072351 *	1.349623	85:74	0.872357	159	53.46%
(-5,+5)	0.071921	1.131892	0.013141	0.193415	82:77	0.396526	159	51.57%
(-5,+1)	0.098991	1.312483	0.031298	0.406513	84:75	0.713746	159	52.83%
(-2,+1)	0.097132	1.145736	-0.00212	0.087293	79:80	-0.07931	159	49.69%
(-1,+1)	0.122141	1.363382	-0.00614	0.431332	79:80	-0.07931	159	49.69%
(-1,+0)	0.104508	1.003397	0.033741	0.386829	83:76	0.555136	159	52.20%

Table 2. Panel A1: Daily and Standardized Cumulative Abnormal Returns of Cross-Border Expansion JV Announcements (EMC Region -Asia)

The table presents the Daily and Standardized Cumulative Abnormal Returns (SCARs) of 360 cross-border JV expansion announcements by Emerging Market Multinationals (EMCs) originate from Asia over the 1991-2012 period. Daily Standardized Cumulative Abnormal Returns (SCARs) are computed from the market model as prediction errors. Day 0 refers to the announcement day of acquisitions as reported SDC Database. Z-statistics [Wilcoxon Sign-Rank Test] is used to test for the statistical significance of mean [SCARs]. The statistical significance of mean [median] difference between groups is computed by One-Way ANOVA [Mann –Whitney Test for unmatched pairs]. Z statistics (Doukas' test) is used to test for the statistical significance of positives/negatives. ***, **, and * denote statistical significance at the 1%, 5%, 10% levels, respectively.

Interval	Mean	Z-Value Mean	Median	WSRT Z for Median	Positive: Negative	Doukas Z for Positive: Negative	Total Number of Events	Positive Market Reaction %
(-10,+10)	-0.04681	-1.03012	-0.09114 *	-1.34799	163:197 **	-1.79196	360	45.28%
(-10,+5)	0.006974	0.150243	-0.01431	-0.30771	179:181	-0.10541	360	49.72%
(-5, +5)	0.00793	0.167758	-0.06738	-0.52836	166:194 *	-1.47573	360	46.11%
(-5, +1)	0.041484	0.815749	-0.02186	-0.16499	177:183	-0.31623	360	49.17%
(-2, +1)	0.035857	0.720794	-0.02976	0.051622	170:190	-1.05409	360	47.22%
(-1, +1)	0.045985	0.847009	-0.00519	0.740419	179:181	-0.10541	360	49.72%
(-1, +0)	-0.00372	-0.06796	-0.0148	-0.19763	175:185	-0.52705	360	48.61%

Table 2. Panel A2: Daily and Standardized Cumulative Abnormal Returns of Cross-Border Expansion SA Announcements (EMC Region -Asia)

The table presents the Daily and Standardized Cumulative Abnormal Returns (SCARs) of 149 cross-border SA expansion announcements by Emerging Market Multinationals (EMCs) originate from Asia over the 1991-2012 period. Daily Standardized Cumulative Abnormal Returns (SCARs) are computed from the market model as prediction errors. Day 0 refers to the announcement day of acquisitions as reported SDC Database. Z-statistics [Wilcoxon Sign-Rank Test] is used to test for the statistical significance of mean [SCARs]. The statistical significance of mean [median] difference between groups is computed by One-Way ANOVA [Mann –Whitney Test for unmatched pairs]. Z statistics (Doukas' test) is used to test for the statistical significance of positives/negatives. ***, **, and * denote statistical significance at the 1%, 5%, 10% levels, respectively.

Interval	Mean	Z-Value Mean	Median	WSRT Z for Median	Total Number of Events	Positive: Negative	Doukas Z	Total Number of Events	Positive Market Reaction %
(-10,+10)	0.108167 **	1.695172	0.06855	1.190677	149	77:72	0.409616	149	51.68%
(-10,+5)	0.129134 **	1.858415	0.072351	1.155263	149	79:70	0.737309	149	53.02%
(-5, +5)	0.054838	0.870527	0.002718	0.001914	149	76:73	0.24577	149	51.01%
(-5, +1)	0.061745	0.834648	0.031298	0.189513	149	79:70	0.737309	149	53.02%

(-2, +1)	0.051815	0.613621	-0.01411	-0.30628	149	73:76	-0.24577	149	48.99%
(-1, +1)	0.090315	0.988696	-0.00891	0.0536	149	73:76	-0.24577	149	48.99%
(-1, +0)	0.078274	0.732971	0.029988	-0.10816	149	77:72	0.409616	149	51.68%

Table 2. Panel B1: Daily and Standardized Cumulative Abnormal Returns of Cross-Border Expansion JV Announcements (EMC Region –Latin America)

The table presents the Daily and Standardized Cumulative Abnormal Returns (SCARs) of 20 cross-border JV expansion announcements by Emerging Market Multinationals (EMCs) originate from Latin America over the 1991-2012 period. Daily Standardized Cumulative Abnormal Returns (SCARs) are computed from the market model as prediction errors. Day 0 refers to the announcement day of acquisitions as reported SDC Database. Z-statistics [Wilcoxon Sign-Rank Test] is used to test for the statistical significance of mean [SCARs]. The statistical significance of mean [median] difference between groups is computed by One-Way ANOVA [Mann –Whitney Test for unmatched pairs]. Z statistics (Doukas' test) is used to test for the statistical significance of positives/negatives. ***, **, and * denote statistical significance at the 1%, 5%, 10% levels, respectively.

Interval	Mean	Z-Value Mean	Median	WSRT Z for Median	Positive: Negative	Doukas Z for Positive: Negative	Total Number of Events	Positive Market Reaction %
(-10,+10)	-0.00334	-0.02393	0.099936	0.417092	11: 9	0.447214	20	55.00%
(-10,+5)	0.263065 *	1.466297	0.302428 **	1.77264	14: 6 **	1.788854	20	70.00%
(-5, +5)	0.331771 **	1.861926	0.338254 **	1.668367	13: 7 *	1.341641	20	65.00%
(-5, +1)	0.273875 *	1.222586	0.158313 *	1.251275	14: 6 **	1.788854	20	70.00%
(-2, +1)	0.371548 **	1.802263	0.3909 **	1.598852	13: 7 *	1.341641	20	65.00%
(-1, +1)	0.227136	1.024957	0.152863	0.59088	11: 9	0.447214	20	55.00%
(-1, +0)	0.114247	0.54207	0.135024	0.59088	11: 9	0.447214	20	55.00%

Table 2. Panel B2: Daily and Standardized Cumulative Abnormal Returns of Cross-Border Expansion SA Announcements (EMC Region –Latin America)

The table presents the Daily and Standardized Cumulative Abnormal Returns (SCARs) of 9 cross-border SA expansion announcements by Emerging Market Multinationals (EMCs) originate from Latin America over the 1991-2012 period. Daily Standardized Cumulative Abnormal Returns (SCARs) are computed from the market model as prediction errors. Day 0 refers to the announcement day of acquisitions as reported SDC Database. Z-statistics [Wilcoxon Sign-Rank Test] is used to test for the statistical significance of mean [SCARs]. The statistical significance of mean [median] difference between groups is computed by One-Way ANOVA [Mann –Whitney Test for unmatched pairs]. Z statistics (Doukas' test) is used to test for the statistical significance of positives/negatives. ***, **, and * denote statistical significance at the 1%, 5%, 10% levels, respectively.

Interval	Mean	Z-Value Mean	Median	WSRT Z for Median	Positive: Negative	Doukas Z	Total Number of Events	Positive Market Reaction %
(-10,+10)	0.543493 **	1.635833	0.634011 *	1.480872	7: 2 **	1.666667	9	77.78%
(-10,+5)	0.489189	1.171949	0.235876	1.006993	6: 3	1	9	66.67%
(-5, +5)	0.506876 *	1.340145	0.288563	1.006993	6: 3	1	9	66.67%
(-5, +1)	0.794753 **	1.628149	0.237824	1.243933	5: 4	0.333333	9	55.56%
(-2, +1)	0.917221 **	1.912319	0.423228 *	1.480872	6: 3	1	9	66.67%
(-1, +1)	0.732094 **	1.687354	0.412045 *	1.599342	6: 3	1	9	66.67%
(-1, +0)	0.689751 *	1.462561	0.341026	1.243933	6: 3	1	9	66.67%

Table 2. Panel C1: Daily and Standardized Cumulative Abnormal Returns of Cross-Border Expansion JV Announcements (EMC Region –Eastern Europe)

The table presents the Daily and Standardized Cumulative Abnormal Returns (SCARs) of 3 cross-border JV expansion announcements by Emerging Market Multinationals (EMCs) originate from Eastern Europe over the 1991-2012 period. Daily Standardized Cumulative Abnormal Returns (SCARs) are computed from the market model as prediction errors. Day 0 refers to the announcement day of acquisitions as reported SDC Database. Z-statistics [Wilcoxon Sign-Rank Test] is used to test for the statistical significance of mean [SCARs]. The statistical significance of mean [median] difference between groups is computed by One-Way ANOVA [Mann –Whitney Test for unmatched pairs]. Z statistics (Doukas' test) is used to test for the statistical significance of positives/negatives. ***, **, and * denote statistical significance at the 1%, 5%, 10% levels, respectively.

Interval	Mean	Z-Value Mean	Median	WSRT Z for Median	Positive: Negative	Doukas Z for Positive: Negative	Total Number of Events	Positive Market Reaction %
(-10, +10)	0.004936	0.006845	-0.5217	0	1: 2	-0.57735	3	33.33%
(-10, +5)	0.170191	0.509052	-0.01858	0	1:2	-0.57735	3	33.33%
(-5, +5)	-0.22095	-1.11535	-0.06194	-1.1547	1: 2	-0.57735	3	33.33%
(-5, +1)	-0.106	-0.20546	-0.36004	0	1: 2	-0.57735	3	33.33%
(-2, +1)	-0.82408	-1.21443	-0.875	-1.1547	1: 2	-0.57735	3	33.33%
(-1, +1)	-0.60047	-0.75072	-1.10493	-1.1547	1: 2	-0.57735	3	33.33%
(-1, +0)	-0.70632 *	-1.58585	-0.53643 **	-1.73205	0: 3 **	-1.73205	3	0.00%

Appendix B

ANOVA, Cross-Sectional Regression and Logistic Regression Tables

Table 9.1. ANOVA SCAR versus Expansion Type - Differences between Expansion Types i.e. JVs, and SAs

Exp Type	SCAR (-10, +10)	SCAR (-10, +5)	SCAR (-5, +5)	SCAR (-5, +1)	SCAR (-2, +1)	SCAR (-1, +1)	SCAR (-1, 0)
JV (Mean)	-0.0502	0.0123	0.0113	0.0393	0.035	0.039	-0.007
SA (Mean)	0.1281	0.1452	0.0723	0.0989	0.0971	0.122	0.104
F Value	2.8	3.09	1.39	1.76	1.64	2.95	2.91
P Value	0.061	0.046	0.25	0.173	0.195	0.053	0.055
R2	0.57%	0.63%	0.28%	0.36%	0.33%	0.60%	0.59%
Adj R2	0.37%	0.42%	0.08%	0.15%	0.13%	0.40%	0.39%

Table 9.2. ANOVA SCAR versus Expansion Type - Differences between Expansion Types i.e. Asia, Eastern Europe (EE), and Latin America (LA)

Regions	SCAR (-10, +10)	SCAR (-10, +5)	SCAR (-5, +5)	SCAR (-5, +1)	SCAR (-2, +1)	SCAR (-1, +1)	SCAR (-1, 0)
Asia (Mean)	-0.0053	0.0162	0.0025	0.0125	0	-0.006	-0.041
EE (Mean)	-0.2781	-0.2481	-0.3056	-0.1969	-0.2142	-0.159	-0.168
LA (Mean)	-0.0599	-0.0249	0.0113	0.0623	0.1545	0.076	0.044
F Value	1.82	1.57	2.2	1.02	2.11	0.71	0.59
P Value	0.162	0.208	0.112	0.361	0.121	0.493	0.555
R2	0.37%	0.32%	0.45%	0.21%	0.43%	0.14%	0.12%
Adj R2	0.17%	0.12%	0.24%	0.00%	0.23%	0.00%	0.00%

Table 10.1 Cross-Sectional Regressions: Standardized Cumulative Abnormal Returns of Emerging Market Multinationals (EMCs)

The dependent variable in the regressions is the standardized cumulative abnormal return (SCAR) of EMCs engaged in cross-border expansion over the 1991-2012 period. SCARs are defined over various event windows around the acquisition announcement. Foreign to Total Sales (FSTS) ratio is the percentage of foreign sales of the EMC divided by net sales. All EMC related independent variables refer to the year prior to the acquisition (t=-1). t-values are reported in parenthesis. ***, **, and * denote statistical significance at 1%, 5%, 10% levels, respectively.

Independent Variables	SCAR (-10, +10)	SCAR (-10, +5)	SCAR (-5, +5)	SCAR (-5, +1)	SCAR (-2, +1)	SCAR (-1, +1)	SCAR (-1, 0)
Intercept	-0.5523 (-0.55) [0.581]	-0.7502 (-0.84) [0.401]	-0.7613 (-0.89) [0.374]	-0.8521 (-0.88) [0.383]	-0.685 (-0.65) [0.514]	-0.352 (-0.32) [0.753]	0.811 (0.79) [0.481]
Eco & Pol Freedom 1/ No Eco & Pol Freedom 0					0.10 (2.17)** [0.031]	0.14 (2.92)*** [0.004]	
FS/TS	0.2676 (1.39)* [0.164]		0.2984 (1.64)** [0.101]				

Target Private 1 / Target Public 0						0.4787 (1.36)* [0.175]	
EMM Hi-Tech 1 / Non Hi-Tech 0			-0.2306 (-1.37)* [0.173]			-0.3055 (-1.39)* [0.167]	
No ADR							
Lev 2			-0.6193 (-1.72)** [0.088]				
Investment Size Large 1 / Small 0	- 0.00021659 (-2.22)** [0.028]	- 0.0002699 (-3.15)*** [0.002]	- 0.00024822 (-2.87)*** [0.005]	- 0.0002268 (-2.29)** [0.024]	- 0.0003491 (-3.26)*** [0.001]	- 0.0004113 (-3.72)*** [0.000]	- 0.0002262 (-2.21)** [0.029]
Level of Control High 1 / Less 0	-0.005829 (-2.52)*** [0.013]	-0.003657 (-1.77)** [0.078]	-0.002691 (-1.36)* [0.176]				
EXP1		1.2699 (1.45)* [0.150]			-0.3659 (-2.42)*** 0.016	-0.3954 (-2.44)*** [0.015]	-1.5 (-1.48)* [0.140]
EXP2		1.5053 (1.73)** [0.087]					
R^2	7.60%	8.80%	8.00%	8.70%	6.00%	8.40%	10.80%
Adj-R^2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.00%

Table 10.2 Cross-Sectional Regressions: Standardized Cumulative Abnormal Returns of Emerging Market Multinationals (EMCs) by Expansion Type

The dependent variable in the regressions is the standardized cumulative abnormal return (SCAR) of EMCs engaged in cross-border expansion over the 1991-2012 period. SCARs are defined over various event windows around the acquisition announcement. t-values are reported in parenthesis. ***, **, and * denote statistical significance at 1%, 5%, 10% levels, respectively.

Independent Variables	SCAR (-10, +10)	SCAR (-10, +5)	SCAR (-5, +5)	SCAR (-5, +1)	SCAR (-2, +1)	SCAR (-1, +1)	SCAR (-1, 0)

Intercept	0.12019	0.1279	0.06914	0.09475	0.08784	0.11006	0.09975
	(1.77)**	(1.83)**	(1.01)	(1.28)*	(1.16)	(1.37)*	(1.23)
	[0.078]	[0.067]	[0.312]	[0.200]	[0.244]	[0.172]	[0.220]
Exp1	-0.16704	-0.18109	-0.12308	-0.14339	-0.13553	-0.19339	-0.21537
	(-2.09)**	(-2.21)**	(-1.54)*	(-1.65)**	(-1.53)*	(-2.05)**	(-2.26)**
	[0.036]	[0.027]	[0.125]	[0.098]	[0.126]	[0.041]	[0.024]
Exp2	-0.17039	-0.11563	-0.05787	-0.05545	-0.0528	-0.0712	-0.10712
	(-2.10)**	(-1.39)*	(-0.71)	(-0.63)	(-0.59)	(-0.74)	(-1.11)
	[0.036]	[0.165]	[0.477]	[0.529]	[0.557]	[0.458]	[0.269]
R^2	0.50%	0.50%	0.30%	0.30%	0.30%	0.50%	0.60%
Adj-R^2	0.30%	0.30%	0.10%	0.10%	0.10%	0.30%	0.40%

Table 10.3 Cross-Sectional Regressions: Standardized Cumulative Abnormal Returns of Emerging Market Multinationals (EMCs) by Regions

The dependent variable in the regressions is the standardized cumulative abnormal return (SCAR) of EMCs engaged in cross-border expansion over the 1991-2012 period. SCARs are defined over various event windows around the acquisition announcement. t-values are reported in parenthesis. ***, **, and * denote statistical significance at 1%, 5%, 10% levels, respectively.

Independent Variables	SCAR (-10, +10)	SCAR (-10, +5)	SCAR (-5, +5)	SCAR (-5, +1)	SCAR (-2, +1)	SCAR (-1, +1)	SCAR (-1, 0)
Intercept	-0.0599	-0.0249	0.01125	0.06229	0.15448	0.0764	0.044
	(-0.68)	(-0.27)	(0.13)	(0.65)	(1.58)*	(0.73)	(0.42)
	[0.498]	[0.784]	[0.899]	[0.517]	[0.115]	[0.466]	[0.678]
Region 1	0.05461	0.04108	-0.00876	-0.0498	-0.1545	-0.082	-0.085
	(-0.59)	(0.43)	(-0.09)	(-0.49)	(-1.50)*	(-0.74)	(-0.76)
	[0.558]	[0.668]	[0.925]	[0.623]	[0.135]	[0.458]	[0.446]
Region 2	-0.2182	-0.2232	-0.3168	-0.2592	-0.3686	-0.2358	-0.2123
	(-1.29)*	(-1.28)*	(-1.87)**	(-1.42)*	(-1.97)**	(-1.18)	(-1.05)
	[0.198]	[0.200]	[0.062]	[0.159]	[0.050]	[0.240]	[0.295]
R^2	0.40%	0.30%	0.40%	0.20%	0.40%	0.10%	0.10%
Adj-R^2	0.20%	0.10%	0.20%	0.00%	0.20%	0.00%	0.00%

Table 18. 1 Cross-Sectional Regressions: Change in EMCs' Operating Return on Assets (ΔROA)

The dependent variable in the regressions is the change in the Return on Assets of EMCs engaged in cross-border expansion over the 1991-2012 period. Return on Assets (ROA) is calculated by dividing a firm's annual earnings before interest and taxes by its total assets in a calendar year. Foreign to Total Sales (FSTS) is the percentage of foreign sales of the bidder firm divided by net sales. All bidder related independent variables refer to the year prior to the acquisition (t=-1). t-values are reported in parenthesis. ***, **, and * denote statistical significance at 1%, 5%, 10% levels, respectively.

Independent Variables	ΔROA (-1 to +1)	ΔROA (-1 to +2)	ΔROA (-1 to +3)
Intercept	0.533	0.097	5.267
	(0.48)	(0.07)	(2.82)***
	[0.629]	[0.941]	[0.005]
FS/TS	-2.417	-4.276	-14.304
	(-1.20)	(-1.80)**	(-4.73)***
	[0.229]	[0.072]	[0.000]
TA	-0.0000002	-0.00000023	-0.0000005
	(-4.98)***	(-4.86)***	(-5.78)***
	[0.000]	[0.000]	[0.000]
TS	0.00000017	0.00000033	0.00000038
	(2.47)***	(3.81)***	(2.89)***
	[0.014]	[0.000]	[0.004]
R^2	7.10%	9.10%	15.40%
Adj-R^2	6.30%	8.20%	14.40%

Table 18. 2 Cross-Sectional Regressions: Change in EMCs' Return on Equity (ΔROE)

The dependent variable in the regressions is the change in the Return on Equity of EMCs engaged in cross-border expansion over the 1991-2012 period. Return on Equity (ROE) is defined as the return on EMMs' investment. It is the ratio of earnings after tax (EAT) to EMCs' equity. Foreign to Total Sales (FSTS) is the percentage of foreign sales of the EMC divided by its net sales. All EMC related independent variables refer to the year prior to the acquisition (t=-1). t-values are reported in parenthesis. ***, **, and * denote statistical significance at 1%, 5%, 10% levels, respectively.

Independent Variables	ΔROE (-1 to +1)	ΔROE (-1 to +2)	ΔROE (-1 to +3)
Intercept	5.853	12	0.96
	(0.65)	(0.86)	(4.67)***
	[0.516]	[0.393]	[0.000]
FS/TS	-21.97	-39.41	-132.17
	(-1.28)*	(-1.47)*	(-6.67)***
	[0.201]	[0.143]	[0.000]
TA	-0.0000081	-0.00000106	-0.0000238
	(-2.47)***	(-2.05)**	(-4.72)***
	[0.014]	[0.041]	[0.000]
TS	0.00000042	0.00000101	0.00000043
	(0.74)	(1.09)	(0.56)
	[0.462]	[0.278]	[0.574]
R^2	2.30%	2.10%	18.90%
Adj-R^2	1.40%	1.10%	18.00%

Table 12. Binary Logistic Regression: Standardized Cumulative Abnormal Returns of EMCs that Practice Cross-Border Expansion Activities

The dependent variable in the regressions is the standardized cumulative abnormal return (SCAR) of EMCs engaged in cross-border expansion over the 1991-2012 period. SCARs are defined over various event windows around the acquisition announcement. Foreign to Total Sales (FSTS) ratio is the percentage of foreign sales of the EMC firm divided by net sales. All EMC related independent variables refer to the year prior to the acquisition (t=-1). t-values are reported in parenthesis. ***, **, and * denote statistical significance at 1%, 5%, 10% levels, respectively

Independent Variables	SCAR (-10, +10)	SCAR (-10, +5)	SCAR (-5, +5)	SCAR (-2, +1)	SCAR (-1, +1)	SCAR (-1, 0)
Intercept	-0.374909	-0.315318	-1.1084	0.405108	20.3692	-0.140981

	(-0.18)	(-0.15)	(-0.51)	(0.18)	0.00	(-0.06)
	[0.858]	[0.877]	[0.607]	[0.858]	[0.998]	[0.953]
Eco & Pol Freedom	-0.0648143	-0.154979	-0.0593948	0.0366066	0.128845	0.0622037
	(-0.28)	(-0.68)	(-0.25)	(0.16)	(0.53)	(0.24)
	[0.778]	[0.500]	[0.801]	[0.876]	[0.597	[0.807]
					-	
FS/TS	-0.321728	0.960714	0.68469	0.229252	0.0460047	-1.73102
	(-0.35)	(1.03)	(0.72)	(0.24)	(-0.05)	(-1.62)*
	[0.727]	[0.301]	[0.472]	[0.811]	[0.962]	[0.105]
Related 1 /Diversified 0	-0.474767	0.0750509	0.102599	0.182277	1.20443	1.31715
	(-1.01)	(0.16)	(0.21)	(0.36)	(2.24)**	(2.48)***
	[0.312]	[0.875]	[0.831]	[0.717]	[0.025]	[0.013]
Geographical/Cultural Proximity 1	0.604714	0.933156	0.815999	-0.176734	-0.645706	-0.340887
	(1.02)	(1.52)*	(1.30)*	(-0.28)	-1.01	(-0.52)
	[0.309]	[0.129]	[0.194]	[0.778]	[0.311]	[0.603]
Target Country Developed 1 / Emerging 0	1.17789	0.947661	0.849063	-0.479445	-1.36797	-0.534485
	(1.45)*	(1.16)	(1.03)	(-0.56)	(-1.53)*	(-0.60)
	[0.146]	[0.245]	[0.305]	[0.579]	[0.126]	[0.550]
EMM Hi-Tech 1	0.441536	0.682345	0.736449	-0.195451	-1.09586	-0.907003
	(0.74)	(1.16)	(1.21)	(-0.33)	(-1.66)**	(-1.40)*
	[0.459]	[0.247]	[0.225]	[0.744]	[0.096]	[0.162]
No ADR	-0.405977	-1.22093	1.22499	-24.654	-44.4938	-5.33336
	(-0.29)	(-0.90)	(0.74)	(-0.00)	(-0.00)	(-2.11)**
	[0.775]	[0.368]	[0.458]	[0.998]	[0.997]	[0.035]
144A	-0.696774	-1.69962	0.520768	-23.255	-42.4466	-3.24987
	(-0.40)	(-0.99)	(0.26)	(-0.00)	(-0.00)	(-1.20)
	[0.689]	[0.322]	[0.793]	[0.998]	[0.997]	[0.231]
Lev 1	-0.764595	-0.849177	1.1684	-23.6124	-43.7122	-5.54593
	(-0.58)	(-0.68)	(0.75)	(-0.00)	(-0.00)	(-2.25)**
	[0.562]	[0.497]	[0.454]	[0.998]	[0.997]	[0.024]
Lev 2	1.31653	-0.0365478	0.0383789	-1.02531	-21.6028	-1.15387
	(0.90)	(-0.03)	(0.03)	(-0.61)	(-0.00)	(-0.66)
	[0.367]	[0.978]	[0.979]	[0.542]	[0.998]	[0.508]
					-	
Investment Size	-0.001955	-0.0009146	-0.0012116	-0.0011762	0.0005805	-0.0002533
	(-1.78)**	(-1.09)	(-1.23)	(-0.98)	(-0.62)	(-0.64)
	[0.075]	[0.274]	[0.219]	[0.327]	[0.536]	[0.521]
					-	
Level of Control	-0.0028274	0.0043749	0.0078463	-0.0037137	0.0078939	-0.0043674
	(-0.44)	(0.67)	(1.19)	(-0.55)	(-1.11)	(-0.61)
	[0.660]	[0.502]	[0.235]	[0.584]	[0.266]	[0.541]
Region 1	1.13429	0.372636	-1.78086	23.1557	23.1101	5.57475

	(0.90)	(0.32)	(-1.32)*	0.00	0.00	(2.71)***
	[0.368]	[0.752]	[0.188]	[0.998]	[0.998]	[0.007]
Region 2	0.398001	0.575007	-1.81835	22.4805	23.3478	4.01715
	(0.29)	(0.45)	(-1.27)	0.00	0.00	(2.32)***
	[0.770]	[0.653	[0.205]	[0.998]	[0.998]	[0.020]

Table 2. Results of test of Cumulative Abnormal Returns (CARs) and CAR differences for industry, illustrate market reaction to International Expansion Activities of EMCs. Interval (-1, 0) denotes a day prior to the announcement of the international expansion. Significance levels are * 10%, ** 5%, and *** 1%.

Table 2. Industry: Cumulative Abnormal Returns of EMCs

	All Int' Expansions		**Hi-Tech**		**Non Hi-Tech / Manufacturing**		**CAR Difference**
Interval	Mean [Median]	Positive (%)	Mean [Median]	Positive (%)	Mean [Median]	Positive (%)	Hi-Tech - Non Hi-Tech [Hi-Tech - Non Hi-Tech]
(-10,0)	-0.0029861* [-0.00525]	45.88%	0.0076511** [-0.00015]	49.63%	-0.0069421* [-0.00625]	44.49%	0.0145933* [0.0061]
(-1,0)	-0.0035361* [-0.0032]	40.66%	0.0016474* [-0.0039]	38.15%	-0.0054639**8 [-0.003]	41.60%	0.0071113* [-0.0009]
(0,+1)	-0.0012992* [-0.00165]	45.79%	-0.0015219* [-0.00325]	41.85%	-0.0012166* [-0.0013]	47.25%	-0.0003052* [-0.00195]

Table 3.a. Results of test of Cumulative Abnormal Returns (CARs) for expansion type illustrate market reaction to International Expansion Activities of EMCs. Interval (-1, 0) denotes a day prior to the announcement of the international expansion. Significance levels are * 10%, ** 5%, and *** 1%.

Table 3. a. Expansion Type: Cumulative Abnormal Returns of EMCs

	All Int' Expansions		**M&As**		**JVs**		**SAs**	
Interval	Mean [Median]	Positive (%)	Mean [Median]	Positive (%)	Mean [Median]	Positive (%)	Mean [Median]	Positive (%)
	-		-		-			
(-10,0)	0.002986***	45.88%	0.015342***	40.55%	0.001038***	48.61%	0.025917***	53.42%
	[-0.00525]		-0.0115		-0.001		0.0049	
	-		-		-			
(-1,0)	0.003536***	40.66%	0.005096***	37.36%	0.006024***	44.84%	0.006873***	39.13%
	[-0.0032]		-0.0038		-0.0023		-0.0035	
	-		-		-			
(0,+1)	0.001299***	45.79%	0.001651***	47.15%	0.004037***	46.35%	0.006362***	40.74%
	[-0.00165]		-0.0013		-0.0018		-0.00315	

Table 3.b. Results of test of Cumulative Abnormal Returns (CARs) for expansion type CAR differences illustrate market reaction to International Expansion Activities of EMCs. Interval (-1, 0) denotes a day prior to the announcement of the international expansion. Significance levels are * 10%, ** 5%, and *** 1%.

Table 3. b. Expansion Type: Cumulative Abnormal Returns of EMCs

Interval	**CAR Difference** MA - JV [MA-JV]	**CAR Difference** MA-SA [MA- SA]	**CAR Difference** JV-SA [JV-SA]
(-10,0)	-0.0143042*	-0.0412591*	-0.0269549*
	-0.0105	-0.0164	-0.0059
(-1,0)	0.0009278*	-0.0119686*	-0.0128963*
	-0.0015	-0.0003	0.0012
(0,+1)	0.0023857*	-0.0080125*	-0.0103983*
	0.0005	0.00185	0.00135

Table 4.a. Results of test of Cumulative Abnormal Returns (CARs) for Corporate Governance Structures, illustrate market reaction to International Expansion Activities of EMCs. Interval (-1, 0) denotes a day prior to the announcement of the international expansion. Significance levels are * 10%, ** 5%, and *** 1%.

Table 4.a. Corporate Structures: Cumulative Abnormal Returns of EMCs

	All Int' Expansions		**144A**		**Level I**		**Level II**		**NO ADR**
Interval	Mean [Median]	Positive (%)	Mean [Median]	Positive (%)	Mean [Median]	Positive (%)	Mean [Median]	Mean [Median]	Positive (%)
(-10,0)	- 0.0029861***	45.88%	-0.009301***	45.39%	0.0016642***	49.31%	- 0.034025***	0.0002275***	43.85%
(-1,0)	- 0.0035361***	40.66%	0.0049121***	41.84%	-0.004171***	41.19%	- 0.009396***	-0.003582***	39.75%
	[-0.0032]		-0.002		-0.0033		-0.00305	-0.0031	
(0,+1)	- 0.0012992***	45.79%	-0.005816***	39.01%	-2.79E-05***	48.22%	- 0.010835***	-0.000459***	45.71%
	[-0.00165]		-0.0046		-0.00125		-0.00185		-0.0013

THE DYNAMICS OF GLOBAL PLANT NETWORKS

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Vlerick Business School and Ghent University (Belgium)

Introduction

Many companies are revising their manufacturing footprint, either with regular intervals and based on an explicit strategy, or through gradual decision-making based on an implicit strategy.
In the academic literature, there is a vast body of knowledge on the location advantages of plants, especially in the economics and international business strategy field. We refer to Dunning (2008) for an overview and discussion. Quite some recent work on plant location advantages focuses on the trend towards re-shoring and near-shoring. See for example Ellram et al (2013), Tate et al (2014) and Kinkel (2012), Also, a lot of work has been done on plant survival and death, especially in the economics literature. See for example Coucke and Sleeuwaegen (2008), Van Beveren (2007) and Bernard and Jensen (2007). However, most of these studies focus on the individual plant as the unit of analysis. They provide little insight in the evolution of the plant relative to other plants in the company's plant network and on the evolution of the structure of the plant network.

This paper presents the preliminary results of a longitudinal study of the plant networks of eight multinational companies, with headquarters in Western Europe. The objective of the study is to gain insights into the dynamics of these plant networks over a period of 20 years.

Research methodology

The research presented in this paper is longitudinal case research. The first round of research was carried out in 1995-1996. Eight cases, from different industries (food, textile, steel products, plastic products, food packaging, electrical equipment and luggage) were studied through in-depth case research. In this round of research, a network typology of plants has been developed, identifying four different types of network positions (Vereecke et al, 2006) and the strategic role of the plants has been identified, based on Ferdows' framework (Ferdows, 1997; Vereecke et al, 2002).

In the second round of research, in 2005-2006, the companies were revisited, using the same methodology, to study the changes in the networks over a decade. One of our conclusions was that the networks were very dynamic. Most of the companies had evolved from mainly European manufacturers to truly global players, to a large extent by establishing or acquiring plants in new or growing markets. We also observed that the probability of survival of a plant was related to its network position and its strategic role.

Another decade later, in 2015, we are again revisiting the companies. Data has been collected in three of the eight companies. We plan to visit four other companies in the next couple of months. One company went bankrupt in 2012, which excludes it from this third round of data collection. This company's data of the first two rounds of the study might nevertheless lead to interesting results as it allows us to study whether its manufacturing network of the past helps to understand the company's negative performance.

Preliminary results

Since data collection is still ongoing, it is too early to draw conclusions, but we can already discuss some first observations.

We observe three different speeds of evolution. Two of the companies have continued to expand their plant network rapidly; the speed of expansion has even accelerated in the last decade; the other two companies have downsized their plant network.

Although preliminary, our study re-confirms the focus on the market as a driver for changing the plant network in the successful companies. The market was and still is the main driving factor behind the international plant network of the manufacturing multinationals in our study. Not surprisingly, there is a higher level of dynamics in developing than in mature regions.

We observe that expansion went hand-in-hand with centralization of competencies. The flexible components of the plant network are typically the server and off-shore plants, whereas lead plants and market masters are the more stable components of the network. This leads to plant networks with proportionally more plants with low competency levels, that rely on a few centers of excellence for the creation of product and process know-how.

Our study also shows that the future of the plant is safer for strongly networked players than for the ones that rely on other plants for know-how and innovations.

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Chinese Industrialisation in the Last Thirty Five Years and its Implications to the International Manufacturing Theories

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Keywords: Chinese Industrialisation, International Manufacturing, and Industrial Innovation

This paper seeks to explore and explain what Chinese manufacturing developments in the last 35 years can inspire and challenge the international manufacturing and operations management disciplines. The paper recognises that the classical industrialisation model and industrial systems have brought China not only to the largest manufacturing nation but also to the tipping point where its success can destroy its achievements and even the world. The new generation of operations and manufacturing strategies have to learn from the Chinese manufacturing experiences and explore new type of strategic and system solutions.

China started its economic reform by adopting the open-door and introducing market policies in the late 1970s. It has achieved the GDP annual growth about 10% continuously in the previous 30 years although it slowed down to 7-8% in the last five years. The industrialisation made China be the largest manufacturing nation in the world in 2012, the second largest GDP country in 2013, and possibly the largest GDP PPP (purchasing power parity) country in 2014.

However, the dark side of the industrial developments has gradually been exposed and caused the global concerns, including environmental pollutions in water, soil, and air; CO_2 emission fast increases speeding up climate changes; all kinds of natural resource limitations potentially constraining manufacturing growth in the future; and social welfare systems lagged behind triggering society unrest risks.

All of the phenomenon from Chinese manufacturing developments have demonstrated serious contradictions at the new level and scale that human being never experienced before. It has significantly challenged some basic operations management principles and assumptions. The principal assumptions of industrial system and its management include:

- Industrial systems are a fundamentally input and output transformation and value creation system
- The main tasks of operations management are to achieve effective industrial system design, efficient operations, and continuous improvements
- System effectiveness is much more critical than system efficiency
- Value creation transformation process has no resource limitation
- Main value creation mainly decided by customer demand rather than resource utilisation/exploitation

The problems and challenges from the Chinese manufacturing developments, however, actually represent the future industrialisation requirements. It demonstrates a new trend or challenge of industrialisation that is how the highly populated developing nations like China and India can achieve sustainable manufacturing development without jeopardising current and future environments and society. How can POM society like EurOMA help industry, not only Chinese or developing nations' ones but all human beings', to tackle the challenges? In another term, the paper's research question is set to explore if the current Chinese industrial systems can cope with the future requirements or challenges.

The paper tries to summarise and integrate various related research work in the last decade to address the question. It reviews the specialised research symposia on Global Manufacturing and China (GMC) in the last ten years besides other publications in the public domain. It summarises many empirical researches conducted by more than 10 doctoral researchers in the last 15 years about Chinese manufacturing evolutions.

Based on the research data and analysis, three main research findings are identified:

1. Chinese manufacturing evolutionary map: it illustrates Chinese manufacturing development key milestones including the policy drivers, grassroots innovation breakthroughs, enterprises restructurings, industrial reconfigurations, and emerging industry growths. It highlights main achievements, serious problems, root causes, and challenges in the last 30 years of Chinese manufacturing developments.

2. Chinese manufacturing key succeed factor identification: based on the evolutionary mapping, the paper recognises three key factors making Chinese manufacturing industry outstanding from economic standard perspective:
   - Good ambidexterity capabilities dealing with market and planning economies, rural and urban markets, and supply and demand relationship, as well as FDI (foreign direct investment) dependency and indigenous innovation.
   - Dynamic reconfigurations of industrial systems on all levels from basic technology, factory, and enterprise to region, sector/industry, and whole nation. Economic reforms and radical transformations are deeply embedded in majority Chinese people's life.
   - Pursuing prosperity through hardworking and dedication used to be the deep-rooted Chinese culture. The Chinese economic reform policy frees and enhances the traditional spirit. It forms a solid foundation for industrialisation.

3. Chinese manufacturing key challenges and backwards: Chinese industrial systems' problems are mainly caused by its successes:
   - The dedication has changed into desperation that single-mindedly pursues economic performance. GDP indicator and material achievements have emerged as the almost everything for the society performance measurement.

   - The dedication has changed the whole China to "excellent students" to learn from all advanced nations through benchmarking, duplication, repetition, and imitation. But Chinese manufacturing ignores its own problem solving even to correctly face them.

- Because of its fast growth and radical changes, Chinese industrial systems lack of systematic review and rationalised redesign. The weak linkages between industry and academia leave many good practices as experiences rather than systems or sciences.

Implications of Chinese industry developments to POM discipline and community can be very inspirational and deep. Chinese manufacturing evolutions highlight the following interesting trends:

- The major POM tasks may need to be adapted from current "design - operation – improvement" toward more radical design and reconfiguration.
- Industrial system boundaries have been changed: not only input-output transformation and value-creation systems but also industrial ecosystems that enables value-creation system can be easily reconfigured.
- New industrial design principle: not only competitive advantages but also more "resource based view" orientation – by more appreciating the intrinsic value embedded within the resource and strategically cascading its full potentials – new RbV 2.0.
- Industrialisation depends not only corporation and firm but also cluster, region, nation, and whole society or community, or an ecosystem.
- Chinese thinking philosophy about Yin-Yang dynamics can be very powerful industrial tool for strategic ambidexterity.

Is the current Chinese industrial systems can cope with the future requirements? No! But, it is no longer a Chinese problem, but the whole human beings' one.

A study on stabilised electric power supply for solar energy based micro-grid systems

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Abstract

Renovation of electric power generation system has been an emerging topic worldwide due to exhausting conventional energy sources. Solar, wind and geothermal energies are considered as possible alternatives for the next generation society. Among them, solar energy is particularly hopeful because of its cleanness, renewability and virtually infiniteness. However, its power is not sufficiently stable similar to the case of the other natural resources. This means neat investigation on the energy harvesting is critical to guarantee stability of power supply. Meanwhile, micro-grid system, featured by local network of separated suppliers or consumers, is considered as a relevant approach for this problem. In this paper, a mathematical model for optimising the stabilised performance of solar energy micro-grid system is developed and its characteristics is examined through simulative analysis. Investigation is carried out for the system with plural spatially dispersed grids. Each grid consists of a storage battery station and a number of households equipped with photovoltaics (PV) panel. Solar power captured by panels and consumed electric energy by each householder are evaluated based on the data of the solar energy value provided by New Energy and Industrial Technology Development Organisation, a government belonged corporation, and the data of 235 households' power consumption obtained by survey respectively. Where the electric power supplied to each grid estimated through solar power-electric energy conversion process and its consumption in each household are both varied.

Recycled Multifunctional Artificial Reefs – a technology favouring sustainable operations in coastal lifestyle

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Abstract
This paper reports an exploratory case study concerning the impact of marine/recreational activities, e.g. surfing or diving, as emergent income sources in Porto Santo Island (Madeira archipelago). It addresses the following potential socioeconomic/environmental benefits of a Multifunctional-Artificial-Reef (MFAR) built from recycled material: (i) enhancing surfable waves quality; (ii) increasing local biodiversity/habitats; (iii) improving touristic attractiveness; (iv) enhancing fisheries incoming; (v) decreasing wastefulness and environmental damage by recycling; and (vi) favouring job creation. A SWOT analysis is proposed to appreciate and classify both internal and external factors concerning the MFAR the interest and feasibility of the MFAR, before its implementation. Factors are evaluated based on 18 environmental and socioeconomic criteria related to MFAR implementation, selected from specialised literature. It is argued that a feasible MFAR constitutes an innovative manufacturing technology with capability to address potential market opportunities that could boost local GDP, while creating job opportunities and promoting biodiversity.

Keywords: Recycled Multifunctional Artificial Reefs (rMFAR); sustainable operations; advanced and innovative manufacturing technology; coastal erosion mitigation.

1. Introduction

In general coastal environments might contribute to several valuable ecosystem goods and services, like recreation opportunities and tourism. In fact, a healthy coastal environment generates significant revenues (Ostberg, Hasselstrom & Hakansson, 2012), and beaches are recognized as a place of leisure, traveler destination and sea recreation, as part of these natural systems with high socio-economic value (Cooke et al., 2012). Moreover, tourism has become one of the world's fastest growing industries, by providing a significant proportion of the GDPs of many countries. A high number of small islands are particularly reliant on coastal and marine tourism. A recent report of World Travel &Tourism Council (WTTC, 2014) about the economic impact of the Travel & Tourism sector in 184 countries, based on 2013 data, shows that the contribution of this sector

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weights 2.9% in the world GDP. In Europe, it corresponds to 3.1%, whereas in Portugal, it represents 9.2% of the GDP (2014), of which more than half is related to coastal and marine tourism (PENT, 2014).

However, because of increasing demand, the attractiveness of coastal zones is also under higher pressure, which has the following consequences: (i) coastal resources are depleted beyond their carrying capacity, (ii) increased erosion and scarcity of space that leads to conflicts between uses, (iii) large seasonal variations that occur in both population and employment, and (iv) degradation of the natural ecosystems that support the coastal zones. By considering these aspects, environmental issues are now not only becoming a significant part of political decision making, but also of business life (Przychodzen & Przichodzen, 2015).

This pro-environmental transition requires a strategic approach to coastal zone planning, a careful management of resources and also an environmental-friendly business emergence, in order to be pursued a sustainable development (Chena & Wu, 2015). Therefore, the pro-sustainability pressure coming from both consumers and European requirements compels firms to offer products and services that closely match the preservation of local environment, cultural aspects and both social needs and concerns, in addition to economic interest. Moreover, younger, more socially and environmentally aware users tend to drive consumption patterns, particularly in the emerging markets of nature and adventure sports, such as those related to surfing, scuba dive or kite surfing (Ford & Brown, 2006).

Nevertheless, coastal management with hard-engineering projects – like coastal armoring such as seawalls and revetments, or sand-trapping structures such as groins, which are designed, either to mitigate coastal erosion and flooding, or to repair/protect the maritime ports – hamper the quality of the surfable waves (Corne, 2009). As a result, either the tourism expenditures, or the community incomes derived from it, decline. This causes social and economic problems that could be avoided, if the environment impact assessment would include surfing in the human, water and landscape factors.

Alternative strategies could still be formulated to keep the quality of surfable waves, despite the hard engineering techniques for stabilisation of the shoreline have already been implemented. One of these alternatives comes from artificial reefs, a new breed of coastal engineering structures. These reefs have become popular technological interventions in shallow water environments characterized by soft seabed for a broad number of purposes, other than improving the wave quality for surfing, such as those related to increase local biodiversity, to provide coastal protection, and to enhance other marine and recreational amenities (Slotkin et al., 2009).

This study focus on the social and economic potential impacts of improving surfing conditions in Porto Santo, one of the Madeira archipelago islands (Figure 1), where eco-tourism and sea recreation activities are considered as two emergent trends and so, as potential main sources of income. Therefore, it is proposed to install a multifunctional artificial reef (MFAR) built up from recycled material, to enhance the quality of surfable waves off the south coast of Porto Santo, in line with recent trends (e.g. Bicudo & Horta, 2009; Bulleri & Chapman, 2010; Corne, 2009; Ng et al., 2013, 2015).

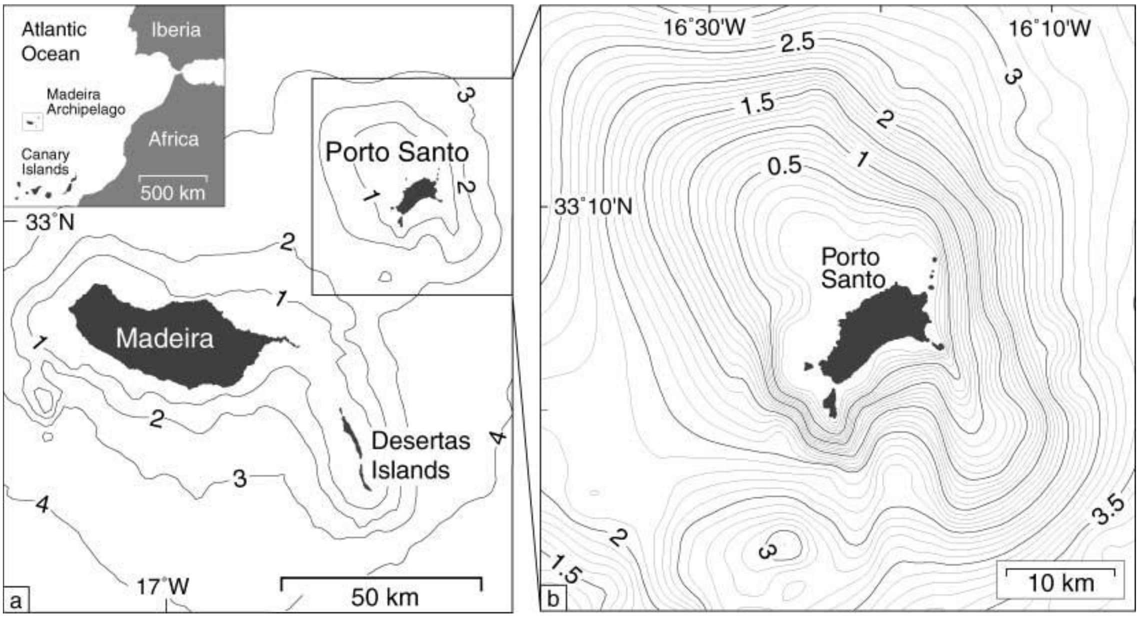

Figure 1. (a) Madeira island group, contour interval 1 km. Inset shows the Madeira archipelago in the central eastern Atlantic. (b) Bathymetry of the vicinity of Porto Santo. Contour interval is 0.1 km. Data from the TOPEX data set (Smith and Sandwell 1997).

The MFAR should also protect the local coastline against erosion, increase the environmental value of the area where it is situated, as well as enhance the surfing possibilities (Black & Meade, 2009; Corne, 2009; Rendle & Rodwell. 2013). Multifunctional artificial reefs have some promising new aspects, too, as follows: (i) firstly, they provide an unimpaired visual amenity, since they are submerged breakwater structures (ASR, 2008); (ii) secondly, their construction may bring local environmental value, caused by an expected increase both in bio-diversity and species abundance (Herbert et al., 2013); (iii) thirdly, they can offer tourist and economic benefits by improving both, diving venues and traditional/sport fisheries activities, due to the enhanced biodiversity and species abundance derived from the new man created marine habitats (Rendle & Rodwell, 2013). Moreover, the MFAR to be proposed for Porto Santo is made from recyclable material, bringing advantages in terms of decreasing waste and damage to the environment, since it reduces the total non-hazardous debris and it also regulates some of the waste that is produced in the islands.

Therefore, this situation demands for an innovative practice in Porto Santo towards environmentally-friendly policies (Stotkin et al., 2009) in the surfing business operations. In this way, the following research questions arise:

RQi – Can an artificial surfing reef, multi-purpose and functional in nature, be able to produce a good quality surfable wave throughout the year, in a small island shore?

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RQiii – How could the MFAR and surf amenities boost business and provide a good sustainable, economic and social solution to balance the effects caused by the seasonality of tourism activities that affect the current day-to-day of Porto Santo?

Considering these research questions, the following objectives were proposed to gain insight if the MFAR might constitute a technology that favours sustainable operations in coastal lifestyle:

(i) To understand and explain the effect of MFAR construction, in a context of coast management, to getting surfable waves in Porto Santo;

(ii) To appreciate the recycled MFAR as an innovative technology favouring both sustainable operations in coastal lifestyle and the potential economic impacts of surfing in the Porto Santo; and

(iii) To anticipate the positive impact of MFAR in surfing practice, ocean environment, and local lifestyle as regards the sustainable development of the Porto Santo coast.

An exploratory study strategy addressing the effective actual potential of MFAR for developing the Porto Santo coast is pursued in order to achieve the research objectives. Therefore, there is a need for appraising the requirements that may hamper or facilitate the MFAR purposes, by following a Triple Bottom Line perspective (Jones-Walters & Civic, 2013) before its implementation and operation. A SWOT analysis is proposed in order to appreciate and classify both internal and external factors concerning the MFAR feasibility. This exercise concerns the environmental, the social and the economic dimensions and the feasibility is evaluated based on a set of selected environmental and socio-economic criteria closely related to the specific area of the MFAR implementation. The study mainly relies on secondary data. Some of the obtained findings are, as follows:

(i) Current understanding of the functional design of these structures might not be sufficient for an optimum performance, but it may be good enough for these structures to be considered as a serious possibility for the production of quality surfable waves;

(ii) From the evidence available, and considering the ability to create surfable waves, the proposed MFAR could not only increase the potential economic impacts of surfing on the south coast Porto Santo, but it would also help to reduce problems related with coastal erosion and loss of marine environments; and

(iii) It seemed that a MFAR could be considered as an investment with a positive impact in the development of (a) the sport and surf-schools, (b) the economy, (c) the employment, (d) the local activities provided by the increase of the population in the zone (investments in the restoring, hoteling and leisure facilities) and, even, of (e) the creation of conditions for the practice of other nautical activities, such as diving and fishing.

In section 2 of this paper, a literature review is carried out. In section 3, the results of the SWOT analysis are presented and analysed. Then, discussion and final conclusions will close the report over the research questions and the objectives.

2. Setting the business context for surfing activities

The Beach and Surf life style

Surfing first gained widespread popularity in the 1950s, when surf movies and beach music become a fashionable subject (Booth, 2013). It started with independent travelers searching for new surfing spots. Surf tourism peaked in the late 1960s, mostly because of: (i) more affordable air travel; (ii) stylish surfboards; (iii) the image of a surfing culture delivered through mass media; and, (iv) the increased accessibility to lessons at surf schools (Butts, 2001; Barbieri & Sotomayor 2013; Ng et al., 2013). Moreover, thanks to lighter new materials used to build up surfboards and surf suits, surf has been adopted by a large mass of people as a business line, a competitive sports branch, and, also, as a leisure time activity (Reichenfeld, 1991).

Nowadays surf has become a significant niche within the adventure/sport sector (Barbieri and Sotomayor, 2013; Buckley, 2002a, 2002b) being characterized by specific travels for the purposes of surfing or attending a surfing event. It has evolved into a rapidly expanding market segment of the wider tourism industry, gaining significant attention in the academia during the previous decade (Martin & Assenov 2012). In addition, surf sites and surfing activities might play a leading role in a region's image, commerce and tourism-based identity (Martin, 2013) like Nazaré, in Portugal west coast, where McNamara in January 2013, caught a 100ft wave (The Guardian, 2014). Some literature also report that surfers are environmentally minded and concerned to achieve a minimal impact on the coastal ecologies (Krause, 2012). This is another issue why surf industry is important for creating a sustainable local economy.

However, it must be emphasized that surfing is not feasible everywhere on the coast, since, a unique combination of geologic features and meteorological conditions have to coalesce to create surfable waves (Preston-Whyte, 2002). For this reason, an increasing number of people surfing in a few areas has resulted into crowded surf breaks, in many of the world best known surfing places (Sweeney, 2005).

So, considering the limitation of spots, surf beaches are under ever-increasing pressures from tourism, coastal development, pollution, and other anthropogenic factors, as surf activities and the related industry grow and expand around the world. Consequently, the management of surfing and surf places has been a relatively new area of study within the past 10 years and much of the focus has been on: (i) the sustainable management of surfers, tourists and the local community in surf destinations; (ii) the economic importance of surf breaks to communities; and (iii) the protection of surf breaks either from coastal development or from hard-engineering projects (Lazarow 2007; Murphy & Bernal 2008; Ponting & O'Brien 2014). Those hard-engineering coastal projects designed to mitigate coastal erosion hamper the quality of surfable waves and this might cause social and economic problems in coastal communities that economically depend on surf tourism and Landscape factors.

The Beach and Surf business

Surfing is an important recreational and business opportunity in many coastal locations. It is an activity where coastal environments and people are closely related and because it is increasing in intensity in traditional locations, surf practice is expanding to new places (Wall & Ślema, 2015).

The rank and geographical dispersion of the most important surf spots, by country or region, are depicted in Table 1 and Figure 2.

The importance of surfing and surf tourism from a business viewpoint, has grown significantly over the past years (Martin, 2013). This combined with the significant growth in participation and rising popularity of surfing in many countries shows the importance of understanding both economic and social value and also the environmental impact of surfing for many coastal locations.

Table 1. Countries ranked according to a number of important surf spots (Wall & Ślema, 2015)

Rank	Country	Surf spots	Rank	Country	Surf spots
1	USA	200	23	Philippines	7
2	Australia	168	24	Netherlands	7
3	Central America	79	25	Japan	6
4	England	75	26	Maldives	6
5	Caribbean	41	27	Channel Islands	6
6	Portugal	40	28	Norway	6
7	Indonesia	38	29	Azores	5
8	New Zealand	37	30	Ecuador	5
9	France	36	31	Madagascar	4
10	Hawaii	32	32	Reunion	4
11	Canary Islands	30	33	Tunisia	4
12	Spain	25	34	Thailand	4
13	Brazil	21	35	Canada	4
14	Ireland	20	36	Senegal	3
15	South Africa	19	37	Denmark	3
16	Pacific	19	38	Chile	3
17	Wales	18	39	Madeira	2
18	Morocco	15	40	Uruguay	2
19	Sri Lanka	11	41	Ghana	1
20	Scotland	9	42	Mauritius	1
21	Peru	9	43	China	1
22	Middle East	7	44	Argentina	1

According to Martin & Assenov (2014) surf tourism takes place in at least 162 countries and these spots incorporate all levels of amenities and services. Most of them are located in the USA, Australia, United Kingdom, Portugal, New Zealand, France, Spain and Brazil, though emerging markets include Russia and Central and South America (Ponting & McDonald, 2013). The map shown in Figure 2 represents some of the most important surf spots per country; however, this map is not extensive.

Figure 2. Map of the most important world surf spots (source: Google Earth)

It is arguable that regions with natural conditions for a good surf practice are able to take advantage of the gains that surfing brings to them. In fact, in those regions, an increasing inflow of people can be expected: surfers, swimmers, spectators, surf schools, and surf competitions, which contribute towards a successful local economy (Barbieri & Sottomayor, 2013). Furthermore, directly and indirectly related urban functions, like surf-stores, accommodation, retail shops, and restaurants, arguably provide the infrastructure for booming surf-related economies.

Moreover, the surf industry promises further growth with the development of more specialized services such as surf schools (Avci, 2015), as well as increase of the market for surfing-related consumer brands (Moutinho, Dionısio, & Leal, 2007), like the equipment manufacturers (as Cobra International, in Thailand) or clothing corporations (such as Quiksilver, Billabong, and Rip Curl) (Martin & Assenov 2012).

Martin and Assenov (2012) reviewed surf tourism studies between 1997-2011 years and found that surfing events, artificial surfing reefs, and the sustainability of both surf sites and host communities are among the most prolific areas under discussion. Key arguments include: socioeconomics, coastal management, and the sustainability of natural resources.

In fact, the surf industry is formal and governmentally recognized in a coastal urban area, where surfing, surf culture and employment in surf related industries comprise a significant proportion of the economic, social and cultural base of the city (Eddie & O'Brien, 2013). The authors also make the point that government support, surf tourism, surf events, surf education, surf media, surf festivals and surf waves improvement with artificial reefs should be analysed together, for developing surfing destinations, as displayed in Figure 3.

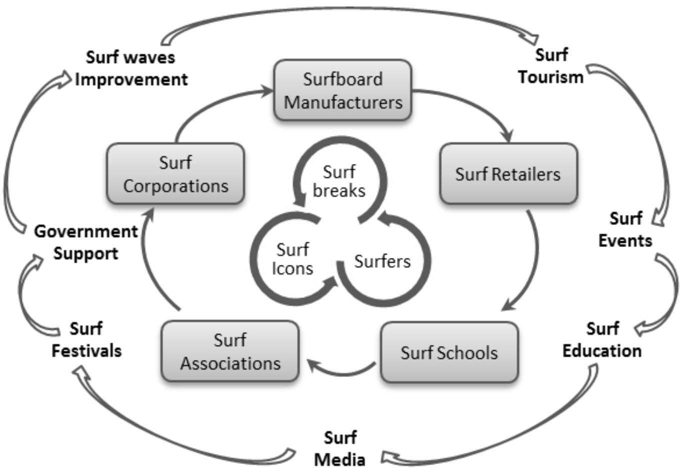

Figure 3. Establishing a holistic context for the surf dynamics (Adapted from: Eddie & O'Brien, 2013).

This model shows that all the surf components are in interaction with each other and that each surf component will affect the challenges of both surfing industry and regions. Moreover, the improvement of surfable waves or their recovery after hard-engineering interventions in the coastal management could be achieved by implementation of artificial and submersed reefs.

The socioeconomic and environmental values of surf

The identification of the wave as a natural resource and the recognition of its economic value is something that has been defended by some specialists (Lazarow, 2007; Martin, 2012, 2013). Thus, the total economic value of waves, such as any natural resource, depends not only on market values but also on other issues without direct impact on the market (i.e., non-market values), such as: direct and indirect use value, option value, bequest and existence values (Lazarow, Miller & Blackwell, 2007). These relationships are expressed in Figure 4.

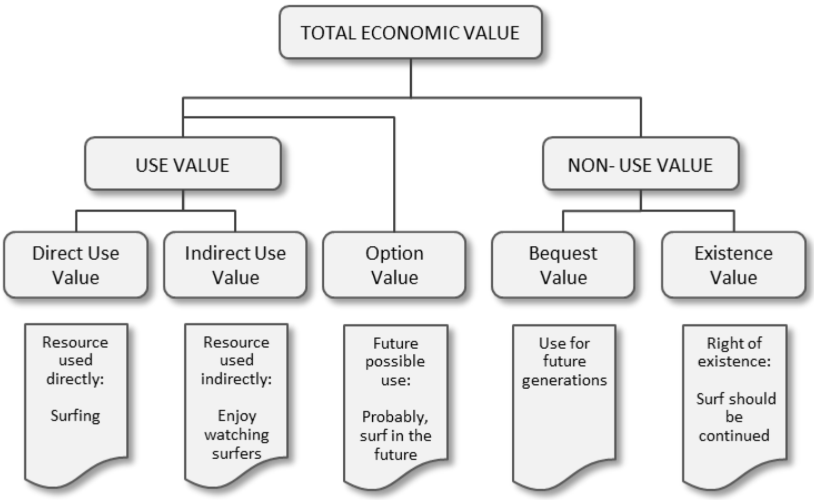

Figure 4. Total economic value of waves, as natural resources (Source: Nelsen, 2009)

There can be no doubt that the value of surfing to society and the impact of surfing on lives and lifestyles cannot be understated as simple amusement. Surfing today represents a very profitable market, an increasing growth industry, and plays a major part in the tourism strategies for many coastal locations.

In addition, Lazarow (2007) and Lazarow et al. (2009) go more in depth to describe the socioeconomic value of surfing (Figure 5) and categorize the significant social, economic and cultural importance of the surfing amenity. Their work also takes into account the need to consider negative impacts in the environment resulting from development or coastal protection works on both surf breaks and natural environment.

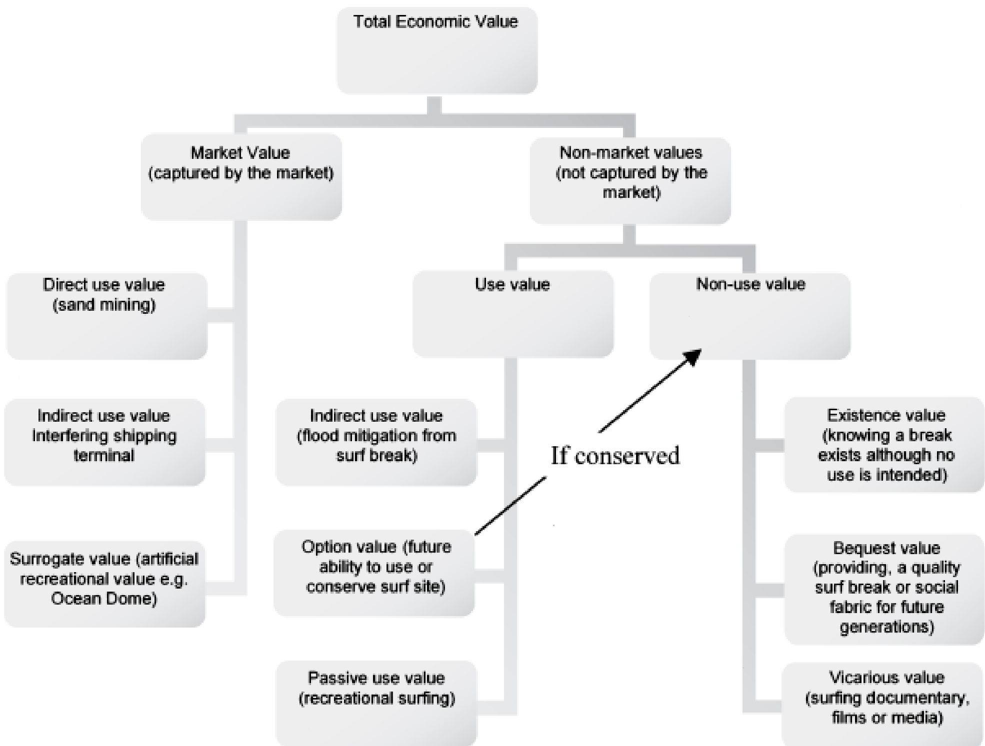

Figure 5. Lazarow's concept of the total economic value of surf (Source: Lazarow et al., 2009)

In these studies, a typology of Surfing Capital is presented as a means of identifying both market and the nonmarket physical, environmental and social aspects of surfing area categories (see Table 2).

Table 2. Typology of Surfing Capital

Item	Description	Natural or Human Impact
Wave quality	Dominant local view of how the wave breaks. Both beauty and physical form become assessable.	Construction of coastal protection/amenity structures (e.g., groynes, seawalls, seawalls, river walls, breakwaters, artificial reefs)
Wave Frequency	Surfable waves measured against an accepted standard.	Sand management (e.g., beach fill, dredging, sand bar grooming)
Environmental	Environmental or biophysical conditions that may mitigate against a surfers' physical health.	- Biological impacts (e.g., water quality or nutrient loading) -Climate change/variability (e.g., temperature change, sea level rise, fewer or more storms, less or more often) -Amenity of the surrounding built and natural environment -Marine predators (e.g., sharks)
Environmental	Societal conditions surrounding the surfing experience.	-Legislation/regulation that might grant, restrict, or control access (e.g., community title, private property, payment strategies, craft registration, proficiency requirement, policing) -Code of ethics (e.g., road rules for the surf) -Signage & education strategies -Surf rage, aggression, intimidation -Self-regulation/localism/lore -Mentoring, sharing, physical activity, challenge, well-being, community spirit self-fulfillment -Local aesthetic

Source: Adapted from Lazarow et al., 2007)

Over the past decade, several attempts have been made to estimate the total number of surfers globally. Some of the most recent evaluations place the number of surfers worldwide at approximately 35 million (e.g. CSR, 2015; Eddie & O'Brien, 2013). The same authors indicate that global surf industry, including travelling, surf-branded clothing and the manufacture of surfboards, has been estimated to be worth EUROS $119 billion annually and grows at 12 to 15% per year (Eddie & O'Brien, 2013).

According to Barilloti's Surfing Macroeconomic Theory: "Waves attract surfers. Surfing attracts energy. Energy attracts people. People attract capital. Investment attracts development. And so it goes." (Barilloti, 2002: 92).

The positive economic impact of visitors in surfing areas is well-documented, namely in South Stradbroke, Australia (Nelsen et al., 2008), Mundaka, Spain (Murphy & Bernal, 2008), Mavericks, central California (Burnett & Coffman, 2009); Nazaré, Portugal (Portugal Global, 2014), and Uluwatu, Indonesia (Wall & Ślema, 2015). A number of studies have employed travel cost and ecosystem services methodologies to calculate the value of individual surf breaks. The data presented in Figure 6 summarizes the results (Thomas, 2012).

However, none of these breaks is able to always guarantee the quality and the number of waves to visiting surfers, regardless the high demand for such places. In fact, all of them are subject to seasonality meaning that they are of low quality approximately 50% of the time (Silva & Ferreira, 2014). Presumably, undertaking adequate management of coast and beach could, perhaps: (i) generate an improvement of surf conditions and (ii) increase the annual capacity of surf breaks by decreasing seasonality effects, it will would also increase their value.

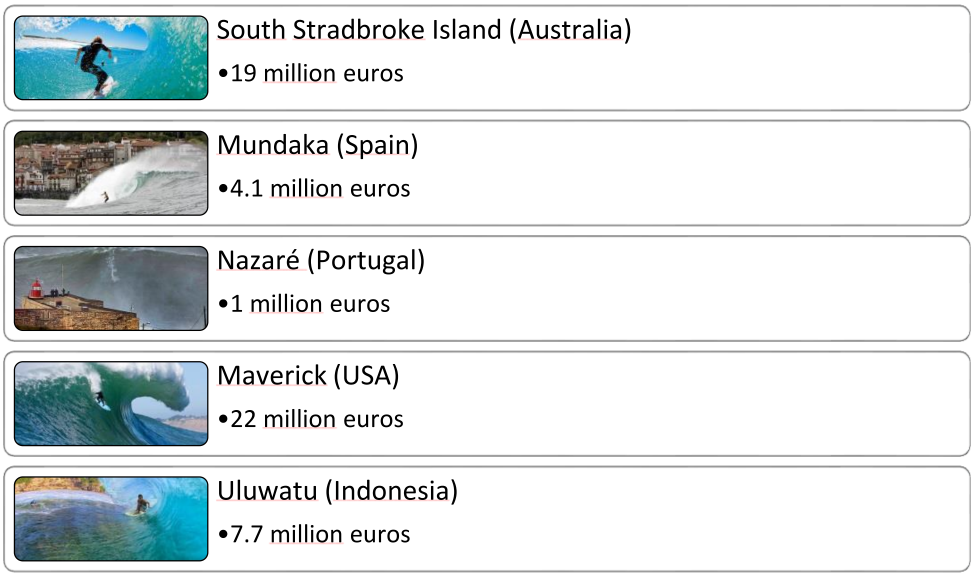

Figure 6. Economic impact of surfers and visitors in some surfing places.

On the other hand, natural and human-induced coastal erosion might seriously affect the seashore, in the long run and so, jeopardize the surfability of coastal zones. When a wave loses its quality due to environmental change (or human built infrastructural changes) it can fall out of fashion rapidly and this can greatly impact the local surf tourism economy.

Hence, many of the coastal zones, adjacent to urbanised areas, that have an active surfing community also have active beach management programs that attempt to protect the coast, preserve both the beaches and its multiple recreational uses and therefore, maintain the jobs and economic activities in coastal communities.

These beach management programs often employ periodic beach nourishment (soft interventions) or coastal structures (hard interventions), or a combination of both, to address beach erosion. Objectives are often to either introduce new sand to a sandstarved system, or to maintain existing sand in a given area (Almeida, 2015). However, conflicts between coastal engineering activities and the surfing community may arise when coastal engineering projects affect: (1) the morphology of the seabed (which is responsible for the wave breaking characteristics), (2) the nearshore wave climate, or (3) beach habitats/water quality (Almeida, 2015). For this reason, surfing conditions should be considered in further studies about the coastal dynamics impact produced by coastline protection interventions, and whenever it its possible, these conditions should be restored, for instance, through the setting up of artificial reefs.

The surf industry in Portugal

Surf is considered both as a sport and an economic activity that has gradually increased in importance, at a steady rate, in Portugal, over the last decades (Bicudo and Horta, 2009). Figure 7 shows the evolution of the number of surfers, surfing regularly at least once per week, since surf has appeared in Portugal, almost 50 years ago.

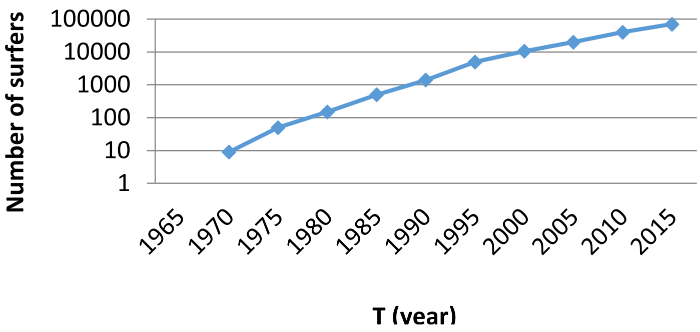

Figure 7. Evolution of the number of surfers, surfing regularly in Portugal, at least once per week, over the last decades (Source Bicudo & Horta, 2009; Guerra, 2014).

Accordingly Bicudo and Horta (2009) and the National Surfers Association report (Guerra, 2014), in a universe of ca. 200,000 practitioners, presently there are 50,000 to 70,000 surfers surfing regularly in Portugal, at least once in a week, during all year. The growth factor is of 25% to 30% per year. So, taking into account those values, and given the excellent natural conditions, Portugal is a key country in the world surfing panorama. Hence, the surfing represents a very profitable market, a growing industry, and plays a major part in the recreation and tourism strategies for many Portuguese coastal communities, either in mainland or in the islands (Figure 8).

Figure 8. Examples of surf practice and surf waves in Portuguese coastline: (a) and (c) MOCHE-RIP CURL PRO – World Championship of Surf, in Peniche, 2014; (b) Porto Santo beach; (d) Garrett McNamara, in 2012, surfing in Nazaré one of the biggest waves ever caught on camera (images are Courtesy of Google Image public search).

Therefore, any negative impact to the surfing amenity in these locations may have serious consequences for the resident surfing population, visitors to the area, the local surf industry and the entire local coastal economy.

Coastal erosion, artificial reefs and surf practice

Coastal erosion is a result of multiple causes, both biophysical and human, and so it is a natural and human induced process. Coastal erosion does not constitute a new phenomenon but it has been aggravated in recent years by: (i) the impacts of climate change; (ii) by the expansion of urban land use and other human occupations; and (iii) by the increasingly artificiality of the land in this land-sea interface (Almeida, 2015).

Therefore, to stabilize shorelines some solutions where adopted, namely “hard” and intrusive engineering solutions to protect populations, like the construction of seawalls, groins, or headlands, and more recently ”soft” interventions like sand renourishment programs during summer season (Almeida, 2015). However, local and active surfing communities states that either, erosion or some hard-engineering coastal projects designed to mitigate coastal erosion, hamper the quality of surfable waves causing social and economic problems, since those affected surfable areas lose touristic appeal (Usher, Goff & Gómez, 2015).

The sustainability of both coastal and surfing communities requires more determination to reverse the patterns of shoreline change problem and requires a greater attention to the weaknesses of the interdependence between natural and social systems. It also requires the need to learn more about the process of coastal erosion in order to discuss policy responses as well as alternative solutions that are technically and economically viable and more sustainable.

To prevent and mitigate the negative impact of coastal erosion in surfing, or to increase the potentialities of surfable beaches, other engineering based measures, such as submerged artificial, reefs could also be undertaken. Moreover, artificial surfing reefs are not a new concept but the idea has come a long way in the past decade. Physically, when a wave rolling along encounters a reef, the lower part of the wave's energy drags against the reef and slows down, but the top part of the wave’s energy continues moving at the same speed and that is why it starts tipping forward, eventually breaking (Mendonça, Neves & Fortes, 2009). So, considering this principle, an artificial reef could reproduce those natural surfable waves and also cooperate to erosion decline since it reduces the speed of the wave progression.

Dias, Carmo & Polette (2010) define MFARs as a submerged breakwaters that promotes the majority of the activities assigned to the classic artificial reefs and provide, in addition, an indirect protection by reducing hydrodynamic loads to levels needed to maintain the balance of the coast. In fact, an artificial reef 150–300 yards (140–270 m) offshore might create surfing opportunities and, by dissipating wave energy, make swimming safer and reduce coastal erosion (Fabi et al., 2011).

Antunes do Carmo (2013) point out that MFAR are simpler, cheaper and more functional than heavy engineering costal works, which have been primarily seen as measure of last resource, satisfying immediate needs of coastal protection. Moreover, many MFAR are built using objects that were manufactured for other purposes, for example by sinking used tyres, scuttling ships, by deploying rubble, construction debris or recycled concrete sleepers. With this recycling, a MFAR thereby helps the overall sustainability.

These MFARs, by producing surfable waves, bring economic benefits that result from increasing tourist flows. At the same time creates more job opportunities for coastal populations, reducing problems and social injustices. In addition these MFARS: (i) increase the width of the beach adjacent to the reef; and (ii) are an important environmental enrichment of the coastal zone, creating new habitats for fish and invertebrate species.

Nevertheless, even with the combined knowledge of civil engineers and ocean floor and currents experts, building a reef that will create a surfable wave isn't easy. Moreover, by altering the behavior of waves and currents, MFARs interfere with the hydrodynamic balance and local sediment transport, and may cause, as well as positive impacts on the coastal segments, negative impacts in adjoining coastal segments (Burchartch & Hughes, 2002; Borrero & Nelsen, 2003).

The previous literature review allowed to identify some key issues within the MFAR research area, which in turn enabled (i) to identify the relevant parameters to address the present exploratory case study; (ii) to design the research methodology; and, (iii) to find the criteria that will allow to choose an appropriate MFAR, regarding the Porto Santo case. The retrieved criteria concerning the MFAR functionality as a coastal defence structure, wave surfability improvement, and the socioeconomic and environmental benefits associated – as well as its amenity aspects, mainly related to surf – constitute useful material for further analysis. A SWOT analysis was found out as a useful technique to support the discussion because it resumes the most important factors affecting Porto Santo MFAR implementation.

3. Case study of Porto Santo MFAR

Context of the empirical study

Porto Santo is an island located in the middle of the Atlantic Ocean that is being affected by coastal erosion. Studies on the morphological evolution of south island beach, from 1976 to nowadays, revealed the existence of erosive effects (ca. 700 000 m^3 of lost sand) and siltation (ca. 350 000 m^3). These effects are both arising from natural, causes such as marine agitation and, also, from anthropogenic actions, such as the extraction of inert materials – e.g. sand, pebble, gravel – as well as, from harbour construction (Schmidt & Schmincke, 2002).

The Porto Santo beach is the most important boost for the island economy and, therefore, the geomorphological changes that have occurred, which affect wave's surfability and beach quality, carry out negative socioeconomic aspects related to the tourist flow decrease, such as unemployment. Some immediate social consequences concern the reduction of the population quality of life, the promotion of poor economic development and the aggravation of seasonality. From an environmental perspective, these geomorphological changes are also harmful since they tend (i) to induce changes in the productivity and biodiversity of marine ecosystems (Beller, D'Ayala & Hein, 2004), (ii) to affect the dunes, the endemic species of flora and the sea birds nesting (NSW, 2001) and, (iii) to damage the dynamics of the shoreline (Cooper & McKenna, 2008).

Therefore, this proposal concerns the analysis of both the interest and the possibility of reestablishment of surfable waves that will increase the potential economic impacts of surfing on Porto Santo but, at the same time, it also considers the protection of the local shoreline and the enrichment of the sea habitats.

In line with recent works (Ng et al., 2013; 2015), it is proposed to install a Multifunctional Artificial Reef (MFAR) build up from recycled material, off the southcoast of Porto Santo, to enhance surfable waves quality. This submerged structure should be designed in such a way that the new bathymetry created can enhance the local surfing conditions. The construction of the MFAR in Porto Santo would allow to restore the island natural conditions, to mitigate the existing erosion and foreseeing the creation of quality surfable wave conditions during the whole year, in order to fulfil the needs of surfers, bodyboarders and practitioners of other sea-related activities. This would allow the island to assert itself in the context of this kind of sport, providing favorable conditions for the consolidation of this tourism market.

Moreover, the construction of these submersed structures may include improved environmental value, caused by an expected increase both in bio-diversity and species abundance, by increased amenity in the form of a diving venue, and by enhanced fisheries coming from the incorporation of specific habitat (Jackson et al, 2004). This MFAR also brings in advantages, in terms of decreasing wastefulness and damage to the environment, since it reduces the total non-hazardous and regulated waste that is produced in the islands. Thus, it can bring net savings for the archipelago businesses and it could also boost local GDP, while creating job opportunities.

General methodological approach

This paper reports an exploratory study that addresses the effective potential of MFARs for developing the island beach, the marine and recreational amenities/activities, namely surfing, in Porto Santo. Since these engineering solutions are offshore submerged structures, it is necessary to decide, besides the adequate place for the installation, the MFAR characteristics and the design that best suits the geological and oceanic features. There is also a need for appraising the requirements that may hamper or facilitate the MFAR purposes, by following a Triple Bottom Line perspective (Jones-Walters and Čivić, 2013), before its implementation and operation. So, a set of requisites and criteria for appraisal of the projected Porto Santo MFAR and a SWOT analysis are proposed, in order to appreciate and classify both internal and external factors concerning the adequateness of the MFAR feasibility for the Porto Santo situation.

Description of the proposed MFAR solution for Porto Santo

It is proposed to build up a 0.6 hectare MFAR in the southern coast of Porto Santo. The planned location of the reef is approximately 200 m from shore on a slightly downwards sand covered bedrock, at a depth of approximately 10 m from mean sea level (Figure 9).

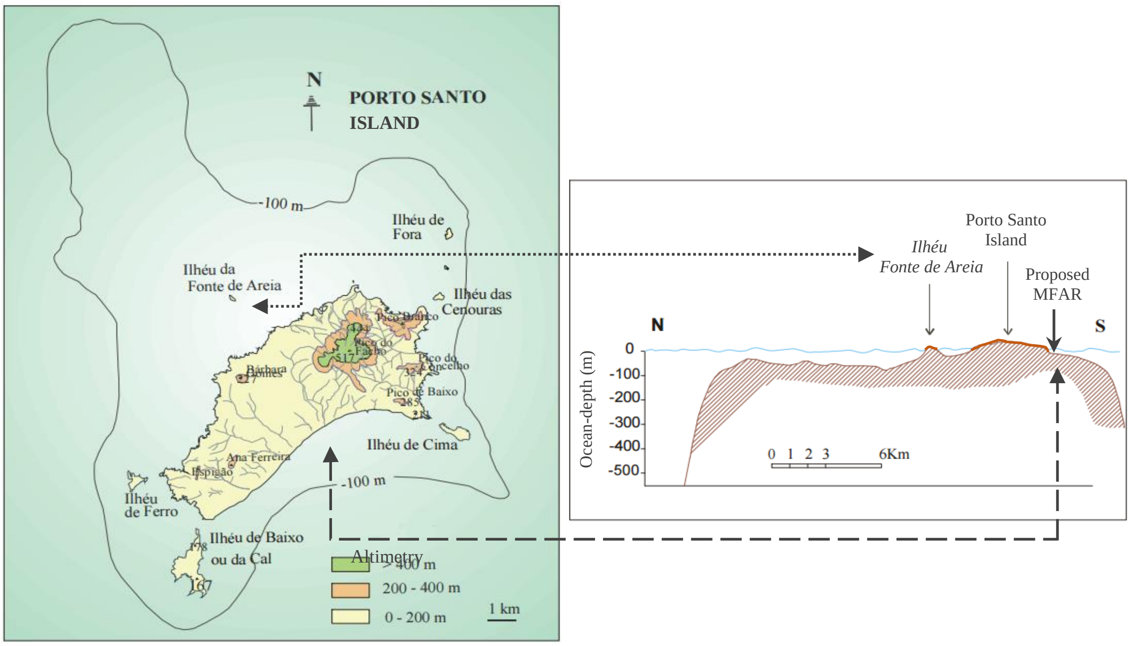

Figure 9. Porto Santo Island and the relative position of the proposed MFAR in the south beach area (adapted from Ribeiro & Ramalho, 2009).

However, the MFAR precise location in relation to the south beach will depend on the following outcomes: (i) climatology and Porto Santo wave's studies; and (ii) south bay bathymetry study. The construction option concerns the utilization of recycled materials that, otherwise, may have ended up in a landfill of Madeira archipelago or into the deep sea.

According to the Lukens and Selberg (2004) work, the rockfill made up of compressed rock blocks is assumed as a technically adequate, cheap and affordable material, after considering the diversity of materials used to construct artificial reefs. This material has also been used in the construction of breakwaters aiming at protecting the coast, since that it has the ability to dissipate the wave energy, due to its resistance to erosion.

Thus, the Porto Santo MFAR rockfill construction should be carried out with both compressed blocks of local rock coming from the excavations of the road tunnels of Madeira, and recycled concrete sleepers. By this way, the material resulting from geotechnical engineering works and urban construction could be finally recovered in an environmentally sound manner. The debris will be reused to create both surfable waves and fish habitats, plus they will provide other beneficial opportunities for the island, both recreational and economic.

The MFAR is a multifunctional submerged structure, which will be designed to modulate the action of sea in the coast through a series of processes and transformations that occur on the wave's structure. Thus, behind the MFAR, current circulation cells are set up. On one hand, they favour the accumulation of sediments on the shoreline and, in the other one, they regulate the wave's action through the combined effects of refraction and diffraction, thereby reducing their erosive effect.

The sharing of investment costs by private concessions and the creation of incentives to the private sector will promote public-private partnerships, boost the local economy and enable/facilitate the construction of such MFAR. Thus, public investments may be reduced and, at the same time, it could be possible to provide to the coastal areas, attractive and sustainable equipment in a touristic, economic and environmental perspectives.

Requisites and criteria for appraisal of the proposed Porto Santo MFAR

The targeting of the key actions on the appraisal of Porto Santo MFAR project and eventual wave surfability should be properly reflected in the definition of both (i) socioeconomic and environmental requisites; and (ii) their relevance criteria. In the implementation of the project, a broad appraisal of social, economic and environmental aspects is needed, and it is expected that each one of these dimensions will result in some quantitative and/or qualitative evaluation criteria or indicators. The set of requisites and proposed specific criteria in the current research (vide Table 3) were adapted from the work developed by Mancini, Reitano and Rossi (1991) and they have also been used by Ng et al. (2015) in a similar investigation.

Table 3 Proposed typology of requisites and criteria for the appraisal of Porto Santo MFAR

Requisites	Criteria
Low costs	**Monetary evaluation of the three main types of costs:** – Project (design and construction costs, including the value of transformation of MFAR pre-existing material by the recycling process) – Operation and maintenance (throughout the project lifespan) – External costs (value of any other committed resource which is not included within the project accounting)
Relevance of benefits	**Monetary evaluation of all expected direct and indirect benefits:** – Reduction of Porto Santo's human desertification and seasonality – Expected increasing of incomes – Intensification of tourism
Limited adverse social effects	**Qualitative evaluation of social impact** – Duration of construction – Possible conflicts of interest between the surfers and non-surfers beach users
Relevant desired social effects	**Qualitative evaluation of social impact** – Employment increase – Improving of sustainable resources management by: (i) increasing the availability and diversity of resources for the surfing activity; (ii) creation of new conditional surfing zones; (iii) creation of new conditional fishing zones (using more selective gear and / or less damaging to the environment); and (iv) increase the profitability of both, surfing industry and fisheries – Socio-economic improvement as a result of the above mentioned effects – Reversibility (theoretical possibility of restoring the previous physical conditions of the place, but also in the sense of recovering the investment as well).
Environmental impacts	**Qualitative evaluation of both shoreline alteration and sea habitats & fauna improvement.** – Debris and pollution caused by the construction and deployment of the reef – Shoreline modifications in front of MFAR due to wave's energy – Slight changes in wave patterns – MFAR displacement or dismantling under adverse storm conditions – Sea fauna modifications and biological production in MFAR zone of influence – Contribution to the recovery of the coastal fishing resources, especially those who are subjected to a more intense exploitation.

Source: Adapted from Mancini, Reitano and Rossi (1991)

The Porto Santo recycled MFAR is a multidisciplinary project which draws on theories and methodologies from environmental sciences, economic and social sciences, in an original approach both to the wave's surfability recovery and to erosion mitigation, under a circular economy model concern. A multidisciplinary consideration is key in achieving a comprehensive assessment on MFAR feasibility due to its diverse multifunctional objectives.

Feasibility and assessment of the impact of Porto Santo MFAR

The SWOT analysis – a structured planning method – has been employed to illustrate significant positive and negative factors both internal and external to the Porto Santo MFAR project (Figure 9) and followed the main lines of Ng et al (2015) work. This exercise concerns the economic, the social and the environmental dimensions. The MFAR feasibility is evaluated based on 18 selected environmental and socio-economic criteria above presented in Table 3, which are related to the place of implementation MFAR. The result of this evaluation is presented in Table 4.

Table 4. Swot analysis of the feasibility and impact of Porto Santo MFAR

	Positive	Negative
Internal	**S**trenghts S1: close proximity to residential areas and adequate walking/cycling distance S2: additional coastal residential areas protection S3: no visual impact S4: no predictable economic, social or environmental conflicts of interest S5: potencial amenities: surf improvement, beach widening and potential marine enhancement (fishery and diving activities) S6: adjustable to sea level rise S7: relatively low-cost due to: - utilisation of seabed similar locally-sourced rocks as construction material - reutilization of construction debris in recycled concrete sleepers assembly - small scale nearshore reprofiling of the natural reef	**W**eaknesses W1: few studies and lack of long-term wave data W2: lack of local real nearshore oceanographic data (bathymetry, surface features, currents, fishery) W3: sea urchins population growth in reef could be a risk for surfers W4: increased visitors might adversely affect the beach W5: uncertainty on wave prediction and coastal change effects
External	**O**pportunities O1: surfing is a growing recreational activity locally and globally O2: Porto Santo has the only sandy beach in Madeira archipelago O3: the Madeira regional government has a strong focus in tourism, new markets and economic growth O4: global awareness towards the need of sustainable development O5: interventions to mitigate coastal erosion are supported by Madeira regional government O6: emergent tendency to consider socio-cultural economic impacts and amenity values in coastal protection works O7: soft-engineering options in coastal defence is gaining popularity over hard engineering works	**T**hreats T1: MFAR technology is recent and only a few exists T2: lack of local MFAR experience and construction T3: Portuguese financial crisis T4: high local and surfing communities hope and media hype T5: local turmoil due to organisations or public opposition to changing nature or installing submersed structures T6: uncertain future effects of climatic variation T7: other coastal prioritary projects

List of recommendations following the SWOT analysis

S-O, S-T, W-O and W-T analyzes are conducted to combine the resources and capabilities of a potential Porto Santo MFAR, by taking into account the external environment. To confirm the feasibility of the MFAR installation, the presented suggestions and recommendations have resulted from these analyzes.

Considering the S-O: 1) Porto Santo MFAR should become an extension of the beach coastal defense project; 2) it is important to reinforce the importance of incorporating a soft-engineering option and coastal protection measures that include amenity values into coastal practices; 3) sustainable development needs to include socio-cultural and economic impact analysis; 4) adaptation strategies should include coastal protection measures that are adaptable to climate variability and change; and 5) niche surfing tourism must be promoted in Porto Santo.

Considering the S-T: 1) create an international multidisciplinary MFAR expert panel, including specialists who have participated in existing installed MFARs; and 2) undertake socio-economic cost-benefit analysis and environmental appraisals for the construction of the Porto Santo MFAR.

Considering the W-O: 1) increasing needs and knowledge on soft-engineering and coastal defense in Porto Santo might speed up local studies, data accessibility and availability; 2) increasing near-shore marine habitats could support research in endemic species, further protection and promote scuba diving guided tours; and 3) anticipate possible damage in the dunes and beach from visitors treading, and so, build adequate access to recreational areas.

Considering the W-T: 1) a previous baseline marine ecology survey and local currents knowledge must be undertaken as part of increasing artificial reefs knowledge; 2) regular monitoring and maintenance of the installed reef is necessary, in order to evaluate the ecological impact and monitoring the conditions of compressed rock blocks and recycled concrete sleepers, after installation; 3) environmental assessment needs to be undertaken to assess impacts on the beach and in the oceanic currents; 4) public and media communication should be well-managed with community awareness programs, regular updates and transparent process.

4. Discussion

Based on a literature review focused on surf and MFAR, two dynamic trends are identified: The first one concerns a new and expanding area of study, reflecting an interdisciplinary nature of research within the fields of economy, sociology, ecology, engineering, environmental and coastal management (Martin, 2013; Scarfe et al,, 2009). The second one concerns the supervision, conservation and improvement of surfing areas, wherein the preservation of coast profiles and habitats are an increasingly important leitmotif (Buckley, 2002a; 2002b).

The broad expansion of surf tourism and the growing popularity of surfing may also suggest a need to redefine the meaning, boundaries, and surf activities in order to better capture the emergent dynamics of the field (Martin, 2013). Moreover, the pro-environment cultural shifts in the surfing subcultures (Brower, 2008), and the impacts of technology and engineering innovations – such as MFARs – to produce waves of sufficient quality to surf (ASR, 2008), potentially act as both tourism drivers, as biodiversity developers and, also, as contributing to the economic recovery, in many coastal locations.

The innovative contribution reported in this paper concerns embracing new manufacturing technologies and capabilities to address potential market opportunities. This research shows that there is room for fine tuning and improving the surfable waves in Porto Santo, and that the construction of a submerged breakwater off the south coast of Porto Santo is a plausible means to achieve this end.

It was found out that some issues are essential for ensuring the project success by using a SWOT analysis supported on a thorough literature review. These issues are key success factors and might be summarized, as follows: (i) the acceptance and participation of the local community and practitioners of sea-related activities in the design and construction of Porto Santo MFAR at all stages of the project, through public participation mechanisms, which is also supported by Cooper & McKenna (2008); (ii) the support and collaboration between, Private, Non-Governmental Organizations, (NGOs) and public local, regional, or national Entities as Fletcher, Bateman & Emery (2011) suggest; (iii) the insertion of the MFAR project in a logic of coordination and preservation of local ecosystems, by pursuing integrated coastal management as Jackson et al. (2004) also propose; and (iv) effective and constant promotion of the newly created spot through marketing campaigns, taking into account all its valences and features, not forgetting the originality and innovation inherent in the MFAR (vide also Evans & Ranasinghe, 2001).

The mentioned key success factors are closely related to: (i) the strict implementation of all determinations resulting from the studies conducted; and (ii) to the differentiation provided by design innovation, by the quality of the wave and by marine biodiversity, as Pickering and Whitmarsh (1997) put it.

So, considering the research questions presented at the beginning of the present work, the results of SWOT analysis and the state of the art of surf improvement by artificial reefs, the construction of a MFAR in Porto Santo seem to be a pertinent option for the production of a good quality surfable wave throughout the year (RQi), for increasing the potential economic impacts of surfing (RQii) and, for boosting business and providing a good sustainable, economic and social solution of Porto Santo (RQiii).

These findings confirm that MFARs appear to be performing well with respect to coastal protection in reefs where coastal protection is the primary objective (ASR, 2008). Nevertheless, the possible development of a marine ecosystem similar to many of the installed reefs also appear to reproduce the positive side effect occurred in some popular locations for fishing and diving, as illustrated in Narrowneck Reef (Jackson et al., 2004). With respect to surfing, the impact of MFARs ranges from improved surfing with predominantly favourable public opinion, e.g. Burkitt's Reef, Cables Reef (Pitt, 2012), and with predominantly non-favourable public opinion, e.g. Narrowneck Reef, (Jackson et al., 2004) to generating an extremely challenging wave, e.g. Boscombe Reef and, or even to an eventual removal of structure, e.g. Dorset's Reef (Daily Mail, 2011). However, in the case of Porto Santo a predominantly favourable public opinion is expected.

To sum up, the global growing emphasis on the importance of incorporating amenity values into coastal protection works enables this research to provide supported sustainable solutions, which are framed in the economic, social and environmental aspects, to other small islands, similar to Porto Santo.

5. Final conclusions

Porto Santo has an economy based almost exclusively on the tourism and this sector has been one of the strategic paths pursued by the local and regional governments for leveraging the local economy. So, financing an investment such as the MFAR, despite its magnitude, does not only make economic sense, but it would also help to reduce social problems, such as seasonality and unemployment. On the other hand, on an environmental standpoint, the island has urgent needs in the protection of its coasts and marine environments, in order to, not only guarantee the sustainability of the beach and local biodiversity, but also the continuity of its tourism flows, in the future.

Pursuing this line of argument, sustainable development should include socio-cultural, environmental and economic perspectives, so that innovative constructions, such as MFARs, would not only allow effective solutions to fight the previously identified Porto Santo problems, but also to enhance and boost the fragile local economy, by differentiating it and ensuring long-term sustainable socio-economic and environmental development. Furthermore, the impact of man-made interventions is also reduced by using recycled material in reef construction and by making it similar to the natural environment as much as possible, despite incorporating features that develop both species habitats and natural conditions and, social and economic value.

By taking a practitioner perspective, the recycled MFAR project is identified as significant enough to be further developed, implemented and operated, in the future, in order to support local government decision making. In this way, both the local surf community and the population could benefit from the existence of an enhanced quality of surfable waves.

Finally, despite the European and global economic situation, and specifically the poor financial and budgetary situation of Portugal and Autonomous Regions, there is a number of other important factors, which should be taken into consideration, since that they may present risks to the Porto Santo MFAR implementation. This kind of scenario includes: (i) the failure to follow the guidelines and recommendations of the feasibility and environmental impact assessment; (ii) the lack of local, regional, national or European support to the project, whether public and private; (iii) the bureaucratic and legal issues inherent in projects of this magnitude and importance; and (iv) the poor Regional, National or International tourism promotion.

At last, it is argued that recycled MFARs constitute a relevant manufacturing contribution that embrace advanced technologies, capabilities and markets, and they may be considered a possible long-term solution for coastal issues, under the umbrella of a Triple Bottom Line approach.

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[(ǂ)] Despite all the other references supporting the text can be found in Sousa, P.B. (2014), they might also be supplied by consulting the following website: https://bibliographyblog.wordpress.com.

Title: Understanding ecosystems: towards a more systemic approach

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Abstract
Recently, the concepts of industrial, business and innovation ecosystems have emerged as important fields in business and in research. The concept of a business ecosystem, as an analogy of a biological ecosystem, enables a broader assessment of the business or innovation phenomena, going beyond traditional firm or value chain boundaries. Whilst ecosystems are often described as 'systems', and could be considered complex adaptive systems, with a few notable exceptions, there are few examples of using systems thinking or recognised systems approaches to studying them.

This paper aims to address this gap. By drawing on systems thinking, established systems methodologies and examples from practice, a simple pragmatic approach to studying ecosystems is proposed. The resulting framework considers conceptual, structural and temporal constructs. The approach is exemplified by a case study exploring an emergent ecosystem.

Keywords
Systems, boundaries, ecosystems, methods

Introduction

The business ecosystem, as a concept, was introduced by Moore (1993), extending previous ideas of value chains, to consider influences and co-evolution beyond the firm. In the 2000s, the concept of ecosystems was extended in the innovation field by Gawer (2013), as platforms, and more recently by Adner (2006, 2012). In related areas the terms innovation ecosystem, business ecosystem, industrial ecosystem and value ecosystem are often used. Over the past decade the number of journal articles focussed on 'business ecosystems' or 'innovation ecosystems' has risen markedly, to around 900 and 500 respectively[1], reinforcing the importance of the concept. Based upon a review of selected articles, it would appear that the different descriptions of ecosystems are largely a function of perceptions about boundaries (and to some extent the lack of objective definition within the research).

Many recent ecosystems papers have little or no recognised systems approach or methodology evident or explicitly identified (Midgley 2015). This is not a new phenomenon. The challenges in studying complex networks and systems (Halinen and Törnroos 2005) and in defining their boundaries (Gibbert and Välikangas 2004) are well documented. Despite this there is no agreed or prevalent methodology, although a number of approaches to studying ecosystems have been proposed, drawing from prior network research (Lin 2009, Rong 2015), or taking a network architecture perspective (Korpela 2013), or defining an approach based on extant ecosystem literature. With notable exceptions (Peltonemi 2006), few approaches attempt to address the business or innovation ecosystem as a 'system' and use systems thinking.

[1] *Based upon an online search in July 2015, of peer reviewed journal articles, in Web of Knowledge (http://apps.webofknowledge.com/)*

So, the purpose of this paper is to address the question: *How to better study and understand business and innovation ecosystems?* In so doing, it is intended to make a contribution to business and innovation ecosystem thinking and to expand the application of systems thinking and methods.

Approach

The research was conducted by a review of three bodies of literature, namely business (and innovation) ecosystems, systems thinking and finally, approaches to studying complex systems, with each drawing largely on major reviews, key or highly cited literature in each domain. Major themes and concepts were coded to develop 'core constructs'. Using systems thinking literature and approaches to studying complex systems (drawn largely from social sciences) a conceptual framework was developed. In addition, noting the issues above, an approach to help objectively define system boundaries was developed from the same literature.

The resulting framework was then used to investigate an emerging innovation ecosystem in healthcare, and used to exemplify the ecosystems framework approach. The interviews were coded and a combination of inductive and deductive methods used to identify key themes and assess the proposed investigational framework.

Systems Thinking

The roots of systems thinking and theory are complex (Von Bertallanffy 1968; Jackson 2000), drawing from mathematics, biology, physics, engineering, cybernetics and information theory, social sciences and philosophy (Boulding 1956; Daellenbach and McNickle 2005). Its application to business issues has had a varied history (Jackson 2000). The early popularity and influence of 'general systems theory' from the 1950s to 1970s, resulted in general agreement of concepts such as 'system', 'elements', 'relationships', 'boundary', 'emergence', 'hierarchy', however during the 1970s and 1980s increasing criticism of the traditional approaches led to fundamental differences in orientation, largely driven by philosophical and methodological issues (Jackson 2000:3). In the 1990s, the popularity of Senge's (1990) *The Fifth Discipline* and the 'translation' from biology of Maturana and Vela's (1980) work on autopoesis popularized complexity and chaos theory (Gleick 1987), therein resurrecting more mainstream interest. Mingers (1997), taking a multi-methodology approach and Taket and White (1997) using a 'framework', rather than a methodology, have attempted to overcome the perceived methodological challenges.

Ludwig von Bertalanffy, in his seminal work *General Systems Theory*, notes that "*an attempt to summarize the impact of "systems" would not be feasible*" (1968:5). Similarly, Cabrera (2006:10) states that "*the literature and field of systems applied across the sciences and social sciences is vast making a comprehensive review impractical*". Midgley (2003a:xix) goes further and does "*not believe it is possible to present a 'neutral' account of either systems thinking or its history… interpretation is inevitable, and what appears central or peripheral depends on the purposes and assumptions*". So, by necessity, this review only covers concepts and topics considered relevant by building from a few seminal works and highly cited works in the relevant fields.

A number of authors (Anderson 1999; Von Bertallanffy 1968; Luhmann 2013; Midgley 2003a) define the main features of complex systems; comprehensive reviews are provided by both Midgley (2003a, 2003b, 2003c, 2003d), Mingers (2010) and Francois (2004). Taking these as a starting point, a summary of the main systems concepts and features are presented.

System Boundaries

Systems are entities with more than one component that are connected or interrelated (von Bertalanffy 1956), as the number of components and connectedness grow, they become complex (Anderson 1999), making predictions of cause and effect difficult. In business complex systems also tend to adapt with time (Holland 1992), making their study more challenging.

In order to understand a system, one has to identify a difference between 'the system and something else' (Luhmann 2013:44) or, put another way, a boundary (Cilliers 2001) between the system and the environment in which it exists. But complex systems are open systems, and in complex systems relationships are important, possibly more so that the components (Cilliers 2001), and this includes the relationship with the environment. The first major challenge in investigating a system is the definition of the system itself and specifically the boundary selection (Daellenbach and McNickle 2005; Heath, Fuller, and Johnston 2009; Midgley, Munlo, and Brown 1998): "*Boundaries [of complex systems] are simultaneously a function of the activity of the system itself, and a product of the strategy of description involved. In other words, we frame the system by describing it in a certain way (for a certain purpose) but we are constrained in where the frame can be drawn. The boundary of the system is therefore neither a function of our description, nor is it a purely natural thing*" (Cilliers 2001:141).

As previously noted, in much ecosystem literature the boundary is often not explicitly identified, neither is the approach used to define it. A key consideration is that *all* causal factors under investigation should be within the system and this provides one test of any boundary selection, and therefore the boundary is something that *constitutes* what is bounded, rather than being a physical separation. Therefore, the boundary is *conceptual* and associated with the objective or the focal issue of the research. Boundaries and identity are important in sense-making (Snowden and Kurtz 2003; Weick 1995). Boundaries may be defined by the researcher or by actors in the system or environment, what is important is that we are critical about how we use boundaries, as it is so influential (Midgley et al. 1998). Defining the boundary introduces risk, that the important aspects may be excluded from the model (Cilliers 2001). To reduce the risk of researcher bias or subjectivity, the actors in the ecosystem should be engaged in helping define or validate the proposed boundary. Where the ecosystem is nascent or developing it may be necessary to engage a number of actors to get different perspectives on the ecosystem, its boundary and the objective.

It could be argued that ultimately the system constructs its own boundaries (Webb 2013), suggesting that to have any confidence in boundary selection, the researcher must engage ecosystem and wider environment actors. Such an approach is proposed here, derived from Cilliers (2001), Webb (2013) and the work by Doreian and Woodward (1994) defining boundaries of social networks. Depicted in Figure 1, it involves starting with a small knowledgeable group who are known to be within the ecosystem and who understand the focal issue, then using that group to identify other key actors to interview, and then using 'snowballing' (Goodman 1961; Scott and Marshall 2009) to extend the interactions to other actors, some of whom will be beyond the system boundary. The proposed process is iterative and whilst the inclusion of actors in the process increases objectivity, there will always be a subjective decision (by either the actors or the researcher) required as to the relevance of certain actors to the focal issue, and therefore whether they are included in the system or not. It is suggested that stakeholder analysis (Freeman 1984; Freeman et al. 2010; Rowley and Moldoveanu 2003; Rowley 1997) provides a means to help resolve this, by addressing the interest and influence each stakeholder (or actor) has on the focal issue.

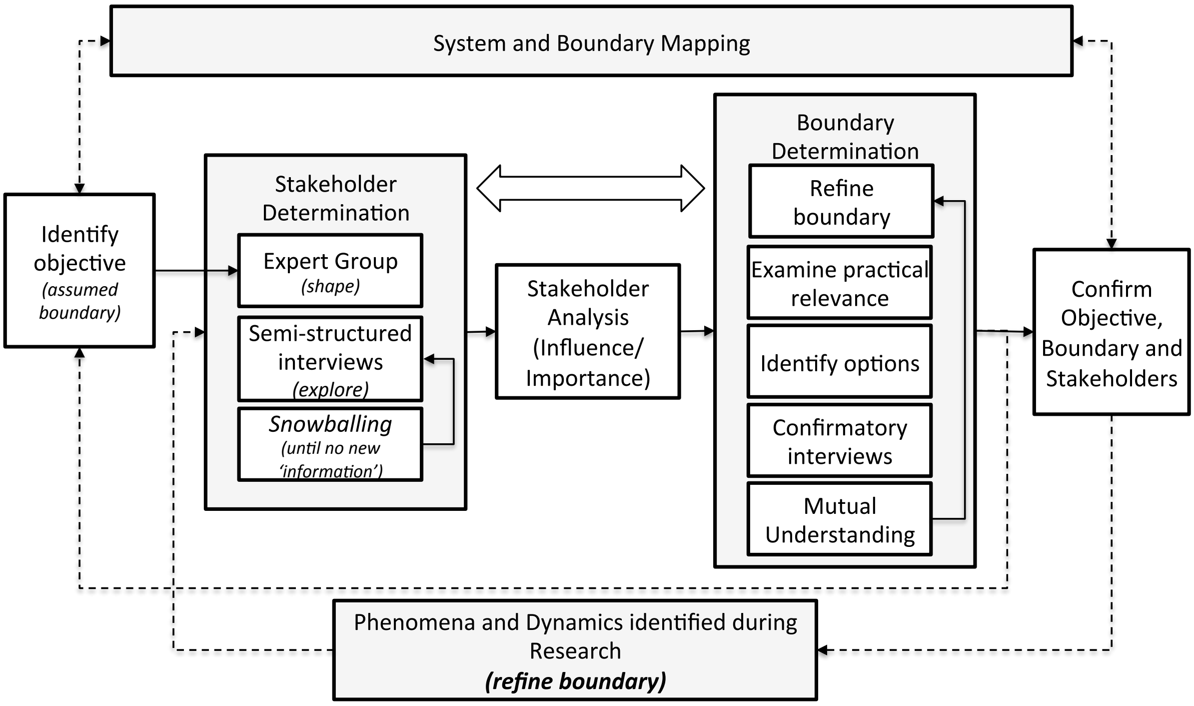

Figure 1 - An approach to system boundary determination

During the process, semi-structured interviewing may be used to help identify the interviewees' perspectives on the focal issue and who is in (or out of) the system. By reviewing the feedback from interviewees on an on-going basis, the identification of new issues and new actors can be monitored. This can then be used as a basis to curtail exploratory interviews and move to confirmatory activities. By interviewing actors who are 'spatially' distant in the ecosystem, the focal issues, the system and its boundary can be tested (or validated). Where study of an ecosystem is longitudinal and evolving the boundary may change, which should be tested to help refine the boundary during the research period.

Structure and Relationships

Complex systems are not homogenous (Cilliers 2001). They have structure and this structure may result in some form of hierarchy (Holland 1997). Using the approach proposed in Figure 1, some of that structure can be identified and mapped, but further in-depth analysis is often required. Many existing mapping techniques exist to understand ecosystems or networks. The choice of methods is dependent on the research, but as a minimum it is suggested that a simple map showing the system's boundary, key actors and key links between them is used to illustrate the ecosystem, an approach similar to soft system methods mapping (Checkland and Scholes 1990). That mapping may focus on spatial, relational or other linkages, as appropriate.

A summary of commonly used mapping approaches is included in Table 1, with identification of the objective and mapping emphasis or focus. Depending on the nature of the investigation a combination of these, or variations could be used to map out parts of the ecosystem.

Table 1 – Examples of Network or System Mapping Approaches

Mapping Type	Objective	Emphasis	Reference
Emerging Industrial System Networks	Industry, Value Chain and Emerging	Influence of supply networks	(Harrington, Baril, and Srai 2012)
Supply Chain mapping	Dynamics and structural impact on actor activities	Trends and Structural Changes	(Kumar et al. 2013)
Global Value Chain mapping	Governance, Value Capture	Governance	(Gereffi, Humphrey, and Sturgeon 2005)
Soft systems methodology	Understand system dynamics	Relationships	(Checkland and Scholes 1990)
Process Flow	Value Definition	Value Capture	(Bowman and Ambrosini 2000)
Road mapping	Dynamics and Patterns of Emergence	Industrial emergence	(Phaal et al. 2011; Probert et al. 2013)

For more complex or diffuse systems, techniques based upon social network analysis (Knoke and Yang 2008) could be employed; a review of these techniques in innovation is provided by van der Valk (2010), who identified three main areas of potential use: networks of collaboration; communication networks; and networks of technology.

A key step in any system or ecosystem is to understand the relationships, which as previously noted, may be more important than the physical structure or individual actors. Relationships and the complexity and interconnectedness of those relationships help define the landscape (Kauffman and Johnsen 1991) and are themselves a *structural* construct.

In the context of studying business or innovation ecosystems, stakeholder theory (Freeman 1984; Friedman and Miles 2002) provide a framework for analysis. Mitchell (1997) proposed a model addressing stakeholder salience and identified three factors: power, urgency and legitimacy. Rowley (1997) considered network density and the centrality of the actor as other factors. Stakeholder models are in themselves considered dynamic, and frequently changing (Mainardes, Alves, and Raposo 2012), so a stakeholder may act in the capacity as a regulator, controller, partner, or be passive or a dependent and that role may vary in time, and this will impact their influencing strategy (Frooman 1999).

System Dynamics

Dynamics (Forrester 1958) are implicit in any complex system. To obtain a true understanding, implies some level of modelling (Sterman 2000). A review of systems dynamics approaches is provided by Martinez-Moyano and Richardson (2013), but this topic is beyond the scope of this paper, which is focussed primarily on qualitative methods, which are the more prevalent in the study of business ecosystems. However some understanding of the system dynamics and its history is important to put the research into context and to help explain observed phenomena (Cilliers 2001; Fuller and Moran 2001). Soft systems methodology (Checkland and Scholes 1990) is a widely used and practical approach to studies of complex systems in business and operations research (Mingers and White 2010). Complex systems exhibit emergence (Goldstein 1999; Holland 1997; Midgley 2008), properties that none of its components (or actors) have, driven by the non-linearity inherent in the complex structure and relationships. The changes are constant and interdependent (Sull and Eisenhardt 2012), as a result of mutual causality and feedback (de Greene 1994). Understanding the dynamics, provides a *temporal* perspective on the ecosystem.

Key Concepts in Systems Thinking

The key concepts and further literature covering systems' boundaries, structure, relationships and dynamics are summarised in Table 2.

Table 2 - Summary of Key Concepts in Systems Theory and Thinking

Key Systems Theory Concepts	Description and Examples	Authors
Definitions		
System	An entity with more than one component that are connected or interrelated.	(Von Bertallanffy 1968) (Anderson 1999) (Luhmann 1984, 2013)
Complex Systems	A system where the number of components or connectedness collectively make prediction of cause and effect difficult.	(Anderson 1999; Von Bertallanffy 1968; Cabrera 2006)
Complex Adaptive systems	A complex system that adapts and evolves with time, social networks, economic networks *(eg business ecosystems)*	(Holland 1992) (Holland 2006) (Hall and Fagen 2003)
Boundary	**(Conceptual)**	
Boundaries	All systems have boundaries, in the real world systems nearly all are 'open', ie there are flows in and out (information, materials, money). In a social context boundaries are not easily definable, but are constructs of the observer or researcher and context sensitive. Note - All causal factors should be within the system being investigated.	(Midgley et al. 1998; Midgley 2003a) (Cilliers 2001) (Doreian and Woodard 1994) (Snowden and Kurtz 2003)s
Structural	**(Physical)**	
Agents (Actors)	An agent is an individual, organisation, institution, or customer that makes a meaningful intervention in the system Note – not all actors have agency	(Giddens 1979)
Hierarchy	Systems are structured into hierarchies or layers. This structure may be asymmetrical. Cross-connections may exist between hierarchies.	(Holland 1992, 2006) (Muller 1997) (Von Bertallanffy 1968) (Cilliers 2001) (Boulding 1956)
Systems within Systems	Associated with hierarchy, systems can consist of sub-systems or be part of supra-systems.	(Anderson 1999) (DeLaurentis and Callaway 2004)
Modular	Systems have subcomponents that can take on modular form, with defined interfaces and interdependencies (or relationships)	(Baldwin and Clark 2000) (Sanchez and Mahoney 1996)
Emergence	A system may exhibit properties that none of its constituent parts do. The non-linearity of the system and its relationships results in unexpected outcomes and structures.	(Goldstein 1999) (Holland 1997) (Daellenbach and McNickle 2005)
Autopoiesis (self-organization, sustained by 'importing energy')	Patterns are created through simultaneous and parallel actions of multiple agents. A system is capable of maintaining and sustaining itself through self-organization.	(Maturana and Varela 1980) (Bak and Chen 1991; Bak 1996) (Wheatley 1992)
Relationships	**(Physical)**	
Rugged Landscape	The combination of number of agents and their connectedness gives rise to a landscape that is uneven, as connectedness increases the 'ruggedness' of the landscape increases. Impacting ability to find the optimum.	(Kauffman and Weinberger 1989; Kauffman 1993, 2000) (McKelvey 1999)

Key Systems Theory Concepts	Description and Examples	Authors
Relationships	The interconnection between agents, these may be physical, contractual etc. There are also relationships between system hierarchies, sub-systems and the environment.	(Hall and Fagen 2003) (Rapoport 1986) (Cilliers 2001) (Frooman 1999)
Critical connectivity	Enables 'weak' ties to play key roles in networks (and is linked to the concept in 'six degrees of separation'	(Strogatz 2001; Watts and Strogatz 1998) (Collins and Chow 1998) (Guare 1990)
Fitness Landscape	Adaption in rugged landscape, notion of fitness for survival (e.g. *Kauffman's model N(K+C) as N, C and K increase landscape becomes more rugged)*	(Kauffman and Levin 1987) (Levinthal 1997) (Wright 1937)
Order and Control	Imposing external controls on a complex system is difficult and often the outputs are counterintuitive. Complex systems maintain a degree of self-order due to interactions and constraints imposed by agents on each other. But eventually they evolve to '*the edge of chaos*'; those that do outcompete.	(Prigogine and Stengers 1988) (Holland 1995) (Khalil and Boulding 1996) (Kauffman 1993) (Snowden and Kurtz 2003)
Dynamics	**(Temporal)**	
Schema or Schemata	The routines, rules, policies and values of agents, these schema are themselves stochastic, giving rise to unpredictability. *Note - in adaptive systems these also evolve over time*	(Argyris and Schon 1978) (Kauffman 1993)
Dynamism	Changes are constant and interdependent, as a result of mutual causality and feedback between two agents.	(Sull and Eisenhardt 2012) (de Greene 1994)
Non-linear Dynamics	Cause and effect are not linear and so a small change may result in a large effect *(e.g. the often used 'butterfly' and 'hurricane' analogy).* Non-linear dynamics are a common feature, resulting in unexpected effects and challenges in determining causality.	(Strogatz 2001; Watts and Strogatz 1998) (Barabasi 2007; Barabási 2002, 2009) (Guastello 1995) (Boisot and McKelvey 2011)
Non-random future	Although not predictable, common patterns of behavior are observable.	(Anderson 1999)
Attractors	An underlying pattern or a condition or set of properties that a system focuses around or evolves towards for a period. A limited area in 'state-time'.	(Strogatz 2001)
Quasi-equilibrium	A state that is approximately in equilibrium, the system will at time exhibit near equilibrium, but the non-linear nature of relationships will over time disrupt that 'equilibrium' and pull away attractors.	(Dooley and Van de Ven 1999)
Self-organizing criticality and punctuated equilibrium	The effect of lower level changes eventually building up to a 'tipping point', which results in a step change at a higher level *(i.e. the equilibrium is punctuated)* and results in a move from one metastable state to another.	(Bak and Chen 1991; Bak 1996) (Eldredge and Gould 1972; Gould 1980)
Co-evolution	The system and agents co-evolve, but systems can only build through its own operations	(Kauffman and Johnsen 1991) (Bak and Chen 1991)

Perspectives and implications for methodology

The investigation of systems may follow a functionalist, interpretive or an emancipatory approach (Daellenbach and McNickle 2005; Jackson 2000), driven by the magnitude of uncertainty, technical complexity and coerciveness or conflict in the system. For the study of ecosystems the assumption is that this would be considered as largely interpretive and therefore requiring a pluralist approach (Jackson 2000). In Midgley's view (2006:470), "*no single set of methods yet developed could have addressed all the issues (in this intervention)*". A further consideration in the study of social systems (such as business or innovation ecosystems) is that the complexity is such that a reductionist or narrow focus is unlikely to uncover causal mechanisms (Midgley 2003d).

Westhorp (2012) uses the concept of 'layering theory' to embed different theories into different layers in the model of the system: "*Layering theories provides a structure and conceptual framework to examine the ways that multiple mechanisms operate in multiple levels of systems to generate outcomes*". In a similar vein Mingers (1997; 2006) calls for a multi-methodology approach to address complex systems problems, a call echoed across major systems thinkers (Midgley 2000). The driver for these approaches is that different 'views' of complex systems may yield different insights and thus, unearth true causality.

Furthermore within the ecosystem, the actors themselves have differing perspectives; so relying on limited interviews (i.e. from just the focal firm) may give a filtered or distorted view. Taking different perspectives provides another *conceptual* approach to studying ecosystem.

Proposed Framework

The proposed framework, derived from the above literature, addresses five constructs, namely: **Boundary, Structure, Relationships, Dynamics and Perspectives** or **BSRDP** (see Table 3). These enable a description of the ecosystem itself using a combination of conceptual, structural and temporal constructs and, as such, provide a more holistic or systemic view of the ecosystem.

Table 3 – Proposed Systems Investigation Framework (BSRDP)

Construct	Investigational Approach
Boundary (conceptual)	Defining system boundary, which for socio-technological systems is conceptual with different perspectives by different actors
Structural (physical)	Define the structure, identify and map different levels, hierarchies and sub-systems (modules) of relevance, and key agents at the micro-, meso- and macro-levels, identify any emergence (in structure).
Relationships (physical)	Understand the key interdependencies and relationships (e.g. contractual and governance) between agents, subsystems and between different system levels, and the 'rules' that govern them, with an emphasis on local causality, non-linearities and dimensions (e.g. scale and power)
Dynamics (temporal)	Understand the system history. Identify major input and output flows, key processes and feedback loops, patterns and trends, with particular attention on the unexpected or 'new' and changes to boundary, structure and relationships.
Perspectives (conceptual)	Use different views and perspectives (both spatial and temporal) to broaden understanding, define 'capability' and 'performance', identify system changes, and to provide an opportunity for 'triangulation'.

Graphically the framework is shown in Figure 2, with the conceptual, structural and temporal components.

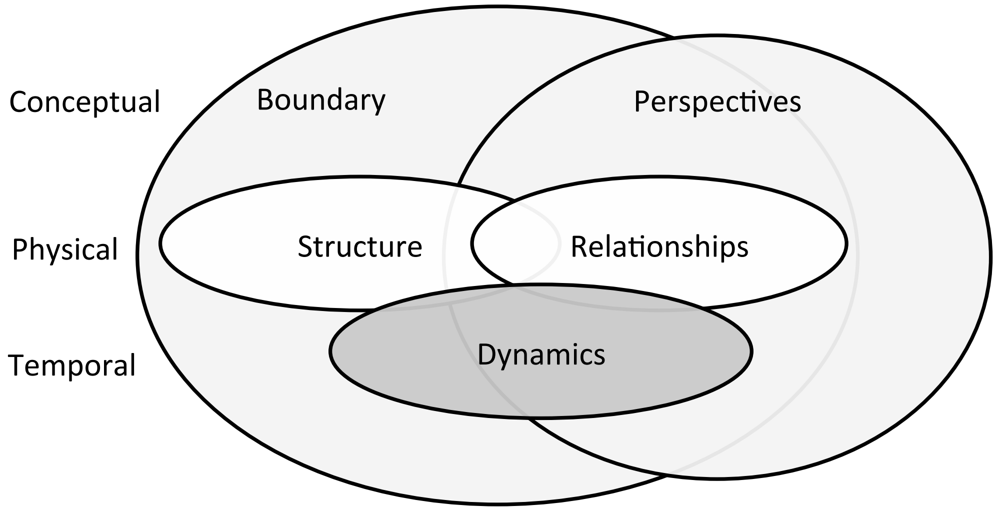

Figure 2 – BSRDP Framework of conceptual, structural and temporal components

Investigation example: a nascent ecosystem

The proposed BSRDP Framework, with a combination of mapping approaches, was used to investigate a nascent business ecosystem, namely the convergence technologies in healthcare innovation. The study sought to understand the extent and characteristics of the ecosystem and some of the issues and challenges as part of a wider research project exploring how organisations innovated in such ecosystems.

From an initial expert group (of actors known to be within the ecosystem) an initial list of potential interviewees was identified. Semi-structured interviews were used, to ask about their understanding of convergence in healthcare innovation, to identify examples, challenges and opportunities and the main actors, then 'snowballing' was used to extend to a total of 23 semi-structured interviews. This resulted in interviews spanning academia, funding bodies, investors, start-ups and multi-national innovators, suppliers, regulators, government institutions and various customer, patient and advocacy groups. The interviews were supplemented by a review of publically available literature and news articles on relevant topics. Finally, four confirmatory interviews were conducted with actors across the ecosystem.

A number of existing and well-recognised tools to capture each aspect of the framework were used, including stakeholder analysis, network and road mapping, and simple frameworks.

Findings

Ecosystem Definition and Boundary Selection

The ecosystem was complex; involving cross-industry or convergent innovation, so reference to well defined existing systems was not possible. Similarly many of the structures, relationships and dynamics were evolving, making the use of multiple perspectives important to aid understanding.

The methodology, previously identified, to define the ecosystem boundary (Figure 1) was used during the preliminary interview phase. During the early interviews many new actors and issues were identified. These were collated and mapped, and after 18 interviews there was a marked reduction in new actors and issues emerging. Interviews were continued, where they had already been set up, but very few new actors or issues emerged and after 23 interviews, they were concluded.

There was divergence in views as to whether some actors were in the ecosystem or not, a decision to include was made by assessing frequency of occurrence and the stakeholder analysis (continuity of likely interest and influence on outcomes). An extract of the analysis is included in Table 4 (for space reasons this is only a partial table). The findings from these interviews were then summarised in the form of an ecosystem 'map' and a table of key issues and themes.

Table 4 – Examples of ecosystem stakeholder analysis to determine boundary

Ecosystem: Healthcare Convergent Technologies UK Cluster	 Actor Group	Interview incl Count	Rank	Interest H M L	Influence H M L	Continuity L M S	ICC	ICC+Count	Include in Ecosystem
Producers	Diagnostic	17	1	3	2	1	6	23	Y
Producers	Pharma	17	1	2	3	2	12	29	Y
Producers	Med Tech	16	3	3	3	3	27	43	Y
Producers	Health ICT	16	3	2	3	2	12	28	Y
Providers	Hospital Trust	15	5	2	2	2	8	23	Y
Producers	Biotech	14	6	2	2	3	12	26	Y
Producers	Startup/ SME	13	7	3	1	2	6	19	Y
Producers	Other Tech	12	8	2	1	1	2	14	Y
Knowledge	University	12	8	2	2	1	4	16	Y
Infra/Support	SBC/Biocity	11	10	2	2	3	12	23	Y
Funding	VC	11	10	2	3	2	12	23	Y
Payer	CCG / NHS E	10	12	2	3	3	18	28	Y
Policy	DoH/OLS	9	13	1	2	2	4	13	Y
Reg	NICE	9	13	1	1	2	2	11	Y
Providers	Comm Pharmacy	3	36	2	2	2	8	11	Y
Res Fund	TSB/IUK	2	40	2	2	2	8	10	y
Payer	Private Ins UK	2	40	1	1	1	1	3	n
Suppliers	Comms Tech	2	40	1	1	1	1	3	n
Suppliers	Tech Res Org	2	40	1	1	1	1	3	n
Suppliers	CMO	0	55	1	1	1	1	1	n
Producers	Ind Associations	0	55	1	1	1	1	1	n

Ecosystem Structure and Relationships

For some parts of the system more in-depth 'subsystem maps' were developed or where they existed, examples were obtained from public sources, for example the complexity of the landscape for the UK Government support for research and innovation is summarised by Dowling (2015:10). Four further interviews with actors from diverse parts of the suggested ecosystem were then interviewed to confirm, or validate, the ecosystem boundary (i.e. which actors were in or out) and the key themes. An example of a generic high level map showing the key actors in clusters (or groups) and the key links (or relationships) between these groups is shown in Figure 3. In this high level map some of the actors within the clusters are in the ecosystem, some are out, depicted as the boundary crossing the cluster. More detailed maps (for each cluster) identify specific actors in and out of the ecosystem (see Figure 4 for an example).

The mapping was used to show high level interactions or relationships, but a more in depth understanding was developed using simple stakeholder analysis and tables to map the actors interest, influence and timing (i.e. urgency and continuity).

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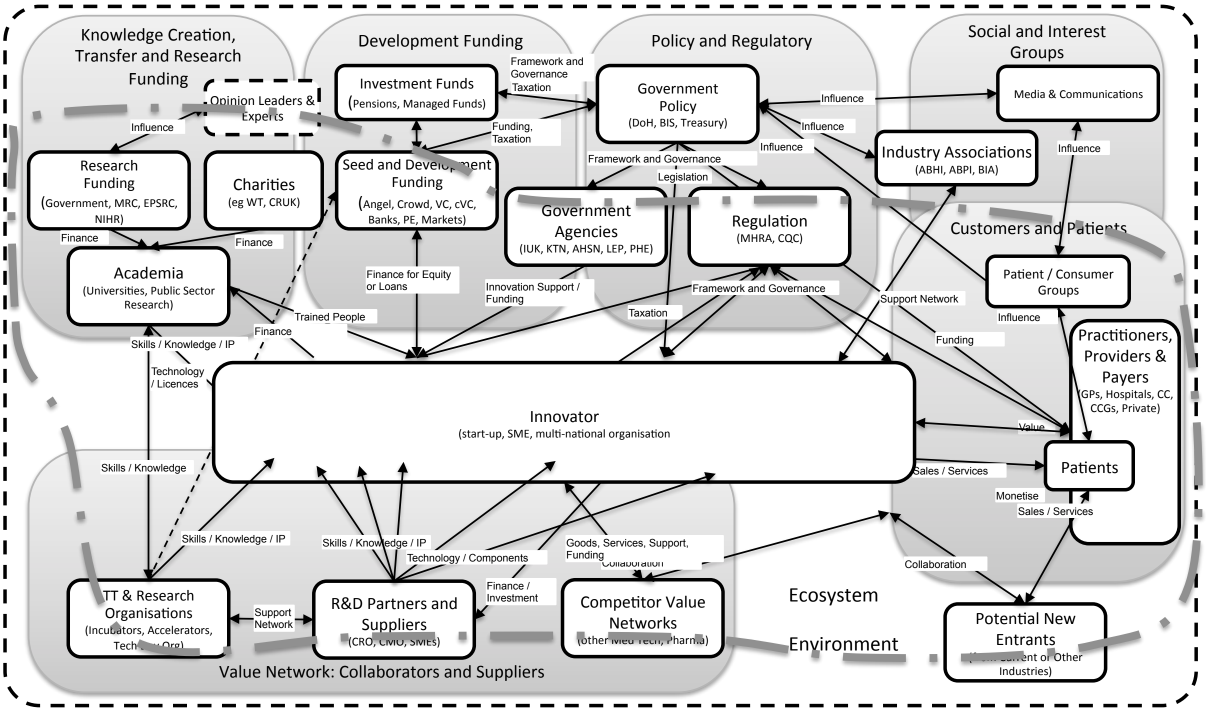

Figure 3 – Example of a generic high-level ecosystem map

Ecosystem Dynamics

In addition to mapping the ecosystem, the interviews provided information on the key issues, challenges and opportunities in the ecosystem. Using inductive coding, key themes emerged; these provide some insights on the dynamics and risks. A summary of these is shown in Table 5.

More in-depth understanding of the dynamics was obtained by studying the sub-systems and by using soft systems methodology approaches to map the actors, their relationships and dynamic effects. However this does not provide a timeline perspective.

The dynamics of the overall ecosystem, in terms of trends in technology, funding and markets and the innovation of new products was mapped in detail using a technology roadmap (Probert et al. 2013), a high level (and much simplified) version is depicted in Figure 5.

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Table 5 – Summary of high-level ecosystem issues identified by actors

Ecosystem	Business Model	Knowledge / Technology / Science	Value Network / Supply Chain	Funding / Investment	Relationships / Culture	Policy / Regulation	Support
Issues							
Evolving, heterogeneous ecosystem - several 'not obvious' entrants possible	Convergence requires focus on business model, not just product or techology	Major differences in approach across industry sectors - so there is a culture as well as science difference	Impact of obsolesence in CH / electronics components etc versus regulated development life-cycle	VCs and PEs operate in different markets. Few cross sector investors.	New players eg ICT/Tech-but not yet clear of their intent or approach.	All markets regulate differenly - safety, efficacy and market access	No clear support focus. Value of some insitutional and infrastructure activities was questioned
Customer identification is difficult and adoption is poor - risk averse, priority, balance of power/control	Perceived poor engagement of Customers in R&D process	IP space complex. Background v foreground v differentiating. Need to avoid 'wastefulness' of excessively duplicative biotech / pharma R&D	Increased complexity and diversity of supply base (geography, time, type)	Implication for when investors sees a return on investment (late), so seen as higher risk	Limited cross-sector support (infrastructure, policy) other than embryonic KTN/Catapult	Liability issues for new players as they move product/service offering moves downstream	
Very fragmented customer models	Convergence has potential to impact Public Health, Health Delivery Systems and Treatment	Lots of duplication in R&D, diffuse incubators and networks, no connections			Lack of infrastructure to support development. Currently a bottom up enterprise	Data ownership and privacy/security not fully resolved. Lack of interoperability and 'open source'	
	Potential to Transform Care Delivery model, so innovation becomes 'systemic' making innovation more complex	Innovators often miss the key which is to identify how product / service transforms patient outcome in clinically relevant setting.					

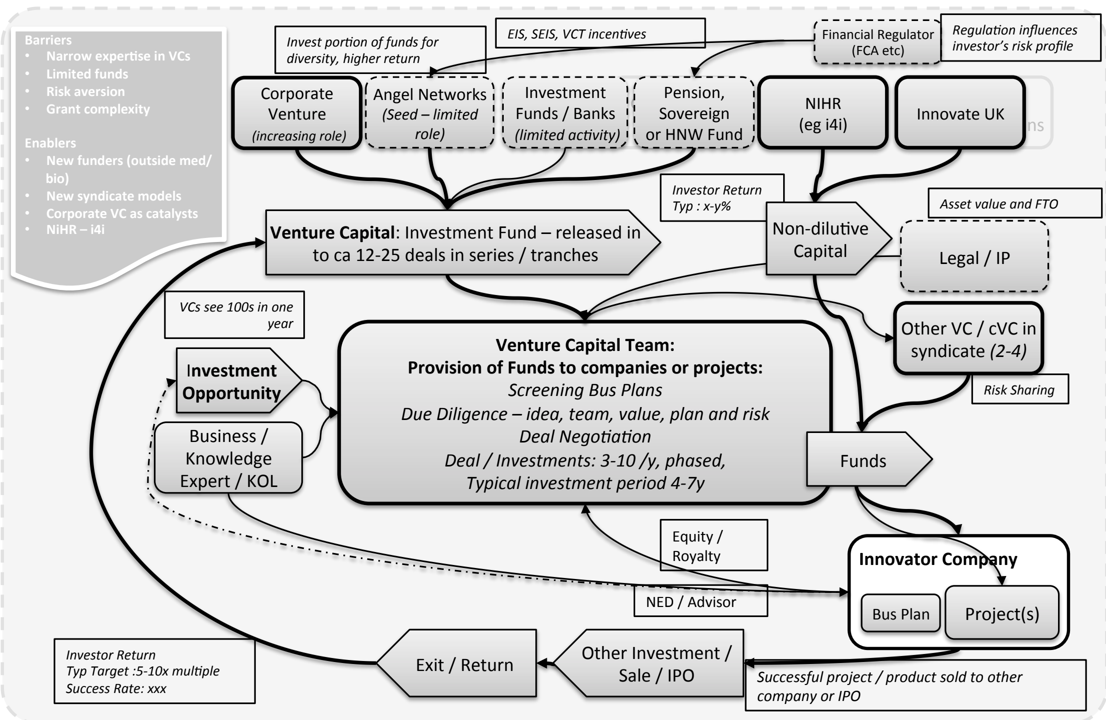

Figure 4 – Example of Ecosystem Dynamics – Development Funding sub-system

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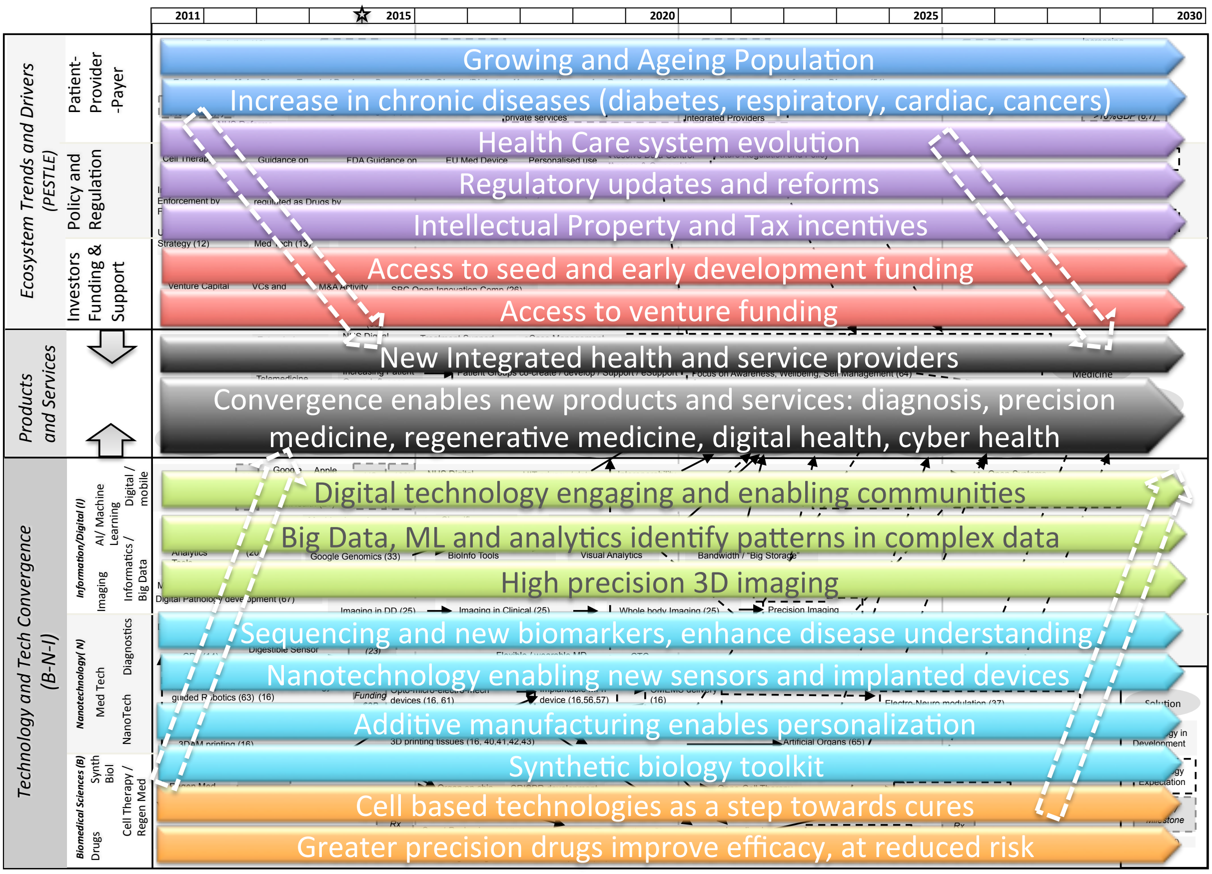

Figure 5 – Summary of ecosystem trends and dynamics

Perspectives

Even in this limited example study, the divergence of actors views indicates the importance of taking differing perspectives and using diverse sources. As an example there was evidence to suggest that smaller firms and start-ups perceived greater challenges in the ecosystem and access to funding, whereas larger firms were more concerned with the value network and supplier issues; investors were more concerned about the business model, and the additional risks convergence brought to the venture; customer groups were more concerned that innovators were not adequately engaging with them in the innovation process.

Summary

A summary of suggested investigational approaches, consistent with the BSRDP Framework, is provided in Table 5. It is suggested that the key is not the individual approaches or tools, which can be tailored to the specific research project, but the concept of considering the ecosystem from a combination of boundary *and* structure *and* relationships *and* dynamics *and* perspectives, that provides a more systemic investigational framework, and one that is more consistent with systems theory and philosophy.

Table 5 – Summary of suggested approaches

Aspect	Suggested Activities or Approaches for Ecosystem Investigation
Boundary and Structural	• Identify ecosystem and boundaries (see Fig 1) • Identify a small number of Key Actors, known to be in the ecosystem, use their knowledge to snowball, to ensure diversity in interviewees • Map system structure and identify the key sub-systems (or sub-groups) • Use ecosystem actors to confirm proposed boundary and key issues
Relationships	• Link the main actors and sub-systems showing key relationships between key actors • Identify influence-impact relationships between key actors. Where is the balance of power? How central are actors to the network? • Identify different perceptions of agents about key issues
Dynamics	• Describe or map ecosystem background (i.e. historical perspective) • Map Trends e.g. – social, economic, technological, legal, political and environmental or ecosystem structure or outputs, using road mapping or similar 'temporal map' • Identify recent phenomena and issues • Recognise the boundary, structure and relationships will evolve (revisit)
Perspectives	• Use combination different interviewees and investigation approaches to provide different perspectives, including: o Use different stakeholder perspectives eg focal firm versus alliance partners versus customers o Use a mixture of documents (public and private), observation and interviews • Consider multiple snapshots v longitudinal studies to capture evolution • Consider appropriate multi-methodologies to address causality

Discussion

Ecosystems are increasingly being defined as an important topic, as such, research on business and innovation ecosystems represents and important field to help describe the phenomena of 21st century business. As previously identified, little research in this area takes a systems approach. To illustrate, even a recently published paper addressing approaches to studying ecosystems (Rong et al. 2015), whilst addressing structure, relationships and dynamics and does not address the fundamentals of systems thinking, boundary considerations, or different perspectives, inherent in any complex socio-economic system.

During the later stages of the development of this framework, a model by Cabrera (2008; 2006) was identified. This model is also based upon extensive systems literature research, but forms a 'foundation for thinking', rather than an investigational framework *per se*. Whilst the Cabrera model and the proposed BSRDP Framework have a number of similarities, the proposed Framework is more influenced by practice and the desire to create a framework to aid research methods. The key differences between BSRDP and the Cabrera model are found in the explicit use of a boundary, rather than abstract '*distinctions*', the explicit reference to dynamics (which are implicit and transcend the Cabrera model), and the recognition that dynamics (or temporal considerations) mean that any of the boundary, relationships and structures may change over the study period. Finally, the broader use of perspectives in the proposed Framework addresses not only the differing perspectives of stakeholders (or the

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systems and observers), but also the different 'output' perspectives of an ecosystem that one can take (i.e. performance or capability). Whilst not derived from it, the BSRDP Framework could be considered a pragmatic investigational tool, aligned with Cabrera's theoretical model.

Conclusions

The BSRDP Framework can readily be used with many existing tools, such as network mapping, road mapping, soft systems methodologies and stakeholder analysis, and provides an approach to integrate these views thereby providing a more systemic approach. As such, the proposed approach contributes to both business and innovation ecosystem literature, and specifically makes a contribution to addressing a known gap in their study (Midgley 2015), which is consistent with a multi-methodological approach.

By providing practical guidance to their study, with examples of methods and approaches and highlighting some of the pitfalls of ecosystem study, this paper makes a contribution to practice. It provides a framework to integrate well-established tools, and provides a pragmatic approach to qualitatively investigating ecosystems. In so doing, it makes a step towards a more coherent, systemic and consistent approach to the qualitative study of business and innovation ecosystems.

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Conceptualising Business Ecosystem Health:

From Regional and Evolutionary Perspectives

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Abstract
Extant business ecosystem research is scarce on local ecosystem phenomenon and ecosystem's lens also complements traditional regional studies with the interdependence in addition to relatedness. Meanwhile, research regarding business ecosystem and cluster performance/health evaluation is surprisingly scarce, though it is crucial for the system to thrive. Prior agglomeration research has focused on cluster formation mechanisms, without investigating clusters from an evolutionary view. Hence, this research will explore business ecosystem health and assessment from regional and evolutionary perspectives. We will propose a business ecosystem health conceptual framework based on an extensive literature review. Our research will contribute to business ecosystem theory and regional studies. In practice, the research may inform individual firms in strategic decisions of entry timing and location and aligning strategies with ecosystem health. Policymakers may also benefit in how to nurture healthy region-based ecosystems and reflecting ecosystem health assessment on regional development. Future work of case studies and objectives is included.
Key words: business ecosystem health, region, performance, evolution, conceptual framework

Introduction
During the past few years, there have been increasing interests in business ecosystems since Moore's proposal of this concept (J. F. Moore, 1996; J. Moore, 1993) borrowed from biology. The ecosystem lens has equipped researchers with a new perspective to understand various questions in different domains such as innovation (Adner, 2006), entrepreneurship (Spilling, 1996), platform (Gawer & Cusumano, 2013) and industrial emergence (Best, 2014; Shang & Shi, 2013). In the meantime, other researchers have also investigated the properties of business ecosystem such as its structures, configurations (Marco Iansiti & Levien, 2004a, 2004b; Rong, Hu, Lin, Shi, & Guo, 2014; Rong & Shi, 2014) and capabilities (Shang, 2014).

However, traditional ecosystem research rejects the role of geography (Shang, 2014). Most research focuses on particular platform and industry, which explains quite a few industry-based (Rong et al., 2014; Rong, Liu, & Shi, 2011; Shang & Shi, 2013) and platform-based ecosystems (Gawer & Cusumano, 2008, 2013). However, on the one hand, ecosystem phenomenon does not always happen across industries or platforms that function "globally" or "internationally", it may as well happen "locally". In fact, there is already a trend calling for researching "local" ecosystem such as a city (Visnjic, Neely, & Visnjic,

2015) or a cluster (Silva & Andersen, 2015). On the other hand, the "interdependence" in ecosystems is crucial to capture the dynamics of regions as well, which, however, is to some extent ignored by traditional regional studies. For example, if we go back to the definition of cluster (M. E. Porter, 1998), it is more emphasizing the relatedness of industries or entities within the cluster but has overlooked the potential of innovation offerings of interdependent complementors (Adner & Kapoor, 2010; Adner, 2006). Hence, the subtle "interdependence" might have produced more diverse characteristics for regions. Through the exploration of regions under the lens of business/innovation ecosystems, we could gain more understanding of the dynamics of clusters.

More specifically, in both business ecosystem and cluster/agglomeration research, the evaluation of their performance or health is surprisingly scarce, though ecosystem and cluster health/performance is crucial for the system to thrive and evolve (Marco Iansiti & Levien, 2004a; M. E. Porter, 2000). From the perspective of the classic industrial economics SCP analytical model (Bain, 1964), the analysis of structure and conduct might have been a lot for business ecosystem or cluster research, but the research of performance, or more specifically, how to assess the performance is still at the very early stage. Also, there is a major gap in the research of cluster evolution and drivers behind each lifecycle stage. Prior agglomeration/cluster research has focused on cluster formation mechanisms (P. R. Krugman, 1991; P. Krugman, 1990; M. E. Porter, 1998; Michael E Porter, 1985), leaving a major gap in the development and evolutionary pathways of clusters. Even though there is a growing trend of investigating cluster evolution within the life cycle paradigm (Audretsch & Feldman, 1996; Menzel & Fornahl, 2009), or even beyond life cycles (Martin & Sunley, 2011), researches have significantly lagged behind in looking at clusters from a more dynamic and evolutionary view, rather than a cross-sectional and static view.

Hence, this research is aimed at exploring business ecosystem health from regional and evolutionary perspectives. We start with literature reviews to cover the domains on which we build our conceptual framework. Then research gaps and question will be proposed, followed with our conceptual framework. Future research will be discussed as the final section.

Literature Review

Biological Ecosystem

The word "ecosystem" was first proposed by Tansley, after which it has been widely accepted as the description of a community of living organisms in conjunction with the non-living components of their environment and they interacting as a system (Tansley, 1935). This section will introduce the concepts of biological ecosystem services and functions in order to gain inspirations and borrow analogies.

<u>Ecosystem Functions</u>

Ecosystem functions normally comes along with the discussion of biodiversity (Goldstein &

Goldstein, 1999; Grime, 1997), which refers to the diversity of genes and species etc. When discussing biodiversity, current researches have three different major questions, which involves different usages of "functions" (Jax & Setälä, 2005).The first question is "how does ecosystem biodiversity relates to ecosystem functions?" In this case, function means processes, which normally include a wide range of ecological and physical processes that involve flux of energy and matters (Jax & Setälä, 2005). This stream of research focuses on exploring whether increasing biodiversity will have impacts on certain ecosystem processes such as biomass production and litter decompositions. Another question is to explore how biodiversity relate to the functioning of ecosystems. Here functioning is more a collective set of activities within the whole ecosystem and sometimes can be referring to performance of the ecosystem (Risser, 1995; Schulze & Mooney, 1994). In this scenario, ecosystem functions research are more focused on exploring the minimum requirement of species or biodiversity is needed for an ecosystem to function (Jax & Setälä, 2005). Another stream of ecosystem functions consider this concept to be similar to or equals to ecosystem services, which will be discussed further below.

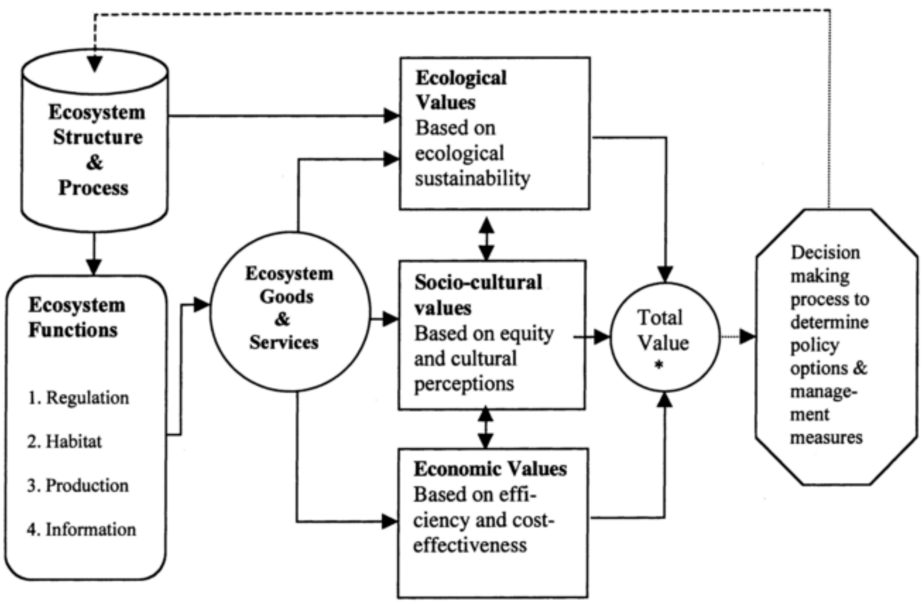

Figure 1 – Framework for integrated assessment and valuation of ecosystem functions, goods and services. (De Groot, Wilson, & Boumans, 2002)

Ecosystem Services

The concept of ecosystem services emerged in the area of biological conservation and ecosystem management as early as 1980s. As mentioned in the above section, it has been closed associated with ecosystem functions. A systemic classification of ecosystem services has indicated that there are four types of functions including regulation, habitat, production and information, and they will deliver ecosystem services that eventually provide ecological, socio-cultural and economic values to the society (De Groot et al., 2002). Here the boundaries of functions and services are becoming blurred. This framework is shown in figure 1. Ecosystem services is formalised and popularised by the United Nations in a report, where ecosystem services is defined as "the benefits provided by ecosystems" including provisioning, regulating, cultural and supporting services and these services are considered to be closely related to human well being (Millennium Ecosystem Assessment, 2005), as is illustrated in figure 2.

These four services are defined as follows (Millennium Ecosystem Assessment, 2005).

Provisioning services are the products obtained from ecosystems, including food, fuel, water, biochemical and genetic resources etc.

Regulating services are the benefits obtained from the regulation of ecosystem processes, including air quality regulation, climate regulation and erosion regulation etc.

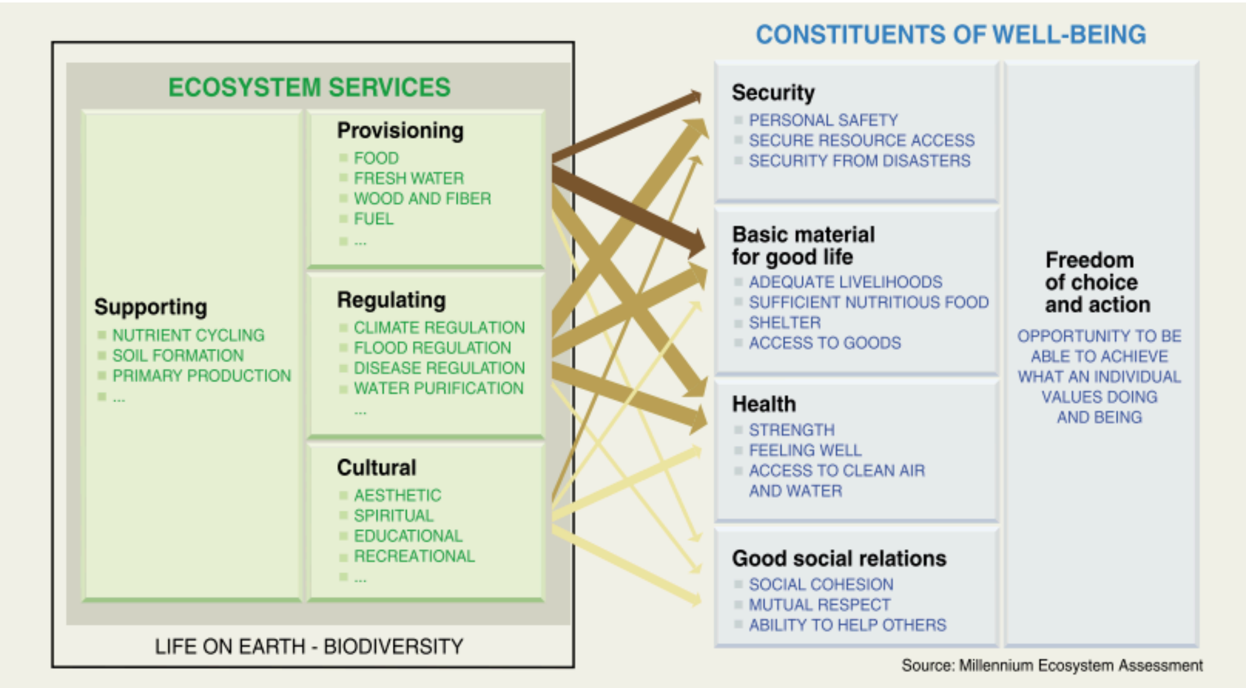

Figure 2 – Ecosystem services and human well being (Millennium Ecosystem Assessment, 2005)

Cultural services are the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences, including cultural diversity, knowledge systems, educational values and inspiration etc.

Supporting services are those that are necessary for the production of all other ecosystem services. They differ from provisioning, regulating, and cultural services in that their impacts on people are often indirect or occur over a very long time, whereas changes in the other categories have relatively direct and short-term impacts on people. These include soil formation, nutrient cycling and water cycling etc. This service is more fundamental compared to the first three services.

Business Ecosystem

Borrowed from biological ecosystems, ecosystem has been used by more and more researchers to describe the phenomenon of massive interaction and engagement of networked companies. Since Moore raised this concept in the 1990s (J. F. Moore, 1996; J. Moore, 1993, 2004), many researchers have contributed to the development of this concept.

Business Ecosystem Conceptualisation

The concept of business ecosystem is first proposed by James Moore in 1993, where he defined a business ecosystem as "an economic community supported by a foundation of interacting organizations and individuals - the organisms of the business world. The economic community produces goods and services of value to customers, who are themselves members of the ecosystem. The member organisms also include suppliers, lead producers, competitors, and other stakeholders." (J. Moore, 1993). Iansiti and Levien, however, insisted that business ecosystem mainly consists of loosely interconnected companies that together create value and share value (Marco Iansiti & Levien, 2004a). Borrowing from biology concept, they also state that business ecosystems are "formed by large, loosely interconnected network" of companies that "interact with each other in complex ways".

Another important conceptual framework is proposed by Adner, which argues the vital importance of complementors (Adner, 2006) – a distinctive component that ecosystem has, compared to traditional supply chain or network theory. Later, Adner conducted empirical research regarding his innovation ecosystem conceptual framework, as shown in Figure 3, in the context of global semiconductor lithography equipment industry, addressing that the bundles of innovation are crucial for focal firms to deliver successful products to final customers by integrating the complementors' innovations with their own products (Adner & Kapoor, 2010). They contend that "greater upstream innovation challenges in components enhance the benefits that accrue to technology leaders, while greater downstream innovation challenges in complements erode these benefit" (Adner & Kapoor, 2010). Kapoor further investigated how complementary activities in the innovation ecosystem affect the technological investments (Kapoor & Lee, 2013).

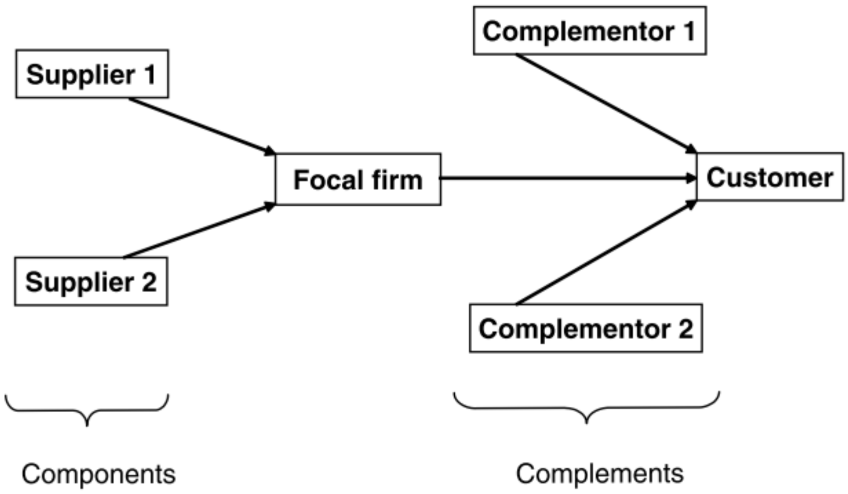

Figure 3 – Innovation ecosystem conceptual framework (Adner & Kapoor, 2010)

Business Ecosystem Configurations

Though there are quite a few papers dealing with contexts where business ecosystem is crossed with other research domains, researches regarding business ecosystem itself, especially on deconstructing business ecosystem, including its configurations and dynamics, still remain in the early stage.

As a fairly new topic, Rong and Shi has done some pioneering work on business ecosystem configurations (Rong & Shi, 2014; Rong, 2011). They have identified 7 different patterns, based on the different configurations and magnitudes of solution platform openness and solution diversity, in the context of mobile and telecommunications industry, as is shown in figure 4.

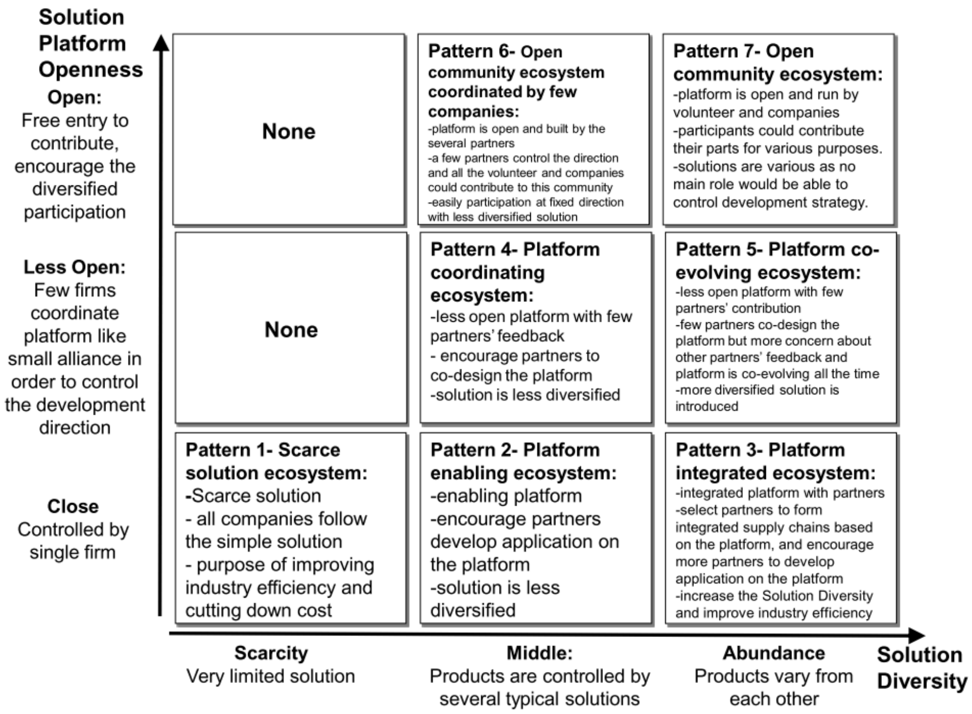

Figure 4 – Business ecosystem configuration patterns (Rong, 2011)

It is proposed that different strategies should be adopted and aligned with different configuration patterns and different patterns might be able to provide different outcomes – platforms, products or service offerings (Rong & Shi, 2014).

Business Ecosystem Dynamics

Business ecosystem dynamics are often associated with its lifecycles. Business Ecosystem Lifecycle is first proposed by Moore, where he divides business ecosystem lifecycles as four stages: birth, expansion, leadership, and self-renewal or death (J. Moore, 1993). Rong further developed business ecosystem lifecycle based on Moore's work, in the context of telecommunications industry. Differing from Moore's, he argues that business ecosystems actually have five phases: emerging, diversifying, converging, consolidating and renewing, with each status linked with different nurturing processes and strategies, as is shown in figure 5.

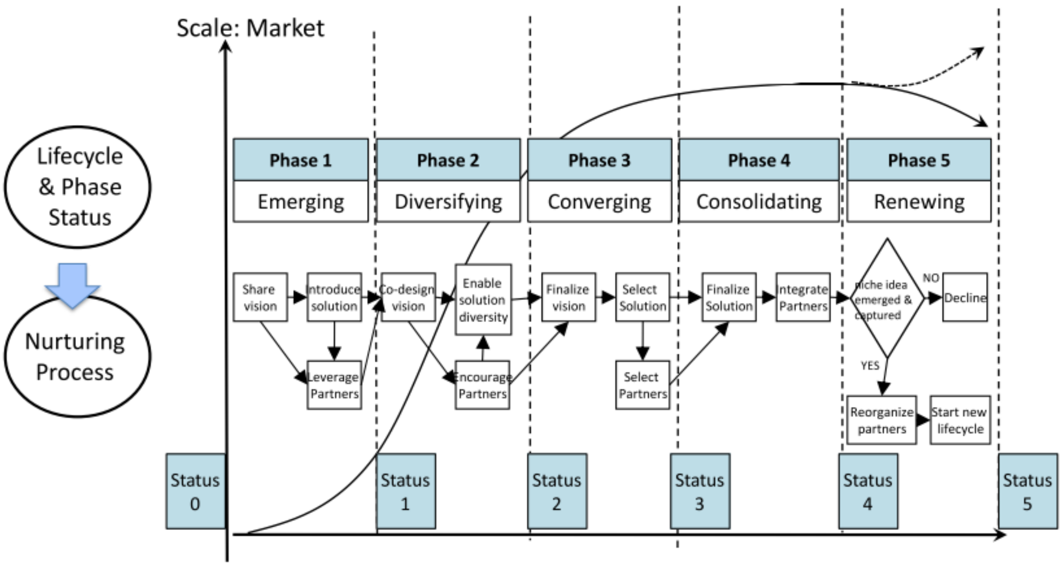

Figure 5 – Business ecosystem life cycles and nurturing process (Rong, 2011)

Also, after Shang and Shi proposed the business ecosystem conceptual model (Shang, 2014), new dynamics are also identified among the interaction between resource pools and supply networks (X. Shi & Liang, 2015; X. Shi & Shi, 2015). They argue that business ecosystem involves an iterative process between resource pools and value networks, which is crucial for firms of later generations to utilize and evolve to the next level (X. Shi & Liang, 2015), in the context of Chinese mobile phone industry, as is shown in figure 6.

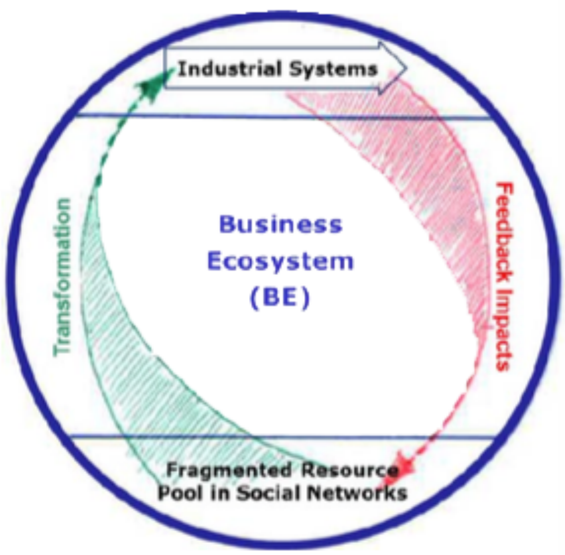

Figure 6 – Dynamic business ecosystem model (X. Shi & Liang, 2015; X. Shi & Shi, 2015)

Business Ecosystem and Regions

Initially, business ecosystem concept rejects the notion of geographical concentration unlike clusters (Shang, 2014). However, researchers have gradually realised that ecosystems sometimes are highly concentrated and it is not feasible to exclude the impact of particular regions otherwise endogenous impact will be very significant. As can be seen from recent entrepreneurial or business ecosystem literatures (Clarysse, Wright, Bruneel, & Mahajan, 2014), emphasis have been put on regional impacts on value creation in the context of transferring knowledge to technologies. Indeed, there is no denying that geographical concentration has played an important part in regional development, which is widely acknowledged in other domains such as economic geography (P. R. Krugman, 1991; M E Porter, 1996). The complex compositions of different stakeholders and complementors have increased the dynamics and liberate business ecosystem from repelling geographical notion is crucial for understanding micro mechanisms inside the ecosystem, rather than being too broad investigating the whole ecosystem internationally or even globally.

Regional Studies

There are quite a few domains dealing with regional development and clustering of industries. We have reviewed related literatures in agglomeration economics and cluster in order to understand the state-of-art of research regarding regions.

<u>Agglomeration Economics</u>

Agglomeration economics dated back to 1920s, when a Cambridge economist Marshall observed that firms tend to concentrated in particular areas and proposed three factors led to this phenomenon (Alfred Marshall, 1920):

1. Local skilled labour pool.
2. Non-tradable specialised inputs.
3. Information spill overs.

Following Marshall's research of agglomeration, many researchers have proposed the potential drivers of agglomeration. Myrdal's circular causation theory (Myrdal, 1957) and Arthur's positive feedback theory (Arthur, 1989) have suggested that manufactures production will tend to concentrate where there is a large market, but the market will be large where manufactures production is concentrated, which partially explained why cluster is formed. Further, Pred and Meyer examined the role of circular processes in the emergence of the US manufacturing belt during 1850s to 1900s (Meyer, 1983; Pred, 1966), but they did not explicitly address the fundamental question of why agglomeration happened (P. Krugman, 1990). In 1990, Paul Krugman finally proposed the reasons of why agglomeration happened. He reveals how manufacturing generally ends up concentrating in one or a few regions (P. R. Krugman, 1991; P. Krugman, 1990, 1991): economies of scale, low transportation costs and the share of manufacturing in the national income.

<u>Cluster</u>

In the management community, Porter's concept of cluster is derived from his research of competitiveness (Michael E Porter, 1985), which laid down the foundation of strategic management. He then argues that cluster is crucial for organisations and firms to compete and thus innovate, which gives the cluster higher competitiveness (Michael E Porter, 1990).

Porter's arguments are derived from his case studies in several different clusters and countries. Porter defines cluster as geographically concentrations of interconnected companies and institutions in a particular field (M E Porter, 1996; Michael E Porter, 1991). He argues that clusters are critical to competition reflecting in productivity, innovation and new business formation. Subsequently, many researchers complement on the research of clusters. For example, Tallman and Jenkins investigated the role of informal knowledge sharing within the clusters and proposed that the informal knowledge sharing is indeed crucial for firms within the clusters to gain competitive advantages (Tallman, Jenkins, Henry, & Pinch, 2004). There are also researches on different types of clusters, in terms of who drives the cluster and what industries the cluster is specialised on (He & Fallah, 2011).

However, the existing researches are more from a static view rather than a dynamic view. Regional economics and cluster research among management communities have focused more on the drivers and factors leading to the agglomeration phenomenon, but failed to investigating the subsequent evolution of clusters. Some researchers have realised this and tried to link clusters with industry life cycle (Audretsch & Feldman, 1996; Menzel & Fornahl, 2009). There are also some initial research regarding conceptualisation of cluster evolutions (Boschma & Fornahl, 2011; Martin & Sunley, 2011). But this stream of research is still at its early stage. Also, research regarding cluster performance is very scarce. Although Porter acknowledges that the health or performance is vital to the development of clusters, there are surprisingly little research regarding evaluating cluster health or performance (Wal, Corbishley, Dodgson, & Gann, 2015).

On "Health"

This section will discuss different usages and definitions regarding the concept of "health" in different domains, in order to build a solid theoretical foundation for subsequent research on "health".

<u>Organism and Human Health</u>

Originally, "health" as a term is specifically for organisms and humans. For general organisms, it is defined as the level of functional or metabolic efficiency (Huber et al., 2011). But for human health, debates have been carrying on for hundreds of years. There are currently five main streams of health definitions, which will be discussed below.

Medical definition: The definition of health in medical practice and research is the absence of disease or disability (Larson, 1999). This definition goes back to as early as five hundred years ago when Descartes began to view human body in the manner of machine model, which is structured and therefore gave birth to the idea of illness occurring on individuals. Although there have been debates about the definition and scope of disease such as the contention of physical and mental illness, social and biological disease, this view has helped medical research advance a lot since the birth of modern science (Larson, 1999).

WHO definition: The World Health Organization has proposed a more holistic definition: health is "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity" (WHO, 1946). However, this definition has been questioned by many researchers. Firstly, the absoluteness of the word "complete" is widely criticised. Secondly, the nature of disease has changed rapidly and greatly since 1946 such as chronic diseases and the old definition seems unfit and outdated. Thirdly, the operationalization of WHO health definition is very poor (Huber et al., 2011) and some even consider it as idealistic and immeasurable (Larson, 1999).

View of adaptation: As the definition of health continuously evolves, the view of adaptation has become more convincing. Since health includes environmental consideration, researchers have gradually turned to the view of adaptation, where they argue that health is about the ability to adapt, rather than perfection or "complete" or "absence of disease" (The Lancet, 2009). The definition of this view has been summarized as "the ability to adapt and to self manage in the face of social, physical, and emotional challenges." (Huber et al., 2011), which has combined all dimensions of the previous definitions.

<u>Biological Ecosystem Health</u>

The concept of natural ecosystem health stems from ecosystem stresses, which represents the responses of ecosystems to external stimulus (Odum, 1985). Ecosystem health is first defined by Rapport in 1985. Relating to the concept of human health, Rapport argues that ecosystem health can be diagnosed and thus defined through multiple indicators and dimensions, which are changes in nutrient cycling, changes in primary productivity, changes in species diversity, retrogression (an apparent reversion to an earlier stage of the successional process) and changes in size distribution of species (Rapport, David J., H. A. Regier, 1985). Further work is conducted by other researchers to differentiate human or animal health with ecological health, reflecting a significant different in diagnosing criteria and indicators (Schaeffer, Herricks, & Kerster, 1988). Rapport further develops the dimensions of evaluating ecosystem health, stating that ecosystem health, as a concept to assess the condition of environment, could be evaluated in six dimensions: primary productivity, nutrients, instability, disease prevalence, size spectrum, contaminants (D J Rapport, 1989). Since the 1990s, researchers have focused on developing indicators of evaluating ecosystem health and conduct quantitative test using their frameworks (Cairns, McCormick, & Niederlehner, 1993; Mageau, Costanza, & Ulanowicz, 1995; David J. Rapport, 1992). At this point, there was no consensus on frameworks of evaluating ecosystem health. In 1999, Rapport proposed his final definition and dimensions of ecosystem health, which is widely accepted as the most accurate and rigorous framework. He argues that ecosystem health can be defined and also evaluated through three dimensions (D.J. Rapport, Costanza, & McMichael, 1999):

1. Vigour: represents the activity, metabolism or primary productivity of an ecosystem;
2. Organisation: represents diversity and interactions between species in the ecosystems;
3. Resilience: the capacity of the ecosystems to deal with disruptions.

Business Ecosystem Health

Business Ecosystem Health is first proposed by Iansiti and Levien (Marco Iansiti & Levien, 2004a) as three dimensions - Robustness, Productivity and Niche Creation, largely borrowed from biological literatures discussing ecosystem health. They claim that the three dimensions are "measures of the extent to which an ecosystem as a whole is durably growing opportunities for its members and for those who depend on it". Dimensions and their definitions as well as main indicators within each dimension are listed in Table 1. It should be noted that some of these indicators might not be applicable in certain industries, according to Iansiti and Levien.

Table 1 – Iansiti & Levien's framework (Marco Iansiti & Levien, 2004a)

Dimension	Definition	Main Indicators
Robustness	Capability of a business ecosystem when "facing and surviving perturbations and disruptions"	Survival rates; Persistence of ecosystem structure; Predictability; Limited obsolescence; Continuity of use experience and use cases
Productivity	A network's ability to consistently transform technology and other raw materials of innovation into lower costs and new products	Total factor productivity; Productivity improvement over time; Delivery of innovations
Niche Creation	The capacity to increase meaningful diversity over time through the creation of new valuable functions	Variety; Value creation

Hartigh, Tol and Visscher constructed a model that "enables managers to monitor the financial and network health of their business ecosystem" (Hartigh, Tol, & Visscher, 2006). Meanwhile, they also discuss the managerial insights drawn from the application of their instrument regarding three aspects – benchmarking and improving business ecosystem performance, partner engagement process and business ecosystem governance. By selecting and specifying every indicator using different measures from different field such as network analysis and financial performance, the authors have established a model that they claim to be "useable in a management practice" and "useable on multiple levels". The dimensions in this model are quite different from Iansiti and Levien's, which are included together with the indicators in each dimension in Table 2.

Table 2 – Hartigh, Tol and Visscher's model (Hartigh et al., 2006)

Dimension	Definition	Indicators
Partner Health	A long-term financially-based representation of a partner's strength of management and of its competencies to exploit opportunities that arise within the ecosystem	-EBIT/total assets -Total revenue/total assets -Liquidity -Solvency & solvency t-1 -Retained earnings/total assets -Total asset growth -Working capital/total assets
Network Health	A representation of how well a partner is embedded in the ecosystem as well as the impact the partner has in its local network	-Number of partnerships -Visibility in the market -Covariance of partner variety with the market

Research Gaps and Question

Based on the literature review and conceptual framework development, we identified the following research gaps:

There is a lack of systemic framework of assessing business ecosystem health. Literatures have acknowledged that evaluating and maintain the health or performance of clusters and business ecosystems is indeed very important for sustaining the competiveness of clusters (M. E. Porter, 2000) and business ecosystems (Marco Iansiti & Levien, 2004a). However, our literature search reveals that even though there is some preliminary work on assessing business ecosystem health (Hartigh et al., 2006; M Iansiti & Richards, 2006; Marco Iansiti & Levien, 2004a), there is still a lack of systemic framework assessing business ecosystem health. In regional economics or new economic geography research, research about evaluating the performance of cluster is still scarce (Wal et al., 2015). Prior research on both business ecosystem and cluster has focused more on the system's characteristics and properties. In the classic industrial economics SCP analytical model (Bain, 1964), the analysis of structure and conduct might have been a lot for business ecosystem or cluster research, but the research of performance, or more specifically, how to assess the performance is still in the very early stage.

There is a major gap in research of cluster evolution and drivers behind each lifecycle stage. Prior regional economics and new economic geography studies have focused on cluster formation mechanisms and drivers (P. R. Krugman, 1991; P. Krugman, 1990; M. E. Porter, 1998; Michael E Porter, 1985), leaving a major gap in the development and evolutionary pathways of clusters. However, it is crucial to put the regions or clusters under the life cycle lens and capture the dynamics for further understanding regions and clusters, in the face of huge industrial uncertainty in the recent decades (Rong, Shi, & Yu, 2013). There is a growing trend of investigating cluster evolution within the life cycle paradigm (Audretsch & Feldman, 1996; Menzel & Fornahl, 2009), or even beyond life cycles (Martin & Sunley, 2011). In general, researches have lagged behind in looking at clusters from a more dynamic view, rather than a cross-sectional and static view.

Region-based business ecosystem research is very scarce. Most business/innovation ecosystems research focuses on particular platform/product/industry, which generates quite a few industry-based or platform-based ecosystems (Gawer & Cusumano, 2008, 2013). In terms of regional studies, clusters and regional innovation systems seem to be explaining the geographical concentration phenomenon quite well. Then why should we research "region-based" ecosystem? There are two main reasons for this. First, ecosystem phenomenon does not always happen across different industries or based on platforms that function "globally" or "internationally", it may as well happen "locally". Our research seeks to break the notion that ecosystem research has a natural rejection to geographical limitations (Shang, n.d.). In fact, there is already a trend calling for researching "local" ecosystem such as a city (Visnjic et al., 2015) or a cluster (Silva & Andersen, 2015). Second, the "interdependence" in ecosystems is crucial to capture the dynamics of regions as well, which, however, is to some extent ignored by traditional cluster research. If we go back to the definition of cluster (M. E. Porter, 1998), it is more emphasizing the relatedness of industries or entities within the cluster but has overlooked the potential of innovation offerings of interdependent complementors (Adner & Kapoor, 2010; Adner, 2006). The subtle "interdependence" might have produced more diverse characteristics for regions as well. Through the investigation of regions under the lens of business/innovation ecosystems, we could gain more understanding of the dynamics and evolutions of clusters, which will in turn, help us address the question of business ecosystem health assessment.

Based on the research gaps identified, the main research question is:

How to assess business ecosystem health from regional and evolutionary perspectives?

Conceptual Framework

The research conceptual framework is consisted of two inter-related components: business ecosystem (regional) health indicator framework (BEHIF), business ecosystem (regional) configurations framework (BECF). Combing the two sub-frameworks with a dynamic and evolutionary view, we propose our business ecosystem (regional) health framework (BEHF)

Business Ecosystem (Regional) Health Indicator Framework

The first sub framework is business ecosystem health indicator framework (BEHIF). This framework is aimed at defining business ecosystem health by three dimensions, which are internal and external basic functions, resilience and adaptation, and providing a framework for assessing business ecosystem (regional) health by specifying indicators in each of the three dimensions. BEHIF is illustrated in Figure 7. Each dimension and its theoretical origins will be discussed in the remainder of this section.

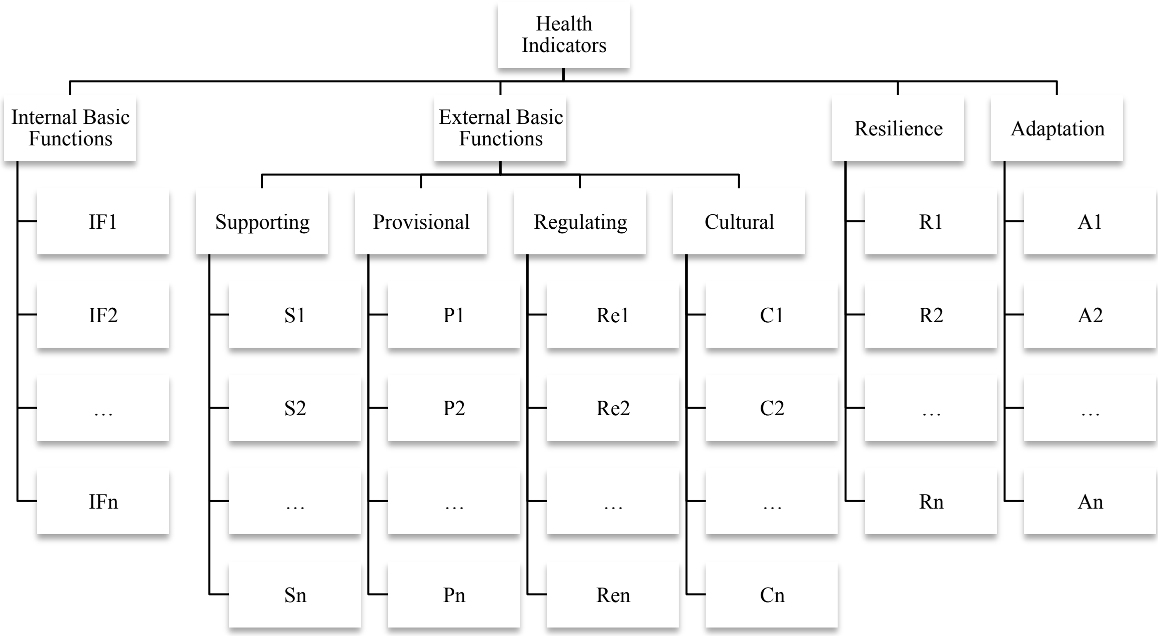

Figure 7 - Business Ecosystem (Regional) Health Indicator Framework

<u>Internal and External Basic Functions</u>

The idea of functions is largely inspired by ecosystem functions and ecosystem health literatures (D.J. Rapport et al., 1999; Schulze & Mooney, 1994), where ecosystem functions are crucial for sustaining "life systems" (D J Rapport, 1989). In this framework, the basic functions include both internal functions that sustain the ecosystem and the external functions that deliver the final ecosystem services that players can benefit from, both of which will be further explained as follows.

Internal basic functions. In this framework, we define internal functions as the functions that are crucial for sustaining the ecosystems. The idea of internal functions is partially borrowed from biological ecosystems, where ecosystem's internal functions such as chemical reactions and physical processes largely contribute to the sustainability of the whole ecosystem (Risser, 1995; Schulze & Mooney, 1994). Meanwhile, in the cluster literature, there are also similar ideas such as investigating the internal factors that contribute to the shaping of certain clusters (Menzel & Fornahl, 2009). Apart from the external effects (Menzel & Fornahl, 2009), clusters' internal capabilities should also be addressed (Starr & Saxenian, 1995).

External basic functions. Here we regard the *external functions* as the services that ecosystems deliver to its players, which is largely borrowed from biological ecosystem services including supporting, regulating, provisional and cultural services(Millennium Ecosystem Assessment, 2005). Supporting services the basics of the basics, which ensure the all other three functions. In ecosystem services, it represents, for example, nutrient recycling, primary production and soil formation (Boyd & Banzhaf, 2007; Fisher, Turner, & Morling, 2009; Millennium Ecosystem Assessment, 2005). In business ecosystem, it could be all kinds of resources (talents and infrastructure), financial support etc.; Provisional services are products and services generated by the business ecosystem and then provided to its players such as financial services, manufacturing resources, knowledge sharing mechanisms, innovation spill-overs etc.; Regulating services are benefits obtained from the regulation of ecosystem process: merger & acquisition, survival of the fittest, IP protection, etc. in business ecosystem context; Cultural services are nonmaterial benefits companies obtain from ecosystems such as business and entrepreneurial climate (General economic environment comprising of the attitude of the government and lending institutions toward businesses and business activity, attitude of labor unions toward employers, current taxation regimen, inflation rate, and such.), cultural impact (characteristics of residences), etc.

Resilience

Recently, the concept of resilience has gradually gained attention from different research areas (Burnard & Bhamra, 2011). It has been widely used in strategic and operations management research including organizational resilience and supply chain resilience.

Organisational resilience. There have been extensive literatures describing organisational responses to threat and disruptions. Staw et.al. have proposed a model of organisational response to threats that typically caused by adverse environmental conditions such as resource scarcity, competition and reduction in market (Staw, Sandelands, & Dutton, 1981). On the basis of their threat-rigidity model, Barnett and Pratt further proposed a learning model highlighting the functionalities of top managers' strategic initiates before the crisis, in the face of latent threats (Barnett & Pratt, 2000). Powley further identified three factors including liminal suspension, compassionate witnessing and relational redundancy that activate organizational resilience (Powley, 2009).

Supply Chain Resilience. The concept of supply chain resilience stems from the research of supply chain risk. Prior research on supply chain risks have examined the impacts of terrorism (Sheffi, 2001) and natural disasters, and how firms could exploit its advantages in dealing with disruptions (Bakshi & Kleindorfer, 2009). As Christopher argued, the uncertainty and turbulence of current markets calls for attention of supply chain vulnerability (Christopher & Peck, 2008) and therefore building a resilient supply chain is crucial for firms to mitigate the risks. Ponomarov and Holcomb further proposed a formal definition of supply chain resilience as "capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function" (Ponomarov & Holcomb, 2009), based on summary of extant resilience research from ecology and organization.

In this framework, we regard "resilience" as the ability to return to a stable state after the disruption, in line with previous ecological research and subsequent metaphor in management research (Burnard & Bhamra, 2011; Gunderson, 2000).

Adaptation

The idea of adaptation has been reflected in management research. The metaphor of adaptation from biological research was introduced by Chakravarthy in 1982, where he proposed an adaptation framework highlighting the transitional process that firms adapt to environmental changes (Chakravarthy, 1982). In highly volatile and complex environments, firms need to have adaptive capability in order to deal with uncertainty and restructure themselves to fit in the new environmental conditions (Sanchez, 1995; Staber & Sydow, 2002).

Indeed, researchers in strategic management have more and more realized that the dynamic and changing environment calls for appropriately adapting the organisations themselves and integrating internal and external organizational resources (David Teece & Pisano, 1994). As such, Teece has proposed the concept of dynamic capabilities: the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments (DJ Teece, Pisano, & Shuen, 1997). Further empirical studies have proved that dynamic capabilities are crucial for firms' survival in the face of fast changing and complex environments (Zollo & Winter, 2002; Zott, 2003).

In our framework, we regard adaptation of business ecosystem as the ability to adapt to the volatile and changing environment in the face of irreversible disruptions.

Based on the above discussion, we will propose our definition of business ecosystem health:

> Proposition 1: *Business Ecosystem health* is consisted of three dimensions: *the basic functions* that sustain the ecosystem and provide services for ecosystem players, the ability of *resilience* to the changing environments and the ability of *adaptation* to irreversible impacts brought by external disruptions.

Business Ecosystem (Regional) Configuration Framework

Prior research by Rong and Shi has investigated business ecosystem configurations and patterns in the mobile phone industry context (Rong & Shi, 2014; Rong, 2011). As has been introduced in the literature review, they developed a business ecosystem typology that, in the horizontal perspective, business ecosystem is described by its solution diversity; while in the vertical line, it is classified by solution platform openness. Their typology can be referred to in Figure 4.

Extant research has also tried to classify cluster based on its characteristics and structures. Markusen has proposed a four-type categorization of technology clusters based on their structures and roles played by: Marshallian that is a classical formation of a cluster, hub-and-spoke that is configured around keystone players, satellite platform that consists of branch facilities of externally based multi-plant firms and the last type state-centered which highlights the domination of large-scale entities such as universities and government (Markusen, 1996). There are also researchers proposing typologies according to the drivers or leading players of a cluster's formation, for example, classifying clusters into university-driven, company-driven and government driven (Potstada & Woywode, 2015). Some researchers consider cluster typology as industry-specific types such as telecommunication industry cluster, IT clusters (He & Fallah, 2011).

In this research, we will propose a regional business ecosystem configuration framework, which is linked with business ecosystem (regional) health indicator framework. An example of typology can be seen in Figure 8.

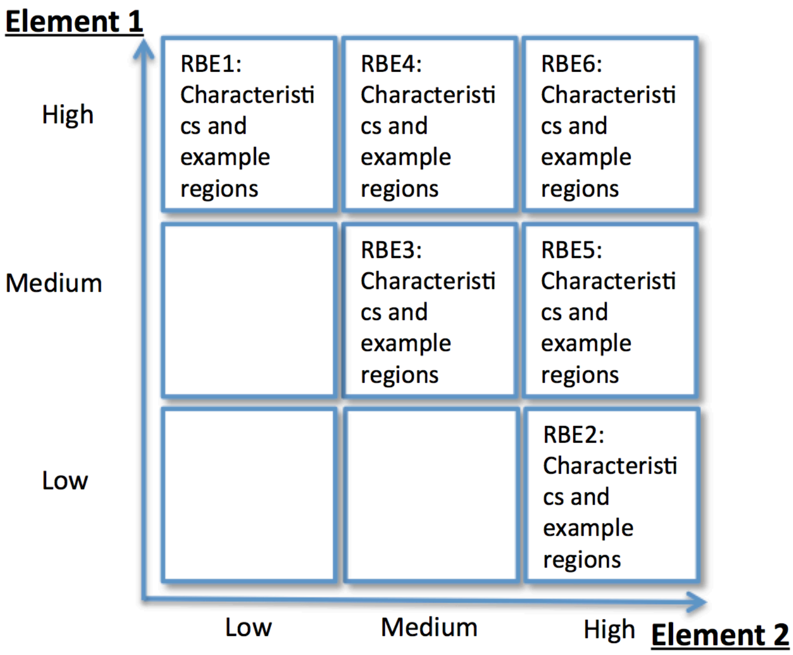

Figure 8 – A regional business ecosystem typology

Each configuring element is determined by the magnitudes of a group of health indicators. These indicators can be in the same dimension, but will be more than likely to fall into different dimensions, reflecting the dynamic and evolving nature of regional business ecosystems, as is illustrated in Figure 9. Hence, our second proposition is:

> *Proposition 2: The configuring elements that determined different types of region-based business ecosystem are linked with different sets of health indicators.*

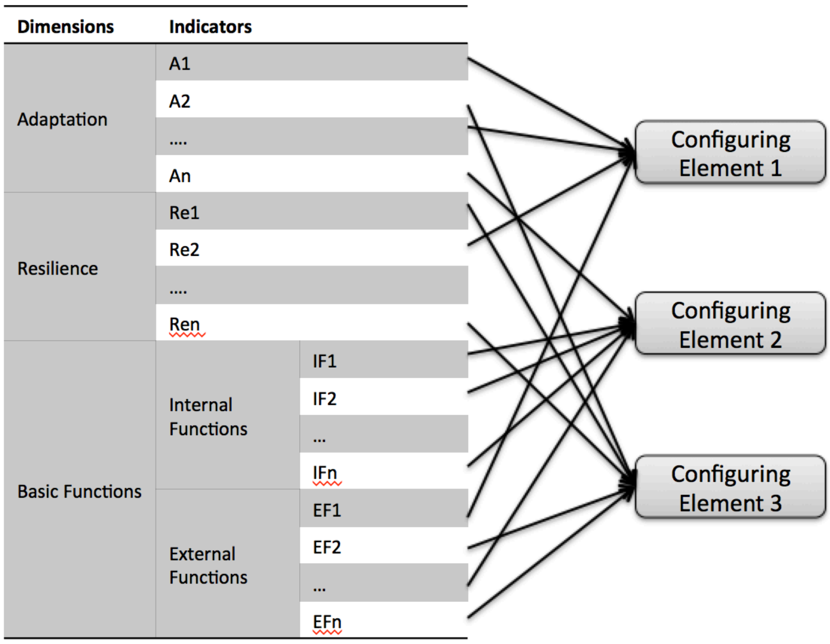

Figure 9 – Linkage between health indicators and configuring elements

Business Ecosystem (Regional) Health Framework

There has been extensive research on how clusters actually formulated (P. Krugman, 1990) and what factors drive their formulation (Alfred Marshall, 1920; P. R. Krugman, 1991) in the regional economics or the new economic geography. However, researches are quite scarce when it comes to the lifecycle or the evolution of clusters. It is intuitive that, the health indicator framework and the regional business ecosystem patterns associated with it will not be static but rather be dynamic. In other words, different health indicators matter and function in different evolutionary stages of regional business ecosystems and the type of clusters may also change during the evolution. The relationship of regional business ecosystem health framework, the indicator framework and the configuration framework is shown in Figure 10.

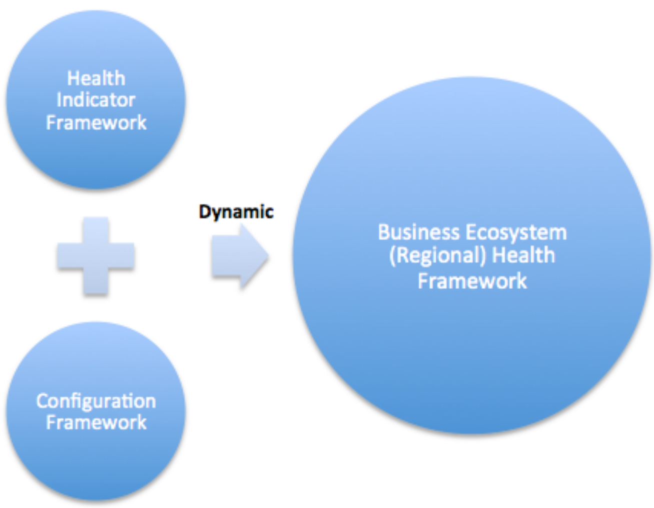

Figure 10 – Integration of two sub-frameworks

Hence, our regional business ecosystem health framework will combine the health indicator framework and the regional business ecosystem configuration framework with a dynamic view, yielding indicator portfolios along different life stages and the typical evolutionary pathways of regional business ecosystems. It is expected that in a particular stage, some health indicators have higher impacts than others and this set of indicators – what we call indicator portfolio – is different in each stage. Extant research has already explored quite a few evolutionary path ways of different networks, such as business ecosystem configurations and evolutions (Rong, 2011), international manufacturing networks' configurations (Y. Shi & Gregory, 1998) and global engineering networks' drivers and configurations (Zhang, Gregory, & Shi, 2008). As for the evolutionary stages, our life cycle of regional business ecosystem is based on Moore and Rong's work (J. F. Moore, 1996; Rong & Shi, 2014; Rong, 2011). Our tentative framework is illustrated in Figure 11.

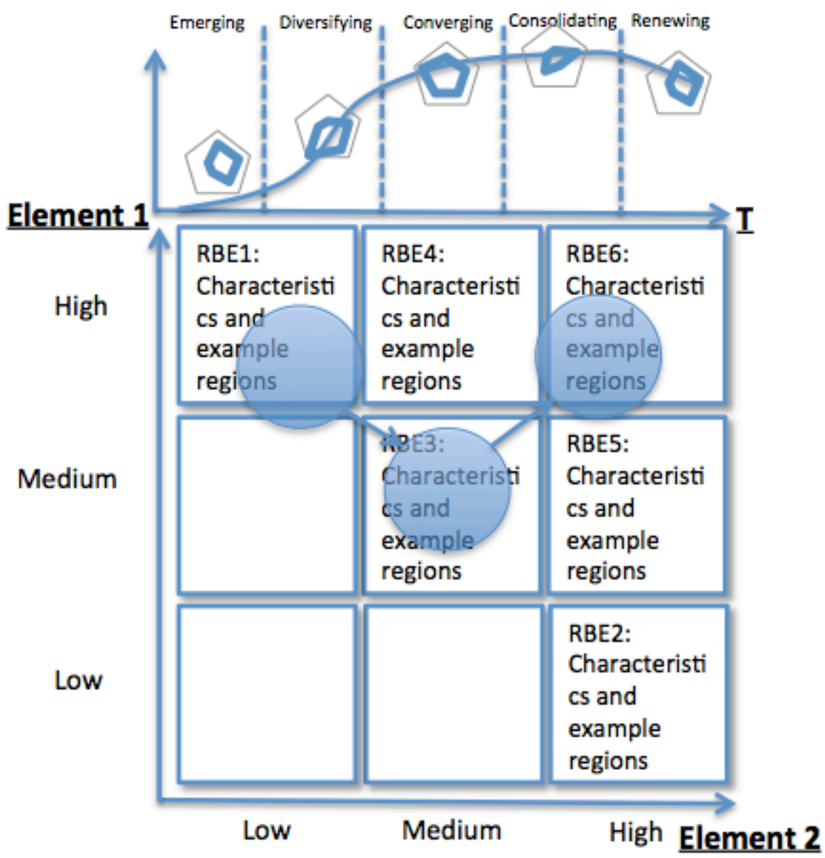

Figure 11 – Business Ecosystem (regional) Health Framework

<u>Proposition 3a</u>: There are several different stages in the evolution of region-based ecosystems. Each stage contains a different indicator portfolio.

<u>Proposition 3b</u>: There exist typical evolutionary pathways for region-based ecosystems, which are associated with indicator portfolios in different stages.

Conclusions

This paper has proposed a research conceptual framework for business ecosystem health and assessment from regional and evolutionary perspectives.

Theoretical contributions

This research is expected to contribute to business ecosystem theory development in two aspects. First, it will fill in the gap by providing a systemic business ecosystem health framework. Such contribution will complement the current business ecosystem theory development, which has been focusing more on structures, configurations and strategies previously. Second, it will break the notion of business ecosystem's natural rejection to geographical limitations, revealing that ecosystem phenomenon does not only happen globally or internationally or nationally, but can also happen locally. It is also expected to contribute to regional studies by identifying regional business ecosystem's patterns and typical evolutionary pathways.

Practical contributions

Where to participate? Players could have a tool to choose what type of region to compete and at which stage they should participate. By choosing the region with the most suitable health indicator portfolios, companies may enjoy the services provided by regional business ecosystems and thrive in a better environment.

Aligning Strategies with Regional Business Ecosystem Health and Patterns. Firms within the particular region-based ecosystem could also benefit from this research. By identifying the regional business ecosystem's health conditions, firms will be able to align their strategies with the ecosystem health and patterns.

Policy Implications

Nurturing Healthy Regional Business Ecosystems. From our research, regional policy makers might be informed with more insights into how regions are evolved and what support government may give during different evolutionary stages.

Reflecting Health Assessment Framework on Regional Development. Our research is also expected to deliver a health assessment tool for regional policy makers to assess their region-based ecosystem's health. Such a tool could inform users how different stakeholders at different evolutionary stages in a typical pathway could coordinate and cooperate with each other to maximize the economic and societal benefits in a particular region.

Future Research

Future work will be mainly conducting in-depth case studies in selected companies of most influential industries in China and UK's two regions respectively, in order to:

- Identifying the dimensions and indicators that determines a business ecosystem's health and developing a systemic business ecosystem (regional) health framework;

- Linking health indicators with configuring elements that determine regional business ecosystems' patterns;
- Identifying different types and patterns of region-based business ecosystem;
- Identifying the typical evolutionary pathways of regional business ecosystems;
- Identifying health indicators' functionalities during different stages of business ecosystems' evolutions.

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From the university to the industry:
A Chinese case study on “transplant with the soil” and the establishment of the innovation ecosystem

Introduction

While assuming the responsibility of educating people, university is also an organization that are generating and transferring knowledge and technology, and acting as an important institutional player in the national innovation system (Etzkowitz & Leydesdorff, 2000; Nelson & Rosenberg, 1993). Over the past few decades, university is conceptualized with another function of establishing relationships with the industry for innovation creation, development and knowledge and technology diffusion (Cohen, Nelson, & Walsh, 2002; Etzkowitz & Leydesdorff, 2000). Such relationships or linkages are regarded as the “fuel of knowledge-based economies” (Ahrweiler, Pyka, & Gilbert, 2011, p. 218) and “national strategic assets” which need to be facilitated, strengthened, and enhanced (Mowery & Sampat, 2006, p. 209). In view of this, since the 1970s, governments throughout the industrialized world have launched a number of policies and interventions to link university’s academic research more closely with industrial R&D (Mowery & Sampat, 2006). Accordingly, commercialization of university innovations, and the development of university-based entrepreneurship ecosystems have gained extensive research attention (Ahrweiler et al., 2011; Etzkovitz, 2009; Fetters, Greene, & Rice, 2010; Leydesdorff, 2013; Li & Zhang, 2013; Meyer-Krahmer & Schmoch, 1998; Perkmann, Neely, & Walsh, 2011; Zucker, Darby, & Armstrong, 2002). Still, there are following deficiencies remained, which the present research aims to remedy.

First, in Perkmann et al. (2013)’s review, they advocated that university entrepreneurship, institutional aspects of knowledge transfer and commercialization should be further studied in other culture contexts than in US or selected European countries. To be specific, prior research are scarce in non-Western contexts, with regarded to the exhibitions of antecedents and consequences of different patterns of university-industry knowledge transfer (Perkmann et al., 2013), and/ or in different innovation ecosystems at different development stages (Adner & Kapoor, 2010; Kodama, 2008).

In China, the commercialization of university innovation is under influence of university institutional patterns and the structural features of industrial and policy environment (Meng, Zheng, & Wu, 2010; Wu, 2014a). Chinese policy makers, as those in industrialized countries, expect that current investments in university-industry collaboration may generate positive effect in the labor market, and a flow of innovative products with high commercial profitability (Ahrweiler et al., 2011). However, the fact is that the “original innovation seed” is still scarce in China, not only due to Chinese universities and research institute’s incompetency in research (Wu, 2014b), but also because of the lack of motivation in universities and research institutes, as well as the poor absorptive capacity in industries (Eun, Lee, & Wu, 2006).Thus, how to fill this university- industry gap in China has become a critical question to be answered.

Furthermore, more recent studies highlighted the highly complex dynamics observed in the innovation process and university-industry network (Bekkers & Freitas, 2008; Bruneel, D’este, & Salter, 2010). In order to facilitate both the researchers and the policy makers with evidence-based research/policy strategies, scholars are emphasizing the importance of more in-depth study at the actor level, including what has happened in university-industry collaboration, what is happening and what will happen in the course of collaboration (Ahrweiler et al., 2011). Demonstrated in case study, the present research aims to provide policy makers and researchers an access point to an evolutionary picture of a Chinese high-tech company’s development in such collaborative relationship in the past decade.

Nuctech Co. Ltd (Nuctech) was founded in 1997, as a high-tech “spin-off” company of Tsinghua University. As an undertaking in nuclear industry, Nuctech’s products range from dental CT scanner to large-scale container inspection machines. The safety container inspection machine is not an ordinary electrical instrument. Instead, the development of this machine is based on highly advanced technology of nuclear industry. That’s why the company’s business success at the 2014 World Cup[1] was deemed by themselves as a demonstration of a globally first-class competitiveness (Nuctech, 2013). Categorized as “capital goods”, the inspection machine’s invention and optimization require long-term accumulation of knowledge and technology reserves. As argued by Lee (2000), the existence of a well-developed capital goods industry is a key indicator to distinguish developed economies and the developing economies. From this perspective, Nuctech’s achievements can be regarded with important strategic significance for China as a global manufacturing powerhouse.

By studying Nuctech’s case, this study explore the role of “transplant with the soil” (TPS) mechanism in the process of knowledge transfer, commercialization and the establishment of the company’s innovation ecosystem with the following research questions: (1) What are the antecedents, consequences and key features of TPS? (2) What are the impacts of TPS on the academics, the university, the industry, and other stakeholders? (3)What are the theoretical, practical and policy implications of this mechanism?

Using a longitudinal single case study approach, the present research followed Nuctech’s case from 2000 to 2014. As the findings revealed, TPS is not only functioning in aforementioned processes, but also contributed to the company’s success in business, and its sustainable development on innovation capacity. Being the first study that documented and analyzed Nuctech’s case in English, the present research contributes to enriching the existing theories and understanding on university-industry linkage, as well as providing tentative answers to solve the existing issues in terms of innovation in China.

[1] At the 2014 FIFA World Cup, Nuctech provided in total 600 safety inspection machines for 9 out of 12 arenas in Brazil (Lu, 2014).

Theoretical review

In modern knowledge-based economies, university not only plays an important role as a solid base of fundamental knowledge, but also is supposed to serve a "third mission" on developing industrially relevant technology for the sake of national economic prosperity (Bruneel et al., 2010; Leydesdorff, 2013). In line with this, there is a huge body of empirical research on the possible ties between universities and industries, including the formation of entrepreneurial university spin-offs, university patents transfer, university-based training, professional development, collaborative R&D and Industry absorptive capacity (Ahrweiler et al., 2011; Bekkers & Freitas, 2008; Kodama, 2008). As one of the important ways for the transfer of academic knowledge and technologies to the industrial domain, timely and effective commercialization may impact other related innovation process and eventually contribute to a nation's socio-economic prosperity (Perkmann et al., 2013; Zucker et al., 2002).

The commercialization of complex academic advances and the "valley of death"

According to Bush (1945)'s "linear model", expending funding of academic research was both necessary and sufficient to promote innovation, which was argued positively associated with a country's economy prosperity. However, though abundant resources had been allocated in the fundamental research at American universities in 1970s, the US economy was greatly challenged by the Japan's speedy growth. Since after this linear model was widely questioned by scholars and policy makers. Many policy makers therefore asserted that academic research in the university may not be a sufficient engine for improving national innovative performance. For example, Scholars (Cohen et al., 2002) found that U.S. universities had very limited impact on triggering commercial R&D projects in most industries, and didn't contribute directly to innovation in the industry. Mowery and Sampat (2006, p. 222) further argued that, for those basic research advances that had been transferred, their effect on the industry innovation were "realized only after a considerable lag".

Among various factors, the complexity in commercialization process is suggested to be one of the primary causes. The commercialization process is often tortuous with several stages, such as small- scale test, large-scale test, and mass production (Wang & Wu, 2001). There are numerous risks brought by the technology and the market during the process, which is known as "the valley of death" (Branscomb & Auerswald, 2002). Even though, the commercialization of *complex* technical advance is rather more difficult, because it involves more cross- disciplinary knowledge and more advanced technical know-how. Some of the knowledge is explicit knowledge, but more is in a form as implicit knowledge, with an innovation process demanding long-term accumulation and learning (Hobday, 1998; Wang & Wu, 2001). Fundamentally different from that of traditional product, the conversion of complex scientific and technological advances is not as simple as the technology patents transfer, nor can be merely solved by the involvement of the venture capital. Instead, Complex Product Systems (CoPS) may only be facilitated through a customized, multi-agent collaboration network, involving borderless integration and more in-depth collaboration between both university and industry (Chen, Huang, & Tong, 2004; Hobday, 1998; Kash &

Rycoft, 2000; Yang & Wu, 2003). To be specific, the innovation model of CoPS is featured with a comparably long-term joint research period, the utilization of more in-depth cross-displinary knowledge, and the introduction of highly advanced technology at a larger scale (Chen et al., 2004; Yang & Wu, 2003).

Industry, university and the relationship

Contrast to prior research that conducted respectively from university or industry perspective (Freeman & Soete, 1997; Lundvall, 1992; Nelson & Rosenberg, 1993), more recent research started paying attention on the collaborative pattern that university may interact with industry. Since 1980s, theories on multi-dimensional interactions and national innovation system have been gradually developed. The triple helix theory was introduced in late 1990s to interpret the interactions among university, industry and government in the concepts of tri-lateral networks and hybrid organizations. By addressing this tri-lateral “network” relationship from a macro-level, the theory is with a clear focus on the national/regional innovation system, and was referred to explain cases when universities are acting as drivers in a regional innovation system (Etzkowitz & Leydesdorff, 1997). The regional clustered high-tech start-ups in the Silicon Valley and Boston area are reported with relationships with the nearby Stanford University and MIT (Etzkowitz, 2003). The spin-offs, venture capital and innovation culture then became the research focuses in this field (O'Shea, Allen, Chevalier, & Roche, 2005; Perez & Sánchez, 2003; Pirnay & Surlemont, 2003; Steffensen, Rogers, & Speakman, 2000).

Different from the triple helix theory that argued a direct and maximized link between university and industry, a contrasting view expressed their concerns on too frequent and too close interactions between the two parties. The so-called “New Economics of Science” (Dasgupta & David, 1994) argued that policies focused on immediate financial returns and aimed to shift resources toward commercial applications of scientific knowledge may eventually jeopardize the national innovation capability. In view of this, a proper and distant division of labor between university and industry should be emphasized and maintained in order to ensure the potential social benefits (Mowery & Sampat, 2006; Rosenberg & Nelson, 1994; Stephan, 1996).

With a specific focus on knowledge transfer between university and industry, Giuliani and Arza (2009)’s cross-cultural research in Chile and Italy emphasized that shared knowledge base is the key driver for establishing high-value university-industry linkage. Bekkers and Freitas (2008)’s study in the Netherlands argued that knowledge transfer from university to industry was affected by several factors, including the disciplinary research advantage, the characteristics of the knowledge and the competency of researchers involved. Findings from Cohen et al. (2002)’s research in the U.S. revealed that, for explicit knowledge, publications, patents, and academic conferences are effective knowledge transfer channels. Due to the coding difficulty, the channels via joint research and development, informal contacts and exchange of experts are more effective in terms of implicit knowledge’s transfer and are particularly relevant when groundbreaking inventions are transferred from the American universities to their spin-offs (Zucker et al., 2002).

Although there has been a surge in research published in this vein, the state of knowledge of university-industry linkage and knowledge transfer remains relatively fragmented and tentative when it comes to the implications in the developing countries (Eun et al., 2006; Lei et al., 2012; Leydesdorff & Zeng, 2001; Wang & Wu, 2001). For instance, there is no further explanation of the triple helix theory’s implication in China, where universities with unique institutional features facing widely different challenges in the tri-lateral networks (Wu, 2014b). Moreover, according to the triple helix theory (Etzkowitz, 2002), business incubators, science parks, seed capitals can be regarded as various manifestations of tri-lateral networks. What is particularly problematic in China is that, the so-called incubators, science parks, and industrial parks are in extremely large quantity, with vast differences in their formation, mechanism, institutional arrangement and financial performance (Wu, 2014b). If all of them are regarded as “bridging institutions” that link universities with industrial innovation (Mowery & Sampat, 2006, p. 209), it may result in research ambiguity to a great extent. Therefore, the implications of these theories in China request further clarification and examination.

Innovation system in China

Nowadays, China’s research population, annual R&D expenditure, academic publications and patent applications are among the largest in the world (Fang, 2012; MOST, 2012). However, the knowledge transfer from the university to the industry was evaluated to be inefficient (CPC Central Committee & State Council, 2012). Meanwhile, the academic and commercial R&D resource-wasting was reported to be astonishing (Li, 2007). According to recent statistics, the commercialization rate in China remains at about 25%, if not over-estimated (China-National-Radio, 2011; Dong, 2013). The restraining factors are reported including university’s propensity to entrepreneurship, the knowledge and technology gap between the universities and the industries, poor labor and knowledge mobility, poor industrial R&D and absorptive capacity, under-funded commercialization, and the “mismatch” between technology and economy (Eun et al., 2006; He et al., 2010; MOST, 2011; Wang, Lei, & Deng, 2008). These factors may result in a long-term lack of interactive exchanges of resources between university and the industry in China (He, 2012), given the fact that Chinese government has sought to, by all means, to foster closer and more frequent university-industry interactions (Fang, 2012).

In recognition of these facts, a growing number of studies have been carried in this filed, seeking to explore effective mechanisms functioning in the university-industry interactions (Diao et al., 2011; He et al., 2010; Li, 2007; Wang & Wu, 2001). In the wide varieties of channels through which knowledge and technology is being transferred from universities to industry, the present study aims to explore the specific features of an important mechanism that observed in a single case study on university-industry collaboration.

Prior research on Nuctech and “Transplant with the soil” (TPS)

By far, there are only a few academic studies documented the Nuctech case. However, the existing study on Nuctech is still in its infancy as many critical research gaps still remain.

First, the existing big gaps of knowledge and personnel between university and industry in China hindered high-quality, high-value added and highly collaborative transfers of complex technology set from university to industry (Wang et al., 2008). Which mechanism may function under this circumstance, is a question to be answered. The answers in the existing literature are either vague, or rely only on large sample empirical research or concept analysis. From this perspective, prior research failed to recognize Nuctech as a typical case, which effectively integrated the resources from the university and the industry. Second, in Nuctech’s case, the collaboration of university scientific research and industrial commercial R&D was accomplished, which is deemed by the company itself as the core competitiveness (Nuctech, 2013). It was observed by prior research (Hu, 2010) when highlighting the importance of collaboration between the university and the industry. However, previous studies present a relatively weak explanatory analysis without summarizing the necessity, the characteristics, the antecedents and consequences of the knowledge transfer and innovation mechanism. In sum, these are deficiencies in prior Nuctech studies that the present research aimed to remedy.

Building on prior work, we conceptualized TPS by analyzing the mechanism and its contribution to university-industry linkage. Obviously, TPS is a metaphor. In nature, the growths of the plants rely on the soil and its climate conditions. Therefore, in order to improve the survival rate of the transplants, gardeners take an approach named “transplant with the soil”. In the present case, the objects to be “transplanted” are the scientific and technological findings from the university, and the “soil” is a metaphor for the environment for them to grow and flourish. During this organized “transplantation”, Nuctech has a complete and speedy access to the research resources of Tsinghua University. The transferred technology platform and research personnel enabled the quick and effective commercialization of scientific and technological advances.

Method

Case study is an important research method in management and organizational studies. By enhancing understandings of the detailed and dynamic case scenarios, case study method often contributes to summarizing new management theories (Eisenhardt, 1989; Hamel, Dufour, & Fortin, 1993; Strauss & Corbin, 1990; Yin, 2009). Prior research (Eisenhardt, 1989; Yin, 2009) concluded that the exploration on a single case study method is proper, when the research opportunity is unique and the case is unusual and insightful. With the comprehensive, long-term and overall process-oriented research perspective, this approach conducts in-depth analysis on the characteristics of the research objects, and facilitates to open the “black box” in organizations.

To improve the external validity of the present single case study, researchers first ensure that this case is with typicality. The researchers then analyzed the case with a large extent by comparing it with related domestic and international cases (e.g. PKU Founder and Stanford Technology Park), in order to establish theoretical insights and enhance the practical implication of this case (Eisenhardt, 1991). Case object accessibility is a prerequisite for the case study method. Data was collected during a long-term observation (2000-2014) via follow-up, interaction, formal and informal communication, and multi-source verification. The various approaches of data collection enhanced the data richness, authenticity and verifiability.

The research flow

There were three stages in the research flow. (1) The start-up (2000-2003): Nuctech made its initial success during this period and its TPS mechanism was noticed by the authors. The authors interviewed a number of experts from Tsinghua University and senior executives from Nuctech. (2) Nuctech tenth anniversary (2007-2009): By then, the company had already become a remarkable fast-growing high-tech company in the market. The authors attended several meetings and anniversary celebration events, meanwhile interviewed the executive management team. (3) 2012 to 2014: Fifteen years after its establishment, Nuctech is a world's leading provider of security inspection equipment. Since then, the company has entered a new stage for development. During this period, the authors conducted the 3rd round research and interviewed employees from both the company and the university. The research flow is illustrated in Figure 1.

Insert Figure 1 about here

Data collection and validity

To study Nuctech's case, the authors conducted a series of in-depth interviews with the senior management teams and a number of key employees from Nuctech and Tsinghua University, as well as the customers of Nuctech and other stakeholders. In total, more than 60 people were interviewed. Fifty percent of the interviews were conducted in the recent four years. The respective semi-structured interviews with 26 important interviewees (including the two chairmen of the board, the vice-president and the assistant to the president) were particularly crucial. In these interviews, collaboration details that were not documented by generally accessible records were collected, as the interviewees were either virtually made all key decisions, or they were the witnesses when those decisions were made. Detailed information of these interviewees is provided in Appendix 1. The semi-structured interview normally lasted for 3 hours. The research team also developed an interview question list for different interviewees including policy makers, researchers, management team, producers, and product end-users. By cross-asking similar questions to different interviewees, concepts, ideas and statements concerning the present research were repetitively verified.

To ensure the construct validity, the triangulation method (Jick, 1979) was adopted, meaning that all the critical information was corroborated with information from different sources to decrease the influence of the information providers' subjective bias.

During the interviews, some interviewees also provided supporting documents, including yearbook, reports, memos, and manuals, as supplements to their comments and opinions. The research team analyzed these data with a systematic approach, aiming to have the first hand and second hand data corroborate each other in the same course. The data were coded in line with approaches documented in prior research (Strauss & Corbin, 1990) to ensure the reliability of ideas and concepts. The summary of second hand source data is available in Appendix 2.

Nuctech’s case and its milestones

Nuctech’s success

In January 1996, Tsinghua University successfully developed a set of technologies on large container safety inspection. The development of these high-tech technologies integrated cross-disciplinary research and process (Hu, 2010)[2]. Utilizing beam technology to collect the information of the quality, contour and structure of objects that are inside a loaded container, this technology set can provide the inspection specialists with a clear view of the inside goods for speculating the real state of the container being tested.

With the purpose to pursue a speedy commercialization of such technology advances, Tsinghua University and Tsinghua Tongfang nuclear technology Co. Ltd. (Tongfang) decided to set up a company, which is the formation of Nuctech. Experts from Tsinghua University and Nuctech co-explored the TPS mechanism. Via TPS, the research team from Tsinghua University utilized the platform at Nuctech and realized a rapid transformation of the research advances. In 1999, Nuctech’s security inspection machines started equipping the Chinese Customs, as shown in Figure 2.

Insert Figure 2 about here

Equipped with advanced technologies, Nuctech and its products quickly became the most powerful international competitor in the market (Nuctech, 2013). As of 2012, Nuctech has provided more than 700 sets of its large container inspection machines to 116 countries with a global market share of more than 50% (Nuctech, 2013). By now, Nuctech has established six product lines, being capable of producing 22 series of different container inspection products[3]. So far, Nuctech had more than 700 domestic and foreign granted patents.
In sum, the company has proven itself to be the most innovative company in the field and a

[2] Development of the technologies were based on research and key technologies in the field of radiation imaging, by incorporating other technologies in accelerator, detector, electronics, computer and information processing, automatic control, precision machining, and radiation protection.

[3] These products include the world’s first on-board accelerator radiation system, the first set of inspection system with combo module and mobility, the first set of container inspection equipment with Dual-energy and substance recognition, and the first X-ray security system for liquid inspection (Nuctech, 2013).

market leader worldwide. The comparison of Nuctech’s key performance indicators and the investment on R&D is illustrated in Figure 3. Nuctech’s growth can be briefly summarized with four stages, as illustrated in Figure 4.

Insert Figure 3 about here

Insert Figure 4 about here

Knowledge accumulation

Market demand is often the most powerful driver for technological innovation. Tsinghua container inspection techniques also were facing significant market opportunities. In the 1990s, the Chinese Customs urgently demanded a large number of container inspection systems with high-efficiency. Supported by the university management team, resources were soon allocated. Coordinated by Tsinghua University, Tongfang[4] invest 30 million Chinese yuan[5] on this container inspection development project for the sake of timely funding. At that time, venture capital in China still remained unknown, though in this case, Tongfang’s investment can actually be deemed as a form of venture capital.

“Transplant with the soil” (TPS)

The container inspection technology projects had several unique aspects, which may result in difficulties for cooperation: First, the technology was relatively advanced, involving cross-disciplinary research and knowledge at a large scale. Second, the research area was relatively sensitive. The industry was controlled and regulated by the government, and with high barriers to entry. There was no qualified nuclear company available, let alone the industrial R&D was insufficient for the technological achievements conversion[6]. Third, the product was demanded urgently by the market at that time.

To overcome these difficulties, Tsinghua University and Nuctech co-proposed a mechanism and named it “Transplant with the soil” (TPS). Functioning in transformation, TPS facilitated in transferring technologies together with the experts from the university, which made Nuctech’s innovation platform completely used by the research team from Tsinghua university. In this circumstance, the project team members were with two roles to play: professors at the university and key R&D personnel in Nuctech. For instances, Dr. Kejun Kang is a professor at Tsinghua university. He was also the president of Nuctech at that time. As he later recalled, the Tsinghua team’s responsibility was not only guided Nuctech

[4] In July 1997, Tongfang formally announced its establishment. As the predecessor of Nuctech, Tongfang contributed to the initial co-establishment of the innovation platform at Nuctech.

[5] 30 million Chinese yuan (CNY) is equal to 4.26 million Euro, or 4.84 million US$, with the present exchange rate (May 2015). By now, Tongfang is still the holding company of Nuctech, with a percentage share of 69%.

[6] In fact, over a period of time after the recognition of the initial success of this technology, Tsinghua University visited quite a few domestic enterprises aiming for cooperation. However, no one was willing to invest in this project and its industrialization.

employees to formalize the developing process, but also contributed to develop the engineers to master the necessary key techniques requested by the rapid formation of manufacturing capability. The project with such a high-tech complex system is far more complicated than handing over the product blueprint. Even in the later stage of manufacturing, the project still required step-by-step support and daily supervision from the Tsinghua team (Zhao, 2014). From this point of view, TPS enabled the university and the company achieving a seamless cooperation, thus result in a speedy conversion of technological advances to the industry.

Different from the PKU Founder’s transfer with authorizations and Stanford’s model on technology transfer, TPS enabled the knowledge owner to obtain a genuine decision-making authority, which means the company’s directorships were actually maintained by the academic staff. This approach promoted the integral integration of the capital and the knowledge and can be regarded a case that the knowledge employed the capital, which is in line with the economic characteristics in the era of knowledge economy (Hong, 1998; Mao & Li, 1998).

The global business expansion

In 2001, just four years after Nuctech’s establishment, Nuctech signed the contract with the Australian Customs on providing two container inspection systems with combo module and mobility[7]. Unlike many Chinese companies competing with “the best price”, Nuctech indeed won the bid with the best performance and a higher quote price than its competitors.

Innovation and technology diversification

To facilitate the technology breakthroughs in key technologies and its commercialization, Nuctech adopted a mechanism that integrated basic research, technology development and manufacturing. For example, Nuctech are making continuous efforts on further advancement of the accelerator technology, in order to optimize the performance of its products[8]. Nowadays, Nuctech’s technologies in the field of radiation detection on large-scale devices, traffic package inspection, liquid screening and nuclear contamination detection are inspiring the industrial R&D of domestic and international security inspection industry. By far, the company is capable of promoting more than ten new products per year.

[7] Nuctech’s first export products underwent rigorous assessment of the Australians. The Australians eventually concluded that, both the advancement of technology and the overall solution are scored higher than those of Nuctech’s competitors in Germany and the United States. Because of outstanding performance of Nuctech’s container inspection devices, the Australian Customs later won the "Australian Prime Minister Award" (Nuctech, 2013).

[8] Nuctech’s container inspection equipment with Dual-energy and substance recognition and its X-ray security system for liquid inspection are all developed based on its technology on this advanced accelerator.

From “transplant with the soil” toward the establishment of innovation ecosystem

Key features of TPS

As the investigation released, TPS played a key role in promoting rapid conversions of scientific and technological advances. The characteristics of TPS can be briefly summarized with the following components:

Shared R&D platform. Large container inspection technology system was developed by long-term research and continued technological accumulation at Tsinghua University.

Shared research personnel. In Nuctech’s case, the appointments of top research scientists and trained personnel with industrial management positions can be regarded as one of the key factors of the immediate success of the invention. At that time, employees from Nuctech’s six technical modules were connected with those working in the six institutes of Engineering Physics Department of Tsinghua University.

Shared culture of innovation. What TPS have brought to Nuctech was not only the technology and experience, but also the team culture of innovation. For centuries, Tsinghua University has formed a campus culture emphasizing the “actions speak louder than words”, “pursuit of perfection”, and “being realistic while innovative”. These values have labelled Tsinghua people the ethos of hard- working, dedication, cooperation, innovation and excellence-orientation.

Institutional support. Institutional obstacle is widely criticized in China for its role played in the inefficient conversion process of scientific and technological advances (Dong, 2013; Fang, 2012; Liu, 2004). For example, in China, there are differences between “in or out of the system (unit)”. The employer (the unit) formed an invisible barrier, restraining the free flow of talents and expertise (He, 2012). In such circumstances, accomplished scientists would not take risks by cooperating with the “outsiders” on innovation projects, because they may lose their permanent jobs in their “ivory tower” “inside the system (unit)”.

Via TPS, the “unit” (University) provides a friendly environment for scientists and researchers by allowing them to have a second job in the industrial project. In addition, the personnel and institutional arrangements ensured that the core member with genuine corporate decision-making authority and management autonomy. These key features of TPS are illustrated in Figure 5.

Insert Figure 5 about here

Nuctech’s sustainable innovation ecosyste

Moore (1993)’s research is among the earliest to introduce the concept of business ecosystem, including not only downstream and upstream service providers, but also the consumers. As an economic community, the ecosystem is composed of interactive organizations and individuals that produce valuable products and services. Iansiti and Levien (2004) further interpreted this framework by analyzing the impact of dynamic ecological system on platform strategy, innovation and sustainable development. Recent research started to address the whole ecosystem structure and its impact on organizations’ strategies, with the key technology independence as an important indicator (Adner & Kapoor, 2010; Kapoor & Lee, 2013).

Via TPS mechanism, Nuctech mastered the key technologies at an early stage. In the later course, Nuctech took the initiatives to establish its innovation ecosystem, for the sake of sustainable development on core competitiveness.

From TPS to the joint research institute. Along with Nuctech’s growth, the company has invested considerably on its own R&D capabilities with clear focuses on product development and technology application. Accordingly, Nuctech’s R&D dependence on Tsinghua University reduced gradually. Tsinghua researchers who were temporarily worked for the project had quit their job at Nuctech and returned to the University. In December 2014, only five employees from Tsinghua University still have part-time job in the company.

There are 966 employees working in the R&D facilities, representing 53% of the total employees of Nuctech (see Figure 6). As an enterprise with genuine innovative focus, in recent years, Nuctech’s annual R&D investment intensity remains approximately at 8%.

Insert Figure 6 about here

In the early theories of university-industry linkage, collaborative R&D was expected to functioning only temporarily. Then collaboration will dissolve, as either one of or both the parties would have difficulty in actively engaging in this cooperative relationship (Ahrweiler et al., 2011). Though long-lasting collaboration seems to be anomalous, Nuctech has established a long-lasting partnership with Tsinghua University by offering industrial support to the academic research with or without direct commercial profitability. In 2004, the two parties co-founded “Tsinghua University - Nuctech Joint Research Institute for Nuclear Technology”. This joint research institute soon became Nuctech’s “Virtual Central Institute”, employed more than 200 researchers. Different from TPS and its short-term effect, the virtual central research institute is positioning as a long-term university-industrial R&D base. Being a media or a bridge, the joint research institute targets a systematical integration of resources from both sides to underpin academic and industrial innovation.

Nuctech, Tsinghua University, and the Joint Research Institute have their roles clearly defined in this collaborative relationship. To be specific, the Department of Engineering Physics of Tsinghua University is responsible for basic research and applied basic research. The Joint Research Institute is responsible for cutting-edge technology and key technology development. Nuctech is responsible for commercialization including product development. Such R&D cooperation is far beyond the application of TPS and with a larger extent of research flexibility. Figure 7 briefly illustrates the differences between TPS and Joint research institute.

Insert Figure 7 about here

The virtual manufacturing ecosystem. With the perspective of building an innovation ecosystem, Nuctech implemented global outsourcing on non-core components and built its global virtual manufacturing network. In addition, Nuctech maintains a close relationship with over 100 domestic downstream manufacturers. The delivery cycle for Nuctech’s product has shortened from 1.5 years to six months (Nuctech, 2013). By far, Nuctech has effectively built its virtual manufacturing ecosystem, with the assembly base in Beijing. Nuctech’s innovation ecosystem is illustrated in Figure 8.

Insert Figure 8 about here

Discussion

With simulation results, previous empirical research suggested that effective university-industry cooperation facilitate the process of commercialization, academic knowledge and technology transfer and innovation diffusion (Ahrweiler et al., 2011). With a case study, the present research introduces TPS as a mechanism promotes university-industry collaborative R&D and contributes to industrial growth and change. Below, we synthesize our findings with a view to developing a fuller understanding of this mechanism.

Theoretical essence of TPS

The antecedences of TPS can be summarized as the following:

Urgent demand from the market. Commercialization opportunities for new technologies are usually fleeting and need to be properly handled (Zhao & Si, 2004). In 1990s, China Customs were facing a grim situation fighting with smuggling crimes. The market’s demand on container inspection was a fleeting opportunity. Via TPS, Nuctech promptly seized this business opportunity.

High complexity of complicated technology. Complicated technology often contains a lot of high-tech complex tacit knowledge with strong adherence, in knowledge itself and related know-how. Nuctech’s project required Tsinghua team to engage in the whole process of the commercialization to solve the technical problems anytime when needed. TPS facilitates the transfer of collective tacit knowledge.

Low industry absorptive capacity of emerging technology. If industrial companies have stronger absorptive capacity, university would find it easier to transfer knowledge and technology to those companies without having to setting up a spin-off (Eun et al., 2006). However, China’s national innovative and competitive performance still remains at a low level and many industries are under-developed (Diao et al., 2011). Therefore, when an early stage technology emerges, the absorptive capacity and competition in the industry is often inadequate to cope with that. In this circumstance, it may be ineffective to transfer the knowledge merely in a form of patents authorization (Lei et al., 2012). From this perspective, TPS may contribute to a rapid increase in industry’s capability in absorbing knowledge and technology.

Blocked innovation channel. Under-developed legal system, lack of trust and credit system are issues that hindered the cross-border free flows of innovation elements, namely capital, goods, people, and knowledge (Liu, 2004). Nevertheless, if an “innovation green channel” does not have a smooth passageway, the innovation outcomes may soon drops into the “Valley of Death”. In essence, TPS breaks the territory of organizational boundaries between university and industry. It creates a “small environment”, which facilitates to rapid commercialization of new technologies. As an “innovation green channel”, this mechanism decreases the environmental differences inside and outside the university. As indicated in the present study, more complicated technology may request wider and smoother passageway in terms of knowledge transfer. The TPS mechanism may facilitate an innovation green channel and eventually avoids the potential dysfunctions of innovation ecosystem.

Theoretical contributions, practical implications

Our primary goal is a systematic elaboration on TPS, while introducing its antecedents, consequences and implications based on a great amount of information collected in the past decade. In OECD countries, recent longitudinal research emphasizes the role of universities as centers for knowledge production within national innovation systems (Mowery & Sampat, 2006). Based on our initial step on exploring a different pattern of university-industry collaboration in Chinese settings, we investigated aspects that are less well examined in prior research in this field. Being differed from the traditional Chinese enterprises' OEM-ODM-OBM model, and nowadays Lenovo, Huawei's “sales -manufacture-R&D” model[9], Nuctech and its practice with TPS is with great importance from both theoretical, practical and policy-making perspectives.

First, our research fills in the research gap with a lack of knowledge and research about the key features, the antecedents and consequences of TPS. As our findings revealed, TPS played an important role in the commercialization of complex research advances, particularly before the establishment of company's own innovation ecosystem. Second, the present research analyzed Nuctech's growth path, together with the exploration of Nuctech's “Virtual Technology Research Institute”, innovation green channel, and innovation ecosystem system. Thus, the present case study not only contributes to a better understanding on the characteristics of China's innovation system, but also is relevant to the enhancement of the innovation theory on University-Industry linkage.

Exploring university-industry linkage is of undoubted interest to practitioners, notably university management team. Nuctech's case support the previous empirical findings that fostering academic researchers' engagement is crucial for the effectiveness in

[9] As a representative of many Chinese high-tech companies, the growth model of Lenovo and Huawei can be briefly described as below: First, acting as a sales agent representing foreign high-tech products with well-known brands to learn from the market. Second, assembling the procured high-tech product components to produce low-end products and brand the company and the products with high quality post-sales service. Third, via increasing R & D investment and patented core inventions, positioning the products gradually with high-end orientation while targeting the international market. This mode is generally referred as “sales-manufacture-R&D” (Zhang, 2003).

commercialization (Perkmann et al., 2013), therefore, a free flow of personnel and resources across boundaries may improve the quality of university-industry relations. Meanwhile, TPS may contribute to solve the issues such as lack of trust inter-institutionally, and traditional shortage on innovation cooperation at institutional culture level and mechanism level, which are major concerns of university managers and industry stakeholders in the collaboration (Wu, 2014b).

Also the industry needs to recognize that collaborations with university present distinct challenges, which is different from those relationships with customers, suppliers or other stakeholders in China. Particularly when companies are linked with the top level academic researchers[10], the company need to take into account that these academics will under most circumstances only work with the project for a comparably short period, as observed in Nuctech's case. Therefore, industrial company's skills in initiating, enhancing and maintaining such collaborative research is particularly important for fostering academic researchers' engagement (Perkmann et al., 2013) and reducing transaction costs in the commercialization process.

Different from other university-industry collaboration that may pursue outcomes in knowledge exchange or public funding, commercialization implies a more narrowly focused interest in the exploitation of a specific technology. With a more entrepreneurial orientation in nature, the commercialization process may be prone to public policy changes in this field (Lei et al., 2012). From this point of view, Nuctech's success with TPS may become a good reference with policy-making implications. The present study may facilitate Chinese policy makers to better grasp the strengths of university-industry collaboration via TPS and its implications in China. As aforementioned, in China, the under-developed legal system, lack of trust and credit system are issues that block the innovation channel and hindered the cross-border flows of knowledge, resources and personnel (Liu, 2004). The practice of TPS in Nuctech's case suggests that policy interventions should be designed with effective approaches to remove these gaps and blockages in this direction and guide both parties in the due course. Last but not the least, this research may benefit policy debates by evaluating whether the existing initiatives are fostering the transfer of technology to the industry and further promoting industrial R&D, or just stimulating the "university entrepreneurship" with short-term financial returns (Mowery & Sampat, 2006). Chinese policy makers, universities and industries should not implicitly assume that "more is better" in terms of university-industry interactions, but seek to differentiate the conditions under which the university-industry collaboration yield benefits on both sides and the society, with minimized risks and failures.

Limitations and future research

This study is a longitudinal single case study and the research period lasted more than ten years. The research approach represents the strength as well as the limitations of the present research in several aspects. First, it would improve the quality and comparability of the

[10] Tsinghua University has consistently been ranked alongside Peking University as the top universities in China.

research, if Nuctech’s case can be compared with other companies that are domestically or internationally at the same scale, or a large-scale comparative analysis are available during the same research period. Second, the outcome of TPS at Nuctech is relevant to the special features of nuclear industry. Due to this context-specific nature, it is difficult to generally conclude, as most research findings interpreted in this field (Perkmann et al., 2013). Therefore, the implication of TPS in other industries requests further investigations. Also as we are aware of, it is difficult to standardize the University-industry linking approaches across a large number of Chinese universities that are at diverse developmental stages and with significantly different resources magnitude. In view of this, we encourage further research study more on Chinese entrepreneurial universities and its relationship with industries in various forms, and with focus specifically on TPS, “innovation green channel”, and “innovation ecosystem”.

Conclusion

In Nuctech’s case, via TPS, the boundaries of company and university were blurred, the university R&D agenda and the industrial needs were integrated, the flow of knowledge was unblocked, the commercialization of scientific advances is facilitated, and the establishment of innovation ecosystem is eventually grounded. Though the present findings that drawn from record-based information on a single case may be with too high level of granularity to generate “a precise estimate” of TPS and its consequences, it may still provide powerful insights to inspire other research in this field, as stated by many scholars (Perkmann et al., 2013; Rawlings & McFarland, 2011) .

Appendix 1

List of Key Interviewees

Title of interviewees	# of Interviewees	Duration (hour X interviews)	Year
The Chairman of the Board, Tsinghua Holdings Co., Ltd. (THHC*)	1	3	2009
The Former Chairman of the Board, Tsinghua Holdings Co., Ltd. (THHC)	1	3	2001
Secretary of the CPC** Committee, Tsinghua Holdings Co., Ltd. (THHC)	1	3	2008
Vice President, Tsinghua Tongfang Co., Ltd.	1	2	2001
Deputy Director of the Department of Engineering Physics, Tsinghua University	1	2	2014
Vice Secretary of the CPC Committee, Nuctech	1	4	2014
Director of President Office, Nuctech	1	3	2014
Assistant to the President, Nuctech	2	2	2014
Head of Miyun Base, Nuctech	2	2X2	2014
Senior Executives of Scientific and Technological Development Office, Tsinghua University	3	2X3	2001 2002
Research Fellow, the Department of Engineering Physics, Tsinghua University	5	1X5	2001 2002
Senior Managers, China National Nuclear Corporation (CNNC)	3	2X3	2007 2014
Secretary of the CPC Committee, Unisplendour Corporation Limited （UNIS）	1	2	2008
Senior Managers, Tsinghua Holdings Co., Ltd. (THHC)	3	2X3	2001 2007
Total	26	53	

* THHC is the parent company of Tongfang, which is Nuctech’s parent company. The current and the former chairmen of THHC are key decision makers for business related to Nuctech
**CPC: The Communist Party of China

Appendix 2

Summary of Main Secondary Sources in the Case Study

Data Categories	Material Brief	Resources	Remarks
Public information	Events and important news	http://www.nuctech.com/ http://www.tsinghua.edu.cn http://info.tsinghua.edu.cn http://www.sohu.com http://www.sina.com http://www.baidu.com	
	Chinese and foreign media reports	Webpage news	30 reports
	Nuctech’s yearly report (2000-2014) Reports by the research institutes	http://finance.sina.com http://business.sohu.com/	
Internal documents and data (web source)	Tsinghua industry briefs	http://info.tsinghua.edu.cn	200 issues
Tsinghua University’s internal documents and data (paper source)	Tsinghua University: Statistics data of Tsinghua industry system Application documents for the National Science and Technology Progress Award	http://info.tsinghua.edu.cn Office of Scientific R&D, Tsinghua University Tsinghua University Library	
Nuctech’s internal documents and data (paper source)	The development of the company Materials for the 10th and 15th anniversary Summaries and reports		
Academic papers	Related academic papers	http://www.cnki.net/	10 papers

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A study on improving corporate lean problem in manufacturing industry through learning visual management cases in other industries

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Abstract
As one of the corporate lean programs of global manufacturing easy to implement, a visual management is focused in this paper. And this paper analyzes advanced cases of a visual management in other industries for studying how to express an abnormal information which should be managed by this scheme. In particular, this paper tackles with the analysis of three traffic lights for walkers in a public transportation system by a state transition diagram. The obtained results of the analysis are 1) an addition of a real time based visualization (RTBV) to a condition based visualization (CBV) and 2) an addition of an animated image visualization (AIV) to a static image visualization (SIV) for future construction of a theory and a practical case related to a visual management system.

Keywords: Corporate Lean Program, Visual Management, Technology Transfer between Industries, Traffic light for Walkers.

1. Introduction
Regarding with a visual management, one of the corporate lean programs easy to implement, the development of useful cases by practitioners have preceded that of related theory by researchers. In particular, a manufacturing industry has led this scheme positively. However there have been recently found some wasteful and unessential cases in various factories as shown from Figure 1 to Figure 5. Figure 1 and Figure 2 are examples of a visualization without identifying true visualized item. The scheme originally has to support an early detection of an abnormal condition and an early solution of an abnormal condition. However there are some cases where a capability of installed tool is low because the item visualized by the tool is not connected directly with an occurrence cause of an abnormal condition. Figure 1 is an example of a visualization of an ambiguous visualized item. Figure 2 is an example of a visualization of too many items as the result of not finding reasonable visualized item. Also a visual management is one support scheme to notice a present condition including an abnormal condition. As the misleading case of a visual management, there are some tools to disappear an abnormal condition incompletely in various factories. Figure 3 is an example of this case. Phenomena like three cases seems to have occurred by Womack and Jones's opinion of a visual management as follows; 'The placement in plain view of all tools, parts, production activities, and indicators of production system performance, so the status of the system can be understood at a glance by every involved. Used synonymously with transparency' (Womack and Jones 2003). This interpretation is wider than Ono's opinion (1988); 'This clarifies what is normal and what is abnormal.' Their opinion maybe means not 'a visual management' but 'a visualization'.
If at all possible, a tool is expected to be utilized natural in relevant operations. But there is a case that a layout of a tool is not considered. Figure 4 is an example of not working a good tool by a mistake of its layout. Figure 5 is an example of a shortage of maintenance and/or a

life-cycle management of installed tools. As the result of the management shortage, many posters of the same purpose are set up at the one place and a posted notice has been left to peel off.

On the other hand, other industries have adopted visual management as one part of the application of lean management, and cases of great interest have been confirmed in the whole world. Manufacturing industry cannot afford to stay inside to their shell. They have to learn the fascination of such cases for shattering their present situation. Based on the above recognition, this paper analyzes advanced cases of visual management in other industries. In particular, the analyzed objects of this paper are three traffic lights for walkers in a public transportation system including one conventional signal. Through the trial, how to express an abnormal information is studied so that bad cases like Figure 1 are not developed from now one.

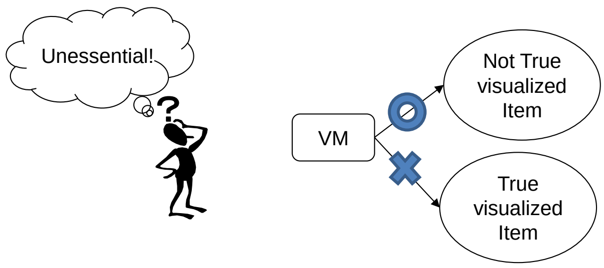


Figure 1. Bad visual management case 1

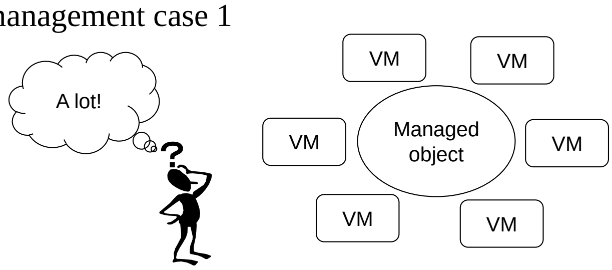


Figure 2. Bad visual management case 2

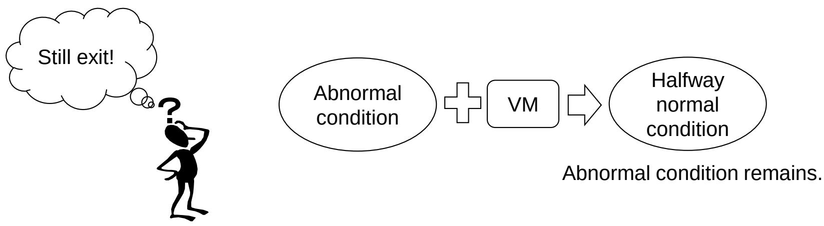


Figure 3. Bad visual management case 3

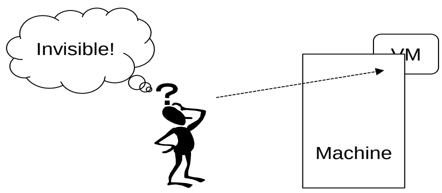


Figure 4. Bad visual management case 4

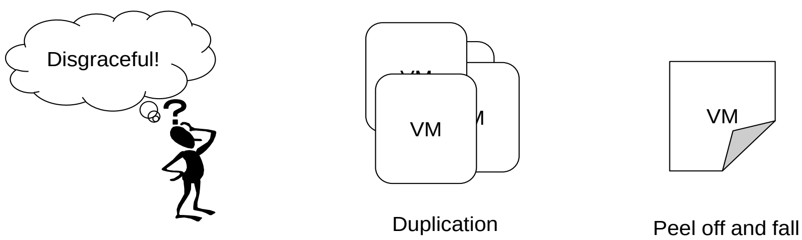


Figure 5. Bad visual management case 5

2. Research category of visual management

There are three research categories of visual management; 1) Visual management design (VMD), 2) Visual management transfer (VMT) and 3) Innovation by visual management (IVM), as shown in Figure 6.

The first category is for discussing how to design a useful technology. It is a basic problem in VM. As the above mentioned, a visual management is confused with a mere notice board. Light-hearted design and implementation of a visual management will invite simplistic result and unessential management. A systematic procedure is needed for designing effective technology. This paper uses one design framework of a visual management which explains in the following section.

The second category is for how to manage a case-base of a visual management considering the reuse of implemented cases. For this category, Murata's and Katayama's (2010a, b) work proposed a technology transfer system for developing the scheme of Kaizen (Imai 198), continuous improvement (CI) (Lillrank 1989) and lean management (Womack 2003). It is performed from the viewpoint of a technology life-cycle management. This means, not only the development and utilisation of relevant cases but also the reuse of those cases concretely is included. Murata and Katayama (2010a) proposed a framework of the case-base by people-oriented case-based reasoning (CBR) (Carbonell 1982). It consists of five phase utilisation procedures of the case base; 1) a clarification of a problem to be solved by a visual management, 2) a retrieval of useful cases in a case-base, 3) a development of new case for identified burden by referring a selected case, 4) an application of the developed case to identified burden and 5) a registration of the implemented case in a case-base. In addition, this category is for a reuse phase of implemented technologies. Two types of this phase were described in the past study (Murata and Katayama, 2014). One is the technology reuse within one industry. The other is the technology transfer between industries.

The researches of the third category are not found in the past studies. This category is focused on in this paper. As the initial trial, a case study is performed to understand key factors of innovative visual management system in this paper.

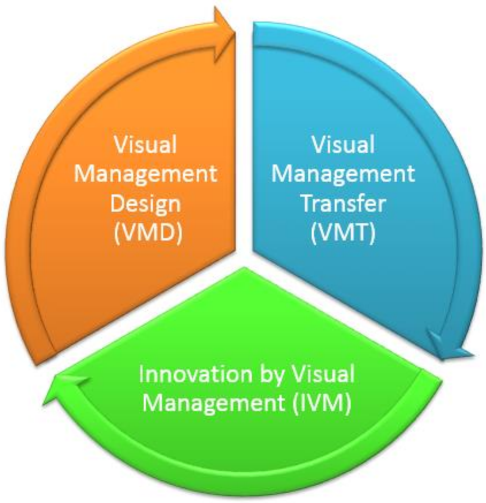


Figure 6. Research category of visual management

3. Methodology

3.1 How to describe cases

The methodology of this paper is a case study. Generally, it aims at disclosing the characteristic of an investigated organization. The analyzed object of this paper is smaller than that of a general case study. It is a case, which is developed by visual management's own tools and their implementation on the investigation site. Through the analysis of cases that deserve special mention, it will be possible to understand the management capability of this site including visual management.

The analyzed objects of this paper are three traffic lights for walkers in a public transportation system. Typical style of the traffic light is illustrated from Figure 7. It consists of two windows. An upper window is a red signal of a human type to stop a walker's crossing. A lower window is a green signal of a human type to permit a walker's crossing. Also, a traffic light has a cycle from the start of walker's crossing to the next opportunity. The case description of this paper is performed by a state transition diagram as shown in Table 1. Vertical axes of this diagram are window's types such as upper window or lower window. Horizontal axes of this diagram are the three states indicated by a traffic light against walker such as a permission of walker's crossing, a warning of walker's crossing and a prohibition of walker's crossing. Moreover a state of a traffic light is described in each cell in this diagram.

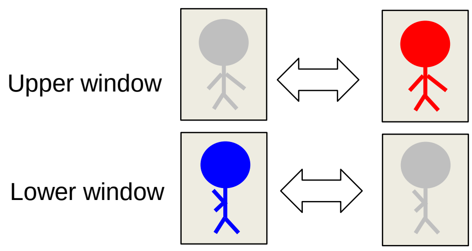


Figure 7. Conventional traffic light for walkers in Japan (Case 1)

Table 1. A procedure for VM system design

Walker's crossing / Windows	Permission	Warning	Prohibition
Upper window	A state of a traffic light for walker.		
Lower window			

2.2 How to analyze cases

A framework of basic mechanism of visual management system is proposed to analyze a case in this paper like Figure 8.

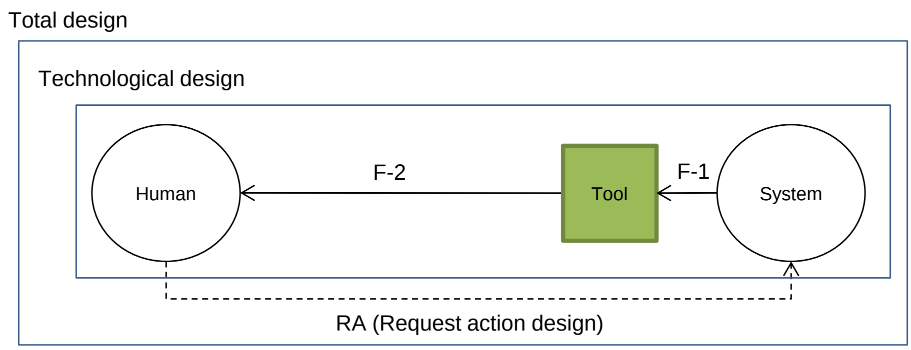


Figure 8. Basic mechanism of visual management system

First portion is the design of request actions of a problem-solving from a system to a human. When skilled person took charge of the system supported by a visual management, it delivered the information of an abnormal occurrence by the visual management. However, a role of a visual management have become larger in accordance with the increase of the

retirement of skilled persons. In other words, a visual management needs to deliver a countermeasure of the controlled system in addition to an abnormal information of the controlled system. In such a situation as shown in Figure 9, it is important to design the request actions.
Second portion is the design of elemental technologies to deliver information for performing each determined request action. In this portion, there are two sub-portions. The first sub-portion is for creating appropriate information managed by a tool of a visual management. The second sub-portion is for effectively transmitting visualized information from a system to a human.

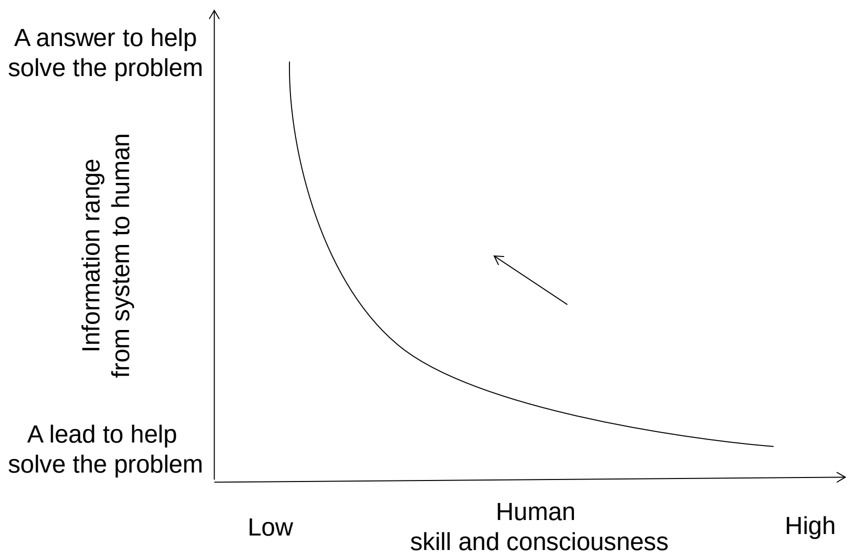


Figure 9. A relationship between information range from a system to a human and a human skill and consciousness

Also, there are five points for designing a visual management system as shown in Figure 10. They are 1) comprehensibility, 2) non-ordinarily, 3) continuity, 4) inducibility and 5) immediacy. These points are related to the design procedure as shown in Table 2 and question items for improving the performance of a visual management system from these points are explained in the table.
The first point is 'comprehensibility'. It is for the design of request actions in the proposed process. In the design, it is necessary to decide the range of information offered by a visual management system for the problem-solving of managed system. If the operator who handles a machine is an expert, all information offered by a visual management system is enough its emergency situation information. However, if the operator is a beginner, a visual management system need offer till the procedure for solving its emergency situation. In case that plural information need to be visualized, necessary visualized information is wider and the design of a visual management system is more deliberated.
The following four points are for the technological design in the proposed process.
The second point is 'non-ordinarily' and the third point is 'continuity'. They are for the creation of visualized item. The former have to pay attention to when a visualized item needs to be designed. When managed system is ordinary condition, a visual management system need not work. The important role of a visual management system is to show the special situation of managed system. 'Non-ordinarily' is used for a good meaning or a bad meaning. Also, for 'non-ordinarily' of bad meaning in particular, there are considered three kinds of abnormal conditions from the viewpoints of an occurrence frequency of an abnormal ; a) a

normalized abnormal (unimproved abnormal), b) an abnormal of periodical occurrence and c) an abnormal of non-periodical occurrence.
As for the latter, a visual management system have to have the structure for monitoring usual condition of managed system to be able to grasp special situation at any time.
The fourth point is ‘inducibility’ and the fifth point is ‘immediacy’. They are for the transmission of visualized item. As for the former, a visual management system needs to have the appeal for operators because their physical condition and mental condition is not always stabilized. For improving inducibility capability of a visual management system, it is necessary to build the device for operator's attracting attention in a visual management system. As for the latter, the timing of information delivery have to be when immediate correspondence to the condition of managed system being needed.

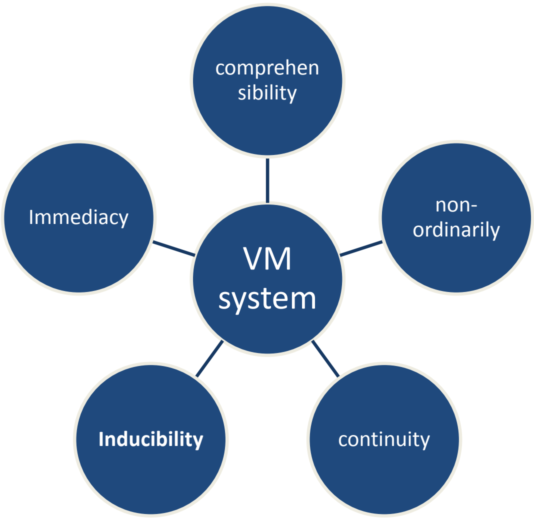


Figure 10. Design point for visual management system

Table 2. A procedure for visual management system design

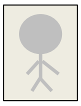
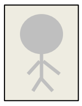
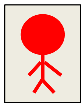
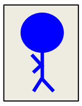
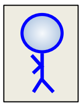
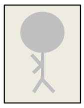
Design process	Design point	
1. Request action design	Comprehensibility	What a range of a problem-solving will you support by a VM system?
2. Technological design		
2-1. Creation of visualized item	Non-ordinarily	What do you visualize?
	Continuity	How do you design a continuous monitoring of a visualized item?
2-2. Transmission of visualized item	Inducibility	How do you design a device for attracting attention?
	Immediacy	How do you design the timing of information delivery?

4. Case Description

4.1 Description of case 1 (Conventional traffic light in Japan)

The first case is conventional traffic light for walkers in Japan. It is a benchmark case in the comparison analysis of this paper. The specification of this case is described in Section 3.1 and Figure 7 mentioned above.
An analysis of the state of this case is illustrated from Table 3. The red signal of human type in the upper window is lighted out and the green signal of human type in the lower window is lighted up when walkers can cross a road. The red signal of human type in the upper window is lighted out and the green signal of human type in the lower window is turned on and off when walkers have to cross a road as soon as possible. The red signal of human type in the upper window is lighted up and the green signal of human type in the lower window is lighted out when walkers cannot cross a road.

Table 3. Analyzed result of case 1 by a state transition diagram

Walker's crossing / Windows	Permission	Warning	Prohibition
Upper window	 light out	 light out	 light up
Lower window	 light up	 turn on and off	 light out

4.2 Description of case 2 (Improved traffic light in Japan)

The second case is improved traffic light for walkers in Japan. This case is illustrated from Figure 11. The target of this case is a prevention of a crossing until just before the traffic light change from green to red and a crossing until just before the traffic light change from red to green. For the specification of this case, an upper window is a countdown method with green dots to inform the rest time of walker's crossing and a red signal of a human type to stop walker's crossing. A lower window is a countdown method with red dots to inform the rest time until walker's crossing and a green signal of a human type to permit walker's crossing.

An analysis of the state of this case is illustrated from Table 4. The countdown method with green dots in the upper window is operated and the green signal of human type in the lower window is lighted up when walkers can cross a road. The all light in the upper window is lighted out and the green signal of human type in the lower window is turned on and off when walkers have to cross a road as soon as possible. The red signal of human type in the upper window is lighted up and the countdown method with red dots in the lower window is operated when walkers cannot cross a road.

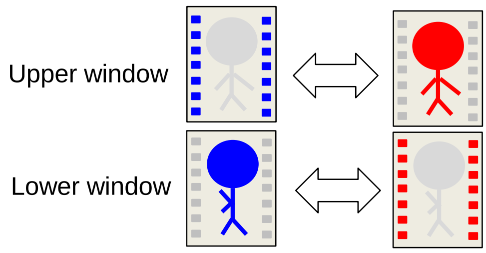
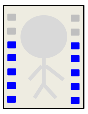
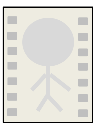
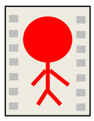
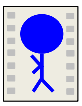
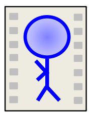
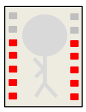


Figure 11. Improved traffic light for walkers in Japan (Case 2)

Table 4. Analyzed result of case 2 by a state transition diagram

Walker's crossing / Windows	Permission	Warning	Prohibition
Upper window	 count down	 light out	 light up
Lower window	 light up	 turn on and off	 count down

4.3 Description of case 3 (Improved traffic light in Taiwan)

The third case is improved traffic light for walkers in Taiwan (Taipei City Government 2015). This case is called ‘The Little Green Man’ and the image of this case is illustrated from Figure 12. The target of this case is a prevention of a crossing until just before the traffic light change from green to red. For the specification of this case, an upper window is a countdown method with figures to inform the rest time of walker’s crossing and a red signal of a human type to stop walker’s crossing. A lower window is a green animation of a human type to permit walker’s crossing.

An analysis of the state of this case is illustrated from Table 5. The countdown method with figures in the upper window is operated and the green animation of a human type in the lower window is walking slowly when walkers can cross a road. The countdown method with figures in the upper window is operated in the upper window and the green animation of a human type in the lower window is rushing when walkers have to cross a road as soon as possible. The red signal of human type in the upper window is lighted up and the green animation of a human type in the lower window is lighted out when walkers cannot cross a road.

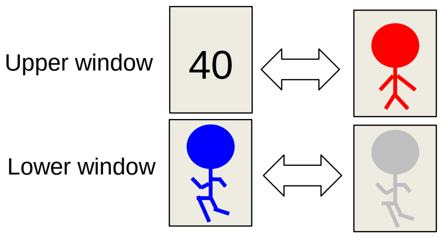


Figure 12. Improved traffic light for walkers in Taiwan (Case 3)

Table 5. Analyzed result of case 3 by a state transition diagram

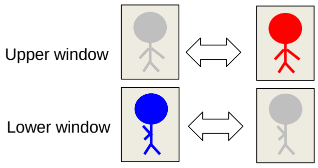
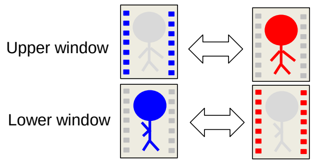
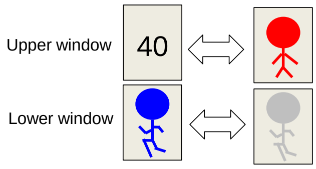
Windows \ Walker's crossing	Permission	Warning	Prohibition
Upper window	24 count down	8 count down	light up
Lower window	walking	running turn on and off	light out

4.4 Summary of three cases’ descriptions

The result of descriptions of all three cases, case 1, case 2 and case 3 are summarized as shown in Table 6. They have the same main target. It is a management of a walker crossing. Two improved cases focus on a part of the time of a walker crossing which has higher rate of occurrence of a traffic accident than other time. Case 2 aims at a decrease of a crossing until just before the traffic light change from green to red and from red to green at the same time. Case 3 tackles with aims at a decrease of a crossing until just before the traffic light change from green to red.

In order to challenge these focused targets, both cases adopt a countdown method. But a form of countdown method is different between case 2 and case 3. Case 2 uses a sign of color dots style and case 3 uses a sign of figures style. In addition, case 3 develops a signal of animation type to promote an improvement of the target of this case.

Table 6. Summary of analyzed result of three cases by a state transition diagram

Case	Case 1 (Conventional, Japan)	Case 2 (Improved, Japan)	Case 3 (Improved, Taiwan)
Picture			
Target	● Management of walkers' crossing	● Management of walkers' crossing ● A promotion of a crossing until just before the traffic light change from green to red ● A prevention of a crossing until just before the traffic light change from green to red	● Management of walkers' crossing ● A promotion of a crossing until just before the traffic light change from green to red
State transition *Underline means a difference of case to the left	1.Permisson A green signal of human type is lighted out. 2. Warning A green signal of human type is turned on and off. 3. Prohibition A red signal of human type is lighted up.	1.Permisson A green signal of human type is lighted out. A countdown method with green dots is operated. 2. Warning A green signal of human type is turned on and off. 3. Prohibition A red signal of human type is lighted up. A countdown method with red dots is operated.	1.Permisson A green animation of human type is walking slowly. A countdown method with figures is operated. 2. Warning A green animation of human type is rushing. A countdown method with figures is operated. 3. Prohibition A red signal of human type is lighted up.

5. Discussion

5.1 From design points of visual management system

It is found from the above analysis of the previous section that improved cases have newly three elemental technologies of a traffic light such as a) a countdown method from blue to red, b) a countdown method from red to blue and c) an animation method. In the following discussion, an effect of each elemental technologies is discussed from a perspective of five design points of a visual management technologies.

The first elemental technology is adopted to case 2 and case 3 however how to express a countdown of case 2 is dots type and that of case 3 is figures. 1) A comprehensibility of the two cases is not changed but more careful through strengthening a prevention of a reckless crossing. 2) A non-ordinarily of the two cases is fractionated through adding detail information, a rest time of a crossing time. 3) A continuity of the two cases is not changed. 4) An inducibility of the two cases, a capability to make walkers hurry to cross a road until the traffic light turns red, is improved. 5) An immediacy of the two cases is shaped by improving a capability of an information transmission when a reckless crossing likely to happen.

The second elemental technology is adopted to case 2. 1) A comprehensibility of the case is not changed but more careful through strengthening a prevention of a reckless crossing. 2) A non-ordinarily of the case is fractionated through adding detail information, a time until a crossing time. 3) A continuity of the case is not changed. 4) An inducibility of the case, a capability to make walkers wait to cross a road until the traffic light turns red, is improved. 5) An immediacy of the case is shaped by improving a capability of an information transmission when a reckless crossing likely to happen.

The third elemental technology is adopted to case 3. 1) A comprehensibility of the cases is not changed but more careful through strengthening a prevention of a reckless crossing. 2) A non-ordinarily of the case is not changed. 3) A continuity of the case is not changed. 4) An inducibility of the case, a capability to joyfully make walkers look for making walkers hurry to cross a road until the traffic light turns red, is improved. 5) An immediacy of this cases is not changed.

5.2 About application of these elemental technologies to future visual management system
These added elemental technologies bring two technological directions of a visual management system. First one is for how to make abnormal information. Conventional case has condition information of an abnormal. However two improved cases have real time information of an abnormal by the countdown method too. Second one is for how to deliver abnormal information. In the improved case in Taiwan, an animation method is utilized to joyfully make walkers look for making walkers hurry to cross a road until the traffic light turns red. It is necessary to make an approach to create an object of interest which indirectly connect to attain an original purpose. These two findings indicate that 1) an addition of a real time based visualization (RAVB) to a condition based visualization (CBV) and 2) an addition of an animated image visualization (AIV) to a static image visualization (SIV) will be necessitated for future development of a visual management system.

6. Concluding remarks

This paper tackles with the analysis of three traffic lights for walkers in a public transportation system for learning more useful visual management system, one of the corporate lean programs easy to implement in manufacturing industry. In particular, how to express an abnormal information by a visual management system is studied. As the result, there are the two following directions of how to express an abnormal information:

1. An addition of a real time based visualization (RTBV) to a condition based visualization (CBV)
2. An addition of an animated image visualization (AIV) to a static image visualization (SIV)

These findings will contribute to a development of a visual management system in practical scene. In addition, this paper gives knowledge related to two research categories of a visual management system. Firstly, obtained results of the technological findings mentioned above are important factors to realize an effective development in the research category of a visual management design (VMD). Secondly, an approach of the case analysis like this paper will be expected to become one methodology on the study of the research category of an innovation by visual management (IVM) in the future.

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Do formal assessments advance the implementation of corporate improvement programs? A research proposal for a field experiment in a multinational company

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Abstract

In recent years, many multinational manufacturers have launched corporate improvement programs in their global production networks. An important issue is whether and how to assess the progress of implementation of these programs in each plant and motivate their further implementation. A common practice is to perform formal top-down assessments by corporate assessment teams. However, these assessment schemes are expensive and it is not clear whether they are more effective than letting the plants use an assessment template to do self-assessment. One can also question whether either of these two options is superior to doing no formal or standardized assessment. These are our research questions. We plan to find the answers by carrying out a longitudinal field experiment in a multinational company. This working paper contains a brief review of the literature, our hypotheses, and a detailed description of the design of the controlled field experiment.

Keywords: Corporate improvement programs, Production improvement, Field experiment

I. Introduction

In their efforts to improve productivity in their global production networks, many multinational companies launch corporate improvement programs (Diederichs et al., 2008). Corporate improvement programs are usually company-specific variants of standard productivity improvement templates, such as lean production, total quality management, six sigma, world class manufacturing, and so on. Netland and Aspelund (2014, p. 392) define a corporate improvement program as “the systematic process of creating, formalizing, and diffusing better operational practices in the intra-firm production network, with the aim of increasing competitiveness."

A central part of a corporate improvement program is a corresponding *assessment* method (Hammer, 2007, Karlsson and Åhlström, 1996, Bititci et al., 2015). An assessment gauges the degree to which the principles and practices described in the improvement program are implemented in a business unit. Another purpose of the assessment is to offer motivation and advice for further implementation. There are many ways to conduct assessments. For example, it is a common practice in many firms to perform formal top-down assessments by corporate assessment teams. Such corporate assessments are expensive to carry out and require extensive coordination between the corporate office and the assessed units. The cost of one single assessment can typically be in the range of $10,000-$40,000 depending on procedure and location. An inexpensive alternative is to let local management assess the implementation in their unit using a standard template. However, such bottom-up self-assessments can be prone to lack of competence, complacency, and manipulation. Which alternative is the better one; top-down corporate assessments or bottom-up self-assessments? Or, perhaps, using no assessment is superior to any of them? These are the research questions we address.

Although the current literature speculates answers to some of our research questions, they are mostly based on anecdotal evidence. We plan to find answers by carrying out a longitudinal field experiment in a multinational company. The field experiment methodology examines a controlled intervention in the real world (List, 2011, Levitt and List, 2009). Our research setting is the company Jotun AS, a leading manufacturer of paint and paint systems. One advantage of doing the experiment in Jotun, which has very similar factories spread across five continents, is that many potential confounding factors are kept practically constant (e.g., manufacturing processes, technology, organizational design, strategy, and culture).

This working paper is not a standard research paper, but rather a research proposal for the field experiment we plan to carry out. We organize the remainder as follows: Section II contains a brief review of the literature on assessments, and develops our conceptual framework and working hypotheses. Section III reviews briefly field experiments as a research methodology. Section IV provides a detailed description of the design of the controlled field experiment. Finally, Section V provides an overview of the experiment schedule.

II. Background and Hypotheses

When a corporate improvement program is launched, its success is inextricably linked to the careful and coordinated change in the firm's assignment of decision rights, selection and monitoring of key performance indicators, and how the firm ties these indicators to performance rewards (Fullerton and McWatters, 2002, Netland et al., 2015). Many improvement programs focus on decentralizing decision rights to those employees further down the organization who possess greater knowledge about customer needs, technological shifts, and market trends than managers at higher levels of the firm do. As such, these employees become empowered to make decisions that satisfy customers, adapt to changes in technology, and respond to market trends more quickly than when decisions require the approval and ratification of senior executives. In addition, empowered employees are motivated to develop and share new ideas to bring continuous improvement, a fundamental aspect of most corporate improvement programs.

Executives have several choices available when deciding how to empower employees and track implementation success. One method, which we refer to as *no assessment*, is to simply empower local employees by providing them with complete autonomy over the implementation process. The benefit of this method, particularly in corporate improvement programs that operate on a global scale throughout “sovereign” factories, is that it allows local employees to implement the improvement program in the manner they consider best for their factory. It also assumedly limits the resistance to change by reducing the feeling of “not invited here”. For example, arguing that assessments can only represent an abstraction of reality, Rother (2010) advises against the use of assessments in lean transformations, because they may steer attention away from the current real problems in an organization. On the other hand, the cost of offering no assessments is that local employees, acting in their own interests and free from monitoring and evaluation by higher-level executives, might prefer to “do things the way they’ve always been done” and simply continue their day-to-day operations, as there is no follow-up from executives on the implementation of the program.

A second method available to managers when deciding how to empower employees and track implementation success is to require local employees to self-assess their implementation performance using a set of key performance indicators provided by senior executives. This method, which we refer to as *formal bottom-up self-assessment*, has the benefit of empowering local employees and providing them with a roadmap of how to implement the program (Jorgansen et al., 2003, Fagerhaug, 1999, Caffyn, 1999, Voss et al., 1994), but requires them to be accountable for their implementation success via self-reported implementation assessments. Hence, when compared with the no assessment method, formal bottom-up assessments provide incentives to implement the program because executives are monitoring implementation success. As such, the formal bottom-up assessment method provides local employees with an incentive to implement the improvement program. However, self-interested local employees might exploit the self-assessment method because executives do not directly verify their self-reported inputs regarding implementation success. Hence, the formal bottom-up assessment method might lead to appearance of implementation success without the commensurate operational performance benefits due to inflated self-reported implementation success.

A third method available to managers when deciding how to empower employees and track implementation success is to have a team of employees from corporate headquarters visit local factories to conduct formal audits of the implementation using a set of key performance indicators provided by senior executives. This method, which we refer to as *formal top-down assessments* or *corporate assessments*, requires considerably more economic resources to implement, and empowers local employees to a lesser degree compared to the no assessment and bottom-up formal assessment methods. Less empowerment can prove costly when implementing a corporate improvement program, as success likely requires all employees to change their day-to-day working philosophies towards continuous improvement (Womack and Jones, 1996, Liker and Hoseus, 2008, Spear and Bowen, 1999). As such, formal top-down assessments sacrifice local employee empowerment to some degree, increasing the potential for local employees to view the improvement program as a short-term effort directed by senior executives rather than a long-term shift in working philosophy that requires all employees to support. This sacrifice, however, might have benefits. In particular, the use of formal assessments completed by employees from outside the local factory communicates the importance of the improvement program throughout the firm, brings new knowledge to the local plant, and provides relatively stronger incentives for local employees to implement the program thoroughly than using no assessment or self-assessment methods.

These arguments lead to our set of research hypotheses:

H1: *Formal top-down assessment* of implementation of corporate improvement programs improves plants' operational performance more than *formal bottom-up self-assessment.*

H2: *Formal top-down assessment* of implementation of corporate improvement programs improves plants' operational performance more than *no assessment*.

H3: *Formal bottom-up self-assessment* of implementation of corporate improvement programs improves plants' operational performance more than *no assessment*.

The model for the design of this experiment is shown in Figure 1.

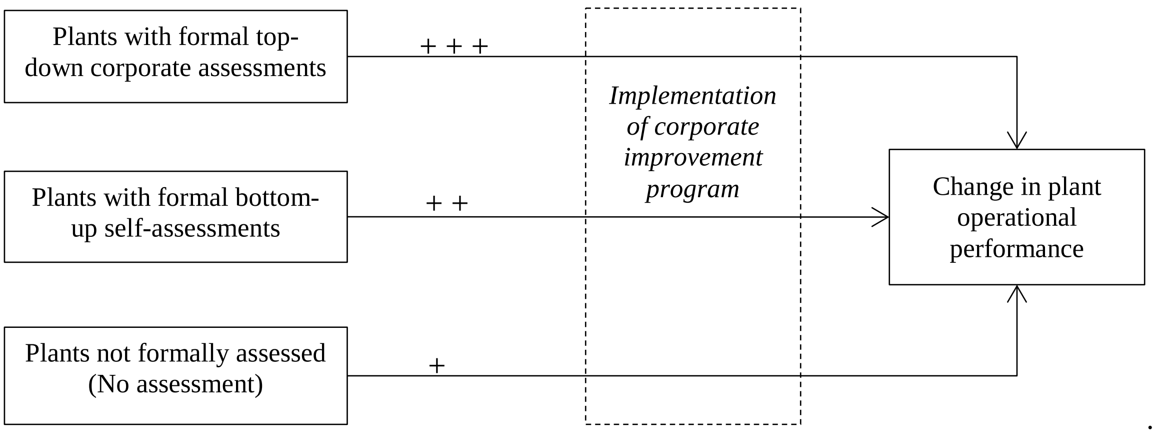

Figure 1 – Schematic illustration of relationships between assessments used in improvement program implementation and change in plant operational performance.

III. Field Experiments as Scientific Method in the Management Studies

Experiments are a fundamental way to establish cause-and-effect relationships among variables. Although the experiment is a primary research method in the natural sciences, engineering, and medicine studies, it has not achieved the same position in management sciences. Bryman and Bell (2007, p. 727) define an experiment as “a research design that rules out alternative explanations of findings deriving from it by having at least (a) and experimental group, which is exposed to a treatment, and a control group, which is not, and (b) random assignment to the two groups.” In other words, the idea is to manipulate a variable through an intervention in the experiment group, in order to discover whether it has an effect on another variable by comparing the experimental group with the control group.

The classic research experiment takes place in a laboratory. A laboratory experiment is carried out in a carefully designed, artificial research environment, which allows the researcher to control for confounding variables in an analysis of a-priori hypothesized relationships. Behavioural economics and behavioural operations management use controlled laboratory experiments to study the processes and effects of decisions and strategies among individuals and teams (e.g., Bendoly and Swink, 2007). Inherent in their design, laboratory experiments have high internal validity, are often easier to replicate, but may suffer from low external validity (Boyer and Swink, 2008, Bryman and Bell, 2007).

Experiments can also be carried out in the field. In contrast to laboratory experiments, a *field experiment* examines an intervention in the real world. Typical field experiments are health or education interventions in a selected population. Experimental samples and a control group are randomly drawn from the population and provided different treatments. The key advantage of field experiments over laboratory experiments is that it takes place in the natural environment of the phenomenon under study. The results from field experiments therefore have higher external validity. The drawback is that field experiments allow for far less control, which explains why field experiments have also been called quasi experiments (Cook et al., 1979). Bryman and Bell (2007) use the term “evaluation research” to denote quasi-experiments that aim to evaluate the effect of an intervention in an organization.

Contrary to the laboratory experiment, which is an established research methodology in the management studies (Bendoly et al., 2006), field experiments are rare (Johnson and Duberley, 2000). Perhaps the most famous field experiments in the management studies is the Hawthorne Experiment at Western Electric Hawthorne Works in Chicago between 1927 and 1932, where a group of six female workers were selected as an experimental group and a set of working variables (working time, breaks, light conditions, lunches, etc.) where manipulated during a systematic study (Mayo, 1949, Roethlisberger and Dickson, 1939).

Field experiments in management studies are rare because they are extremely difficult to conduct. They require the participation of real organizations, and often over long periods. The organization must commit to being the subject of experiment and accept the potential disruption of its operations and the uncertainty of the outcome and the risk of poor return of its investment. On the research side, controlling for potential confounding variables that are present in an organization is often a daunting task.

IV. Research Design: A Field Experiment in Jotun AS

To conduct our research experiment we have teamed up with Jotun AS, a world leading manufacturer in the paint industry. Established in 1926, Jotun is a privately owned company headquartered in Sandefjord in the south of Norway. Jotun has 33 production facilities in 22 countries and is represented in over 90 countries around the world (see Figure 2). Jotun employs 10.000 people. The company's paints and paint systems protect and decorate surfaces in the residential, shipping and industrial markets. A grant from the Norwegian Research Council allows us to maintain a close cooperation with Jotun over several years.

Figure 2 – The research setting: 33 Jotun plants across the world.

Jotun has recently launched a corporate improvement program, called "Jotun Operations System" (JOS). Figure 3 shows the "JOS house". JOS consists of the Jotun corporate values ("loyalty", "care", "respect", and "boldness"), seven JOS improvement principles ("continuous improvement", "competence development", "health, safety, and environment", "maintenance", "planning", "stable processes", and "management by objective"), seven standard production processes ("inbound", "raw material handling", "quality control process", "filling and packing", "finished goods handling", and "outbound"), and three objectives ("employee satisfaction", "customer satisfaction", and "shareholder satisfaction"). Our research focused on the seven JOS improvement principles. Each of the 33 Jotun plants is expected to implement the JOS improvement principles, and, as a result, show continuous improvement in its operational performance.

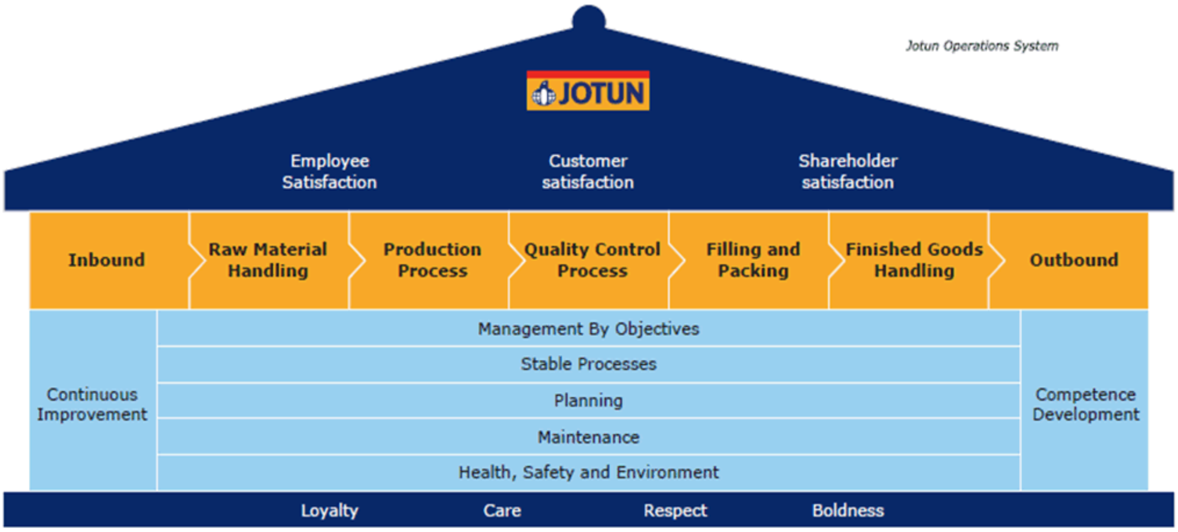

Figure 3 – The Jotun Operations System house.

The assessments (both top-down corporate assessment and bottom-up self-assessment) focus on the plants' implementation of the seven JOS improvement principles. All items will be measured on a detailed 0-5 Likert scale. Currently there are no assessment systems measuring the implementation of JOS in Jotun. Hence, we have a unique opportunity to conduct this experiment.

Selection of Cases

Controlled field experiments use random case selection (List, 2011). However, quasi-experiments that aim to evaluate the effect of an intervention in an organization ("evaluation research") does not always allow randomly assigned test groups (Bryman and Bell, 2007). In our firm of only 33 plants, we find it more useful to assign the plants (our sampling units) into the case groups carefully. This way we can pay attention to potentially confounding parameters such as location, national culture, plant size, plant age, and current productivity performance. The purpose of our careful group selection is to minimize any potential bias in the plant characteristics in each group and ensure comparability among the experimental and control groups, which is exactly the purpose of random selection. We (the authors and the company) plan to divide the 33 plants into three equal groups:

- *Group 1: Formal top-down corporate assessment*
  A team of corporate experts would do periodic assessments of these plants at their sites.
- *Group 2: Formal bottom-up self-assessment*
  These plants would do the assessment themselves but would use the formal (and standardized) template to report their self-assessments periodically.

- *Group 3: No formal assessment*
  These plants will neither be assessed by the headquarters nor be required to fill out the self-assessment template.

The experiment will start in January 2016, and we will follow the progress of program implementation (JOS) and the change sin performance of plants in each group for 18 months. The frequency for intervention for Groups 1 and 2 will be approximately every four months. Thus, we plan to have approximately four assessment interventions in each plant in these two groups and none in the third group.

Measure of Dependent Variable: Plant Operational Performance

Before, during, and after the experiment intervention, we will collect standardized operational performance data from each plant. The operational performance data are key performance indicators related to quality (e.g. "right-first-time"), delivery (e.g. "on-time-in-full"), and cost performance (e.g. "cost per litre", "stock days"), which is automatically reported by the plants every month. Table 2 summarizes the variable definitions for plant performance. We measure "development in plant operational performance" as the average of developments in quality, delivery, and cost performance.

Table 2 – Variable definitions of plant performance.

Variable	Items	Scale
Quality performance	- "Right-first-time" - "Product complaints"	% % of sales
Delivery performance	- "On-time-in-full" - "Service complaints"	% of sales % of sales
Cost performance	- "Cost per liter" - "Stock days raw materials" - "Stock days finished goods"	% of sales # days # days

One concern in field experiments is the presence of "the Hawthorne effect", suggesting that people who are taking part in an experiment perform better just by knowing that they are under observation. We significantly reduce such bias by using operational performance data on the plant level as our dependent variable, and by doing our interventions over a time scope of one and a half year. It is unlikely that managers in any of the three groups (no assessment, self-assessment, and corporate assessment) are able to (nor willing to) inflate the operational performance just because they are aware of the field experiment. There would be a more serious Hawthorne effect if we used the assessment scores, which are collected during the corporate assessments and self-assessments, as our dependent variables (in that case, however, we would also encounter reliability issues with the self-reported assessment data, and lack data for the "no assessment" group). In short, we do not believe that the reliability of our field experiment is reduced due to the Hawthorne effect. Showing consistent improvement in operational performance over a long period of time is hard to manipulate.

V. Schedule

Table 3 shows a rough schedule of the planned activities in the field experiment in Jotun. The field experiment is part of the research project "VALUE: Tools for distributed innovation in multinational companies" (VERDI) funded by Jotun AS and the Norwegian Research Council (running from 2015 to 2018).

Table 3 – Master schedule for the field experiment.

Year	**2015**		**2016**				**2017**			
Activity	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
Preparation and field experiment design										
Field experiment										
Assessment intervention Group 1			x		x	x		x		
Assessment intervention Group 2			x		x	x		x		
Assessment intervention Group 3 (none)										
Data collection operational performance										
Analysis										
Publication and reports										
VALUE Project Steering Group meetings	x	x	x		x		x		x	

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Way of lean thinking and an evolutional technology for greenness

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Abstract: Concept and method of lean management were enriched since the 1930s along with Japanese industrialisation and essence of these was revealed by one of the bestseller book in the business category (Womack *et al.*; 1990). Meanwhile, world-wide movement on green operations has been encouraged through COPs, COP1 in Berlin in 1995 followed by, for example, COP3 as Kyoto Protocol in 1997, up to COP21 in Paris in December this year. In this paper, leanness (understood as efficiency-focused) and greenness (sustainability-focused) are discussed and a relevant technology called "Karakuri", developed and reinforced in lean context, is reviewed for overcoming the trade-off relation of both issues.

Topic: Corporate lean programmes – new horizons
Keywords: green-lean management, performance improvement, loss zerotization, contradiction-driven approach, Karakuri technology, constitutionalisation of competitiveness

1. Introduction

Business environment of industries has been changed these years mainly due to the globalisation. Along with this change, lean management especially technologies and/or methods also has been mutating, however, its original concept and the way of thinking are still robust and popularised among professional managers. In this paper, intending to understand the reason why it is robust, some fundamental features of lean management are summarised for discussion and a recent technological wave among Japanese industries is introduced to getting the right insight on the future industrialising society.

2. Resource-focused

First issue that must be mentioned as the fundamental sense of value of lean operations management is "Loss Zerotization". Generally, loss is created in relation to resources used in operations. Therefore, lean management is considered as a way of resource management. Figure 1 illustrates the distinctive idea on resources and outcomes in lean context where every resource utilised in operations must be converted to the outcome with higher value than that of the input. One example easy to digest is human resource (HR), which can reinforce the ability at the start line through operations.

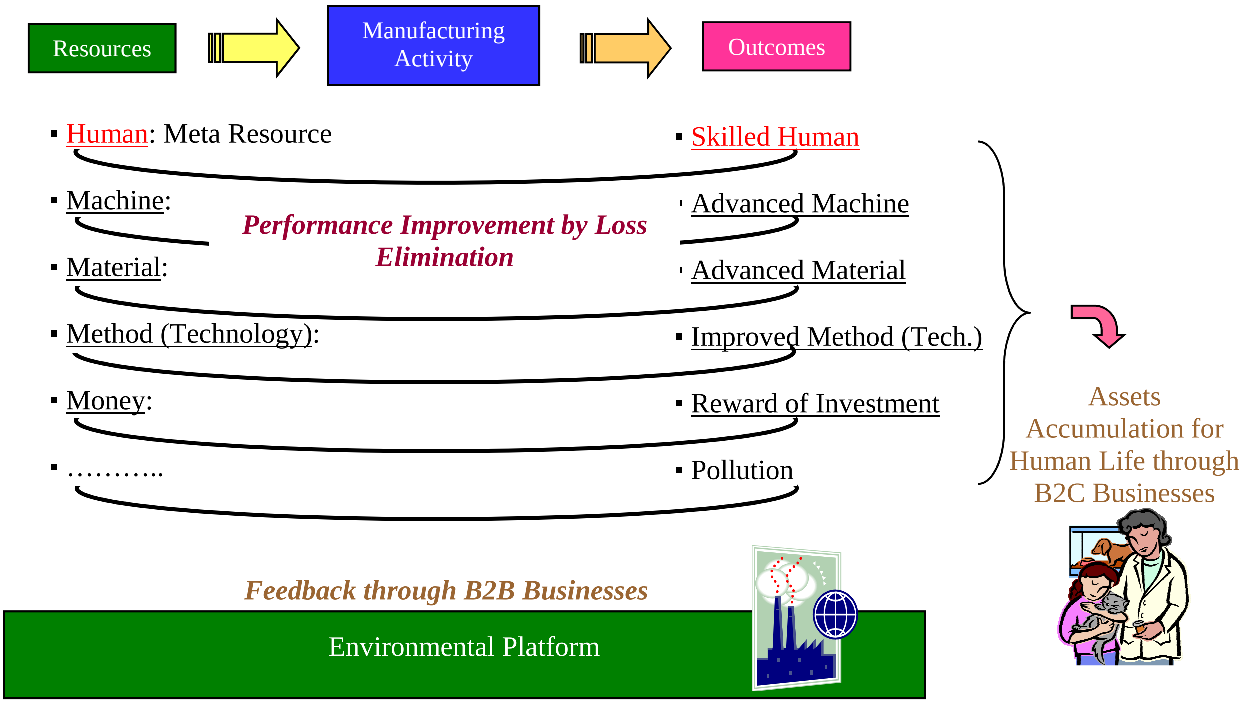


Figure 1. Relationship among resources and outcomes in lean management (Katayama, H.; 2014b)

3. Way of lean thinking (Katayama, H.; 2014b)

One distinctive feature on the lean way of thinking might be "Contradiction-driven Thinking", which the author has been emphasizing for many years. This way is implemented by starting leaders' mission delivery that is the mission impossible and/or difficult in general, then, followers are asked to think and act on the PDCA platform to reach the object as close as possible. There are some examples from the past experience.

Example in TPS (Toyota Production System)

1: KANBAN System for visualizing bottleneck operations invented by Mr. Taiichi Ohno

One important parameter of "KANBAN System" is the number of KANBAN, which is used for visualising weak operative functions by suppressing number of KANBAN one by one. When bottleneck operations are revealed by this way, improvement activity is launched to overcome the weakness.

2: Leader's mission delivered for NPD division by former president Mr. Katsuaki Watanabe.

"Let's develop a car which enables to purify air during it run."

Example in TPM (Total Productive Maintenance & Management)

1: Zero break down by PM (Phenomena-Mechanisms) Analysis developed by Mr. Kunio Shirose

This method is of causal relation analysis between phenomena and mechanisms by using physics, chemistry, mechatronics, statistics etc.

2: Zero fluctuation by 4M Analysis and standardization

This method is of investigating resource conditions and settling the significant parameter values to guarantee stable and quality output.

4. Packaged approach (Katayama, H.; 2014b)

Another specific aspect of lean management is packaged approach.

There are various lean schemes born in Japan and some examples are listed below.

1) Total Quality Management (TQM)

2) Total Productive Maintenance and Management (TPM)

3) Total Productivity Management (TP Management)

4) Hoshin Kanri (Policy Deployment Process)

5) Many company-developed in-house performance improvement schemes such as Toyota System

Each has its own particular structure and that of TPM scheme, for instance, is given below as its structure is very concrete and provides wide range of applicability. The feature consists of following 5 issues.

a) Drivers that are organised in terms of nine major pillar teams

b) Loss analysis as constitutional logic

c) Improvement tools as technological actuator

d) Seven levels of programme

e) Stepwise approach

5. ICT-assisted (Katayama, H.; 2014b)

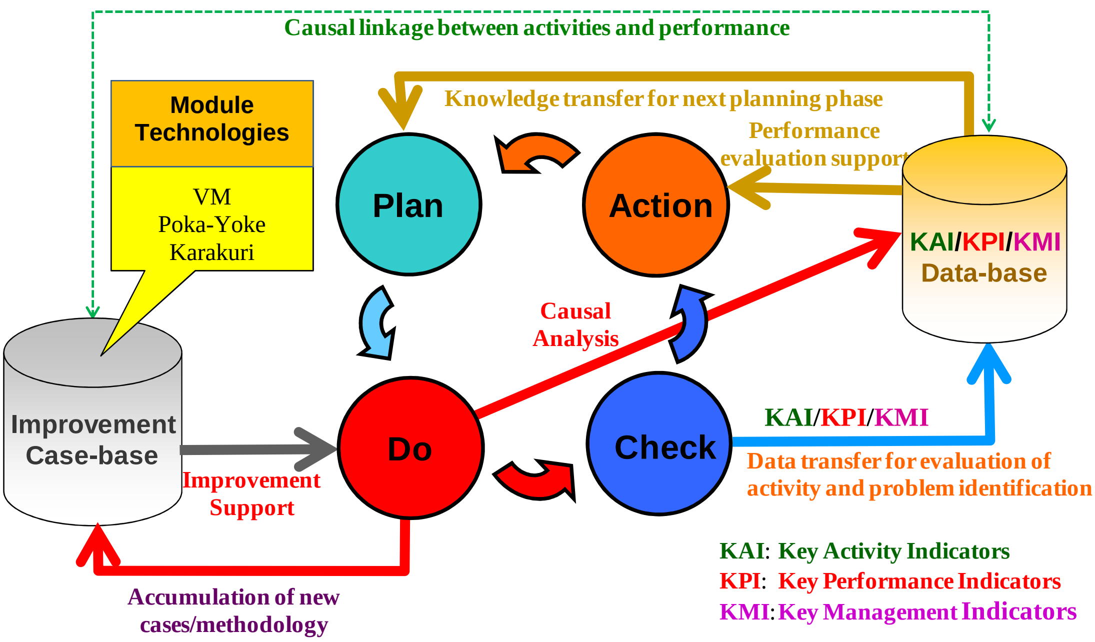


Figure 2. Structure of activated PDCA scheme with improvement case-base and performance data-base (revised version of Katayama, H.; 2014b**)**

Recently, lean is considered to merge with ICT to reinforce its effectiveness. Figure 2 illustrates one hopeful structure of combination of these, where ICT is implemented as a part of lean platform, *i.e.* PDCA iterative cycle with the cases as the contents of the action and their outcomes measured by KSC, KMI, KPI and KAI indicators. These meaning is given below.

a) KSC: Key Social Contributors, which relate to CSR issue.
b) KMI: Key Management Indicators, which directly relate to corporate management, and therefore, has monetary dimension.
c) KPI: Key Performance Indicators, which relate to operational outcome and has physical dimension.
d) KAI: Key Activity Indicators, which relate to operational input and has physical/monetary dimension.

6. Karakuri technology as a green-lean operations management tool

In this section, some unique Karakuri contrivances, which is currently an object of attention among lean management professionals, are introduced.

6.1 Some examples

(1) Automatization of return operation of tray/pallet by Karakuri technology (Katayama, H. *et. al.*; 2014c)

This case is of a relatively popular Karakuri contrivance utilized in in-process logistics. For better understanding, analysis by template form (Katayama, H. *et. al.*; 2014c) is useful, which consists of 15 critical attribute issues, listed below, to characterise the feature of each case.

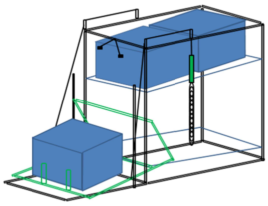
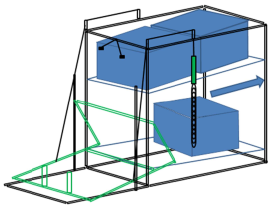
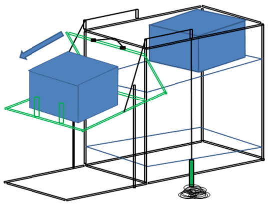
1. Title of Karakuri Contrivance: automatic supply of empty box/pallet/tray
2. Company Name: company A
3. Nickname of the Case: XX
4. Objective Operation: supply of empty box/pallet/tray for automatic parts transportation
5. Feature: one piece flow of empty box/pallet/tray
6. Overall Structure of Karakuri Contrivance: figure is abbreviated
7. State Definition of Karakuri Contrivance:

Table 1 summarises the state definition of the elements utilised in Karakuri contrivance.

Table 1. State definition of each element in Karakuri contrivance

Elements	*Functions*	*States (Code No.: Description of Status)*	*Way of State Transition/Mechanism*
elevator	transportation	0: state of repose at lower position with holding empty box 1: state of repose at upper position without holding empty box 2: state of repose at upper position with pushing up the stopper 3: moving downside and leaving from the stopper with empty box	-gravity -linked wire
stopper	dividing	0: moving downside vertically and contact with empty box 1: state of repose at separated position of empty box and pushed up by the elevator	-elevator -gravity
chain damper (called Squid-Damper)	-potential energy preservation -shock absorbing	0: state of repose at upper position 1: moving downside and contact the chain at the ground 2: state of repose at lower position	-gravity -linked wire -ground

Table 2. Template sheet of Karakuri analysis for item 8 to 15 (Example)

Sequence No.	8. Elementary Operations	9. State and Transition of State	10. State Description (After Transition)	11. Sequence of Karakuri Operation	12. Elementary Mechanisms	13. Physical Phenomena	14. Functions	15. Value
I	Setting the initial state	-elevator: 0 -stopper:0 -chain damper: 0	State 0 	*Transition must be described along with the time sequence and/or cause-outcome order.	-	-	-	-
I I	Forwarding the box with parts by the operator	-elevator: 0 -stopper:0 -chain damper: 0	State 1 	-	-	-	-	-
.	.	.	.	.	.	.	.	.
V	Loading the empty box to the elevator	-elevator: 2 -stopper:1 -chain damper: 2	State 4 	1) the stopper that protect dropping down the empty box was pushed up 2) one empty box was installed on the elevator 3) subsequent empty box ia protected to move by stopper due to the gap between 2 boxes that is made by the steeper slope of elevator than supply conveyor	-	Gravity Force	-	-

From the analysis, utilization of gravity force is very essential to design this contrivance.

(2) Work rotation by Karakuri technology

Second example is simpler than the previous one as shown in Figure 3. Function to provide here is 90 degree clockwise rotation of work that is put on the upper round pallet. Operation sequence is described in Figure 4, *i.e.* ① Work is put on the Upper Round Pallet, of which position is stabilised by stopper A, ②Upper and Lower Round Pallets are inclined left-side together with proper angle (controlled by stopper B) due to the weight change by the Work (Mechanism: see-saw with Fulcrum Bar equipped at the bottom of Lower Pallet), ③Lower and Upper Round Pallets start to rotate clockwise due to the Weight equipped on the Upper Pallet that causes unbalance of gravity (Phenomenon: gravity force), ④Rotation terminates when the Weight hit the stopper C that guarantees exact 90 degree of rotation.

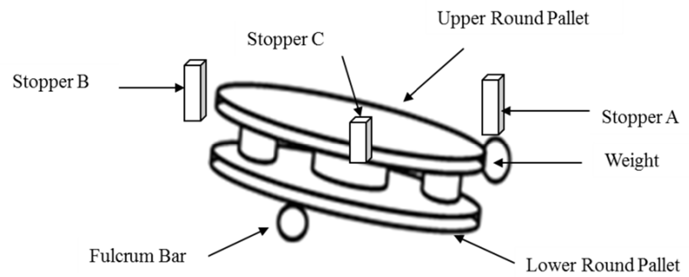


Figure 3. A simplified example of KARAKURI contrivance (Katayama, H. *et. al.*; 2014c)

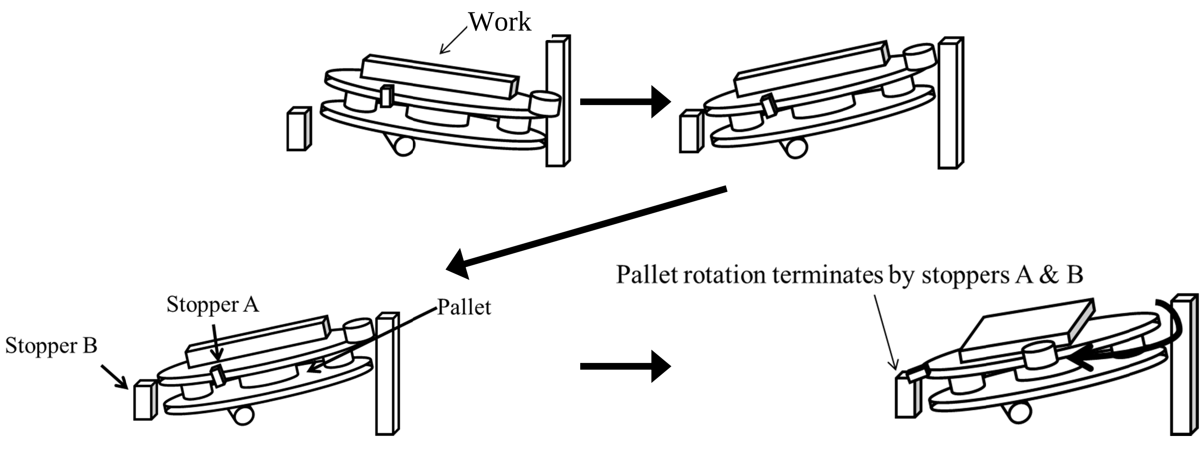


Figure 4. Case of position change of work by Stopper Mechanism (Katayama, H. *et. al.*; 2014c)

(3) Flow-tization of process by Karakuri technology

In this example, manual-based drum can filling operation (See Figure 5) is renovated by implementing Karakuri technology. Current burden of this process is following points.

a. The filling process is bottleneck due to long operation lead time that causes large Work-in-Process inventory in input area of this process.
b. Three filling operators are engaged in this process due to heavy work handling

Utilising three Karakuri mechanisms, *i.e.* see-saw, rotation and stopper, to overcome the above burden, a new operation structure was proposed in collaboration with a friend company.

Figure 6 illustrates operation sequence of the proposed system.

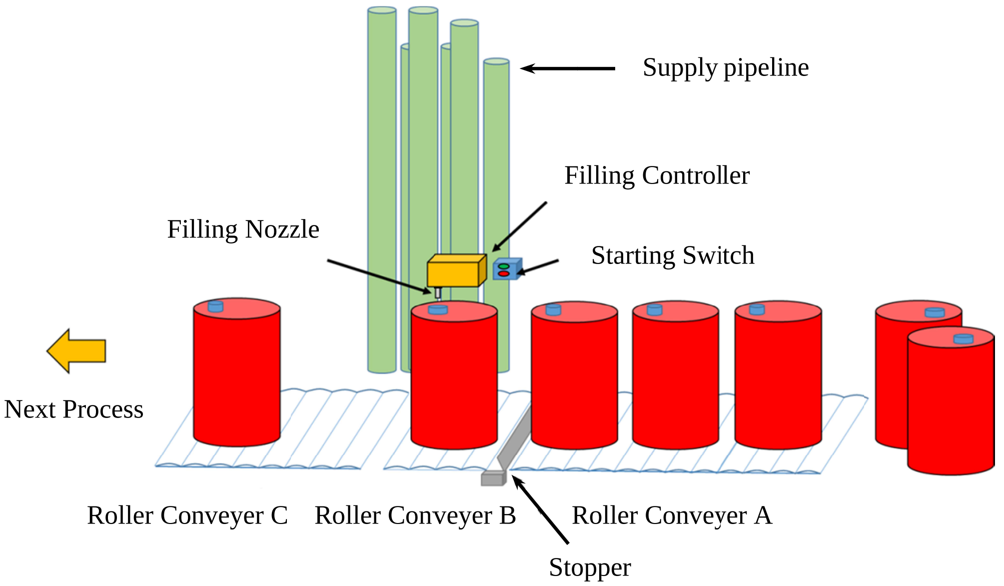


Figure 5. Outline of the drum can filling and transporting process (Before Improvement)

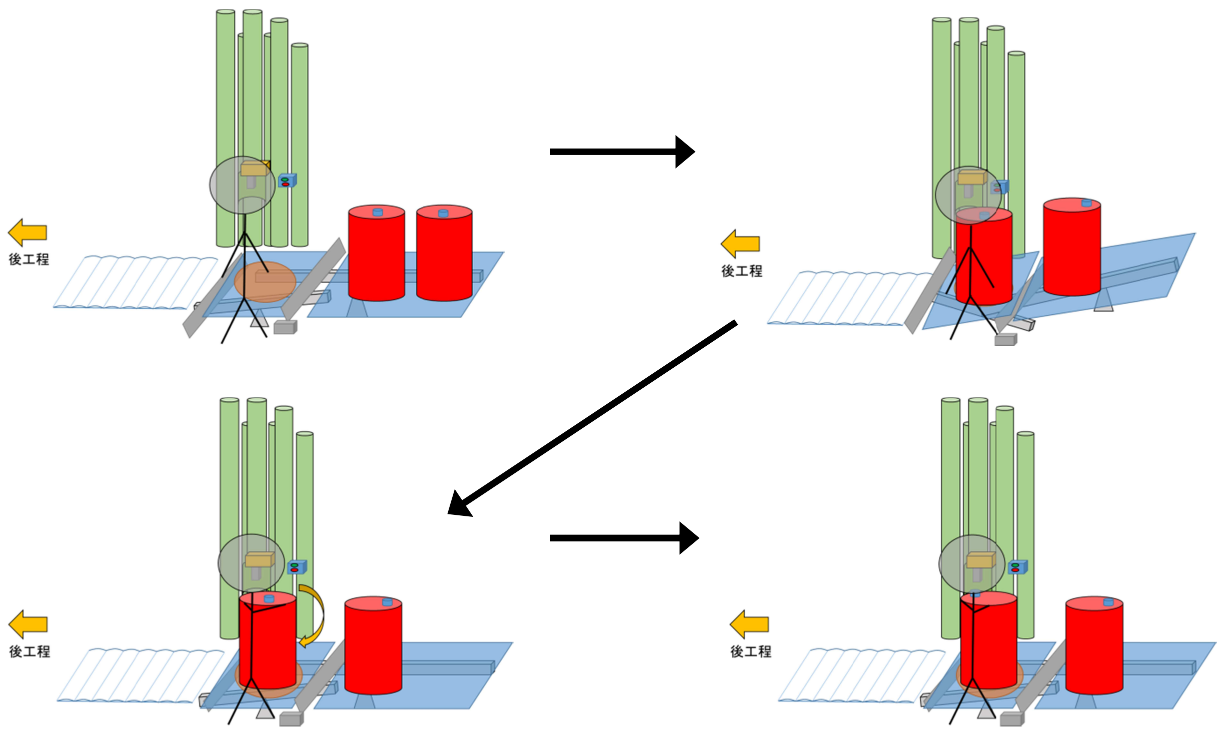


Figure 6. Outline of the drum can filling and transporting process (Before Improvement)

Namely, ① Starting from the initial state where many empty drum cans are waiting on the roller conveyer A that is input buffer area of this process, ②the roller conveyers A and B incline simultaneously as interlocked devices that makes the first drum slide into the filling area properly and the second drum is intercepted by the equipped stopper, ③The drum arrived at filling position where the right position is guaranteed for filling operation by guide bars except the position of the pouring inlet. For one touch setting of pouring inlet to the filling nozzle by the operator, round table equipment is useful., ④Automatic filling operation by current equipment is proceeded in the end.

Figure 7 illustrates improved performance by this examination, where C2 is the process in consideration and C1 and C3 are the transportation processes of filled and empty drums respectively.

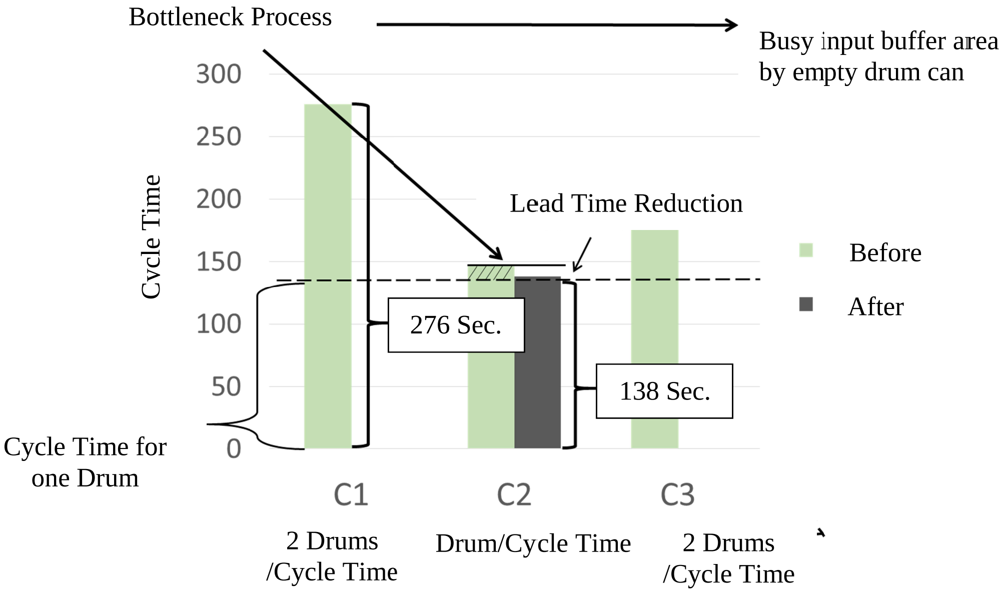


Figure 7. Performance comparison of before and after operations (simulation analysis)

6.2 Summary of functions and related mechanisms

In the past paper of the author, definition of elements on Karakuri technology is summarised by case attributes (1) Purpose, (2) Functions, (3) Karakuri mechanisms and (4) Elementary phenomena/mechanisms. Structural relations between these attributes are illustrated in Figure 8.

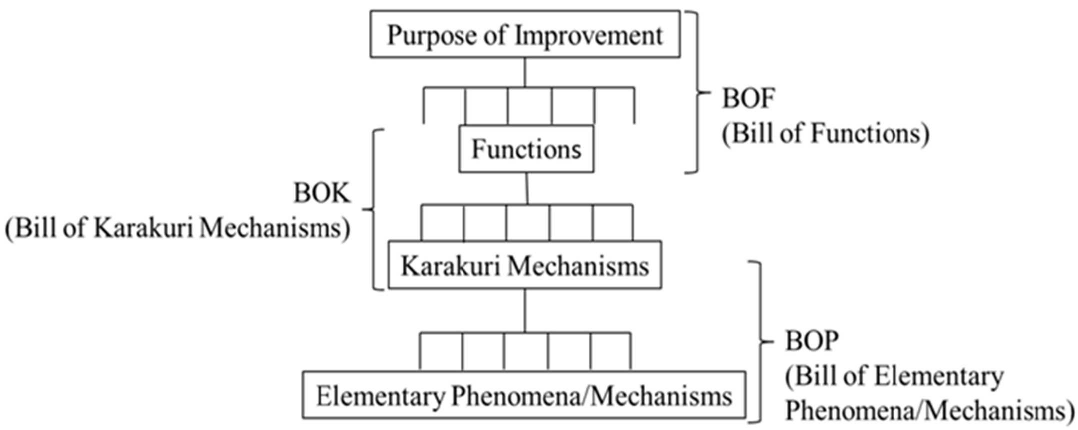


Figure 8. Bill structure for manual work improvement by KARAKURI mechanisms (Katayama, H. *et. al.*; 2014c)

Through substantial number of investigations similar to 6.1, relationship between function and Karakuri mechanism (BOK), for instance, was obtained as Table 3, where 17 functions intended to realize by Karakuri and 14 useful Karakuri mechanisms were identified. These can be a powerful asset for diversification of this technology.

Table 3: Extracted functions and KARAKURI mechanisms
(Revised version of Katayama, H. *et. al.*; 2014c)

Function		Karakuri Mechanism	
1.	Labor Saving	1.	See-saw
2.	Time Saving	2.	Balancer (Tenbin)
3.	Automation	3.	Rotation
4.	Operation Efficiency Improvement	4.	Slide
5.	Power Generation	5.	Link
6.	Output Amplification	6.	Pulley
7.	Change of Power Direction	7.	Spring
8.	Power Transmission	8.	Chain
9.	Switching	9.	Gear
10.	Movement Control	10.	Clutch
11.	Position Fixation	11.	Stopper
12.	Release of Restraint	12.	Lock/Unlock
13.	Movement Termination	13.	Cylinder
14.	Avoidance of Defect/Fuguai	14.	Electro-Magnetic
15.	Support of Direction Change		
16.	Support of Transportation		
17.	Support of Rotation Movement		

7. Concluding Remarks

In this paper, supposing general manufacturing operations, summarises lean sense of value, its way of thinking, feature of its approach and methodology followed by a particular technology called Karakuri that intends to contribute operational greenness. Discussion performed here may lead us to a proper direction for further evolution of lean management, *e.g.* powerful tool development for eliminating less value-added time/labour consuming manual works that leads us to the goal of green-lean operation. Following phrase is a final message from the author.

"Let's perform operations not by using labor power and artificial energy, but by using our Planet!"

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Fifty shades of greywater: an outcome perspective on wastewater system operations' performance

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Abstract

Tightening of regulation on the quality of water and wastewater services often leads to the growth of capital expenditure in industry and higher bills for water customers. Applying an *outcome*-orientated approach to the economic regulation of the sector in England and Wales, shifts the focus away from how many assets a business has, towards whether a company is capable of delivering through its asset base, what ultimately matters to their customers. Although this approach sounds agreeable and almost common sense, its translation into metrics is a challenge with industry requiring a better understanding of the behavioural implications of a regulatory system built around outcomes. This paper contributes to the current debate on how to best address industry's concerns, whilst meeting the regulator's expectations. A way to reconcile performance measurement with a genuine outcome orientation by means of Input-Output Analysis (IOA) is outlined. IOA is identified as a suitable tool to manipulate the empirical data commonly available in industry for the purpose of tackling technical planning, environmental evaluation and costing problems for a multi-stage, multi-input, multi-output (and possibly multi-location) supply network. A simplified wastewater system underpinned by real-life industry data is used throughout the paper for illustrative purposes.

Keywords: wastewater system; supply network; performance; modelling; Input-Output Analysis (IOA)

Introduction

In Europe the tightening of regulation on the quality of water and wastewater services has driven growth of capital expenditures on additional treatment works which, in turn, has almost unavoidably resulted in higher bills for the final customers (ICIS Chemical Business, 2005; Wessex Water Services Plc, 2012). In England and Wales an independent economic regulator, Ofwat (henceforth: the regulator) sets binding price controls for each company that provides water and wastewater services over a multi-year period. This is known as a price review. Controls typically link the allowable revenues to what are deemed efficient levels of capital, as well as operational expenditures, adjusted by a reward and penalty mechanism. For the period 2015-20 the allowed expenditure across 18 wholesale water and wastewater businesses amounts to £40.4 billion (OFWAT, 2014b, pp. A3.4).

The current price review has sanctioned the adoption of an innovative, *outcome*-orientated approach to the economic regulation of the water and wastewater service business. The approach shifts the focus from how many assets a business has to whether it is capable of delivering through its asset base what ultimately matters to its customers (OFWAT, 2014c). Businesses set measures referred to as ‘performance commitments’ (PCs) to demonstrate how well a set of outcomes is delivered over the price control period. Outcome delivery incentives (ODIs) of both reputational and financial natures, reward the ability and penalise the inability of businesses to meet their commitments.

Although the idea of outcomes defined as ‘what ultimately matters to the customer’ sounds agreeable and almost common sense, its translation into metrics is a challenge. Industry recognise that the quantification and monitoring of outcome-based performance measures is not straightforward, and demands a better understanding of the behavioural implications of a regulatory system built around outcomes (ICS consulting, 2015).

This paper aims to speak to the current debate on how to best address industry’s concerns whilst meeting the regulator’s expectations. An approach to reconcile performance measurement with a genuine outcome orientation for use in the water and wastewater service industry is outlined. This is achieved through the use of a two-stage model. At the conceptual stage a blueprint of the delivery system of interest is created and the technological knowledge about the relevant operations involved is mapped. At the quantitative level empirical data commonly available in industry is identified and manipulated to evaluate how the delivery system has performed, or is expected to perform in achieving its ultimate purpose(s) – or outcome(s). Input-Output Analysis (IOA) is employed as a suitable tool to manipulate empirical data about a multi-stage, multi-input, multi-output (and possibly multi-location) supply network in a mathematically rigorous, yet practical way.

The remainder of this paper is as follows. Basic concepts such as input, output and outcomes are investigated. This is achieved using evidence from the servitization of business in other industries, chiefly defence aerospace as well as existing frameworks on performance metrics. An application of IOA is outlined to reconcile performance management with a genuine outcome orientation making reference to a simplified wastewater system underpinned by industry data. The paper closes with a discussion of practical recommendations for the water and wastewater businesses, current limitations, and suggestions for further research.

Input, output, outcome orientation: evidence from the literature

As mentioned in the introduction, the distinctive trait of the regulatory approach adopted in the water and wastewater sector in England and Wales is an orientation towards ‘outcomes’. Instead of setting targets in terms of ‘length of pipe built’, so to speak, the focus is on what customers ultimately want companies to deliver. Outcome orientation is not unfamiliar in other industrial settings. In defence aerospace the outcome orientation underpins the shift from a business centered on selling ‘asset and support’ to one aiming to deliver value ‘in-use’ by enabling customers to attain beneficial service outcomes through incentivized contractual mechanisms known as performance-based contracts—PBC (Baines and Lightfoot, 2013). The challenge in PBC is to identify and agree on contractually binding outcome metrics which capture what customers ultimately derive value from (Selviaridis and Wynstra, 2014).

Doost (1996) defines ‘outcome’ as some level of accomplishment of the enterprise. Therefore, the distinction between output and outcome depends on where the boundaries of the analysis are drawn. For example, a manufacturing department in a company may be given credit for producing more units of a product than anticipated whilst cutting on departmental expenditures. However, such push on productivity is detrimental from an outcome perspective if the result is poor quality and excess inventory of unsold or returned items. By contrast, an input orientation focuses on how much has been spent over a period of time (e.g., calendar year) on categories such as labour, goods, services, and capital disregard what has been accomplished as a result of that spending. An input orientation characterises the public sector because in National Accounts it is a convention to equate the sector's output to the inputs used up in producing such output (Anagboso and Spence, 2009).

The basic 'input-transformation-output' structure is at the core of generic operations models regardless of which specific industry they refer to (Waller, 2003). Transformation may occur in a multitude of steps and locations. For an organization it can be difficult to express quantitatively what the ultimate deliverable downstream from the outputs of each transformation is. For example, the defence sector's outcome should ideally consist of rather vague 'units of security' or 'units of peace and stability' (Anagboso and Spence, 2009). How one conceptually frames the ultimate deliverable determines the metrics and models chosen.

Neely *et al* (2000) review several performance measurement frameworks only one of which explicitly differentiates between input, process, output and outcome measures. Later reviews tend to ignore this distinction despite a focus on the supply chain (e.g., Elrod *et al.*, 2015). Applications of the 'input-transformation-output-outcome' structure include the performance evaluation of logistic processes (Stainer, 1997), healthcare systems (WHO, 2010), defence supply chains (Klapper *et al.*, 1999), and service-based production processes (Yalley and Sekhon, 2014). Although the difference between inputs, output and outcomes is recognised, the firm is often addressed aggregately as a single transformation stage.

In the water and wastewater service sector similar concepts of input, output and outcome are used (OFWAT, 2011). However, the practical implementation of these concepts through metrics is shaped by the different viewpoints involved (Figure 1). Figure 1(a) depicts the ideal relationship between outcomes, PCs and ODIs emphasizing the centrality of outcomes. If the viewpoint of the regulator is taken (Figure 1(b)) the focus is placed on the allowable expenditure for each business during the price review period. The PCs of a company are taken into account insofar as they trigger adjustments in the allowable expenditure (OFWAT, 2014c). Hence, the relevant metrics are the explanatory variables included in the econometric models used by the regulator to estimate company-specific expenditures. Conversely, the perspective taken by industry (Figure 1(c)) starts from a situation where a company failing to meet its PCs is concerned with identifying possible causes of non-compliance, and favours the use of reliability engineering techniques (Tynemarch Systems, 2015).

Identifying and measuring only adverse outcomes such as PCs failures can be counterproductive, as demonstrated in the field of aviation safety (Hollnagel *et al.*, 2013). More important is to investigate how the work within a delivery system is continually adjusted to succeed under varying conditions in everyday activities. A key idea in operations management is that performance is attained through the actions a business undertakes, and that performance measurement is ultimately the process of quantifying such actions (Neely *et al.*, 2005). Activities are, by definition, purposeful because they are performed to contribute towards the realization of one or more outcomes (BS ISO/IEC, 2002). Hence, a performance measure which relates to an outcome should provide an assessment of the result that occurs from carrying out a set of activities compared to their intended purpose (Klapper *et al.*, 1999).

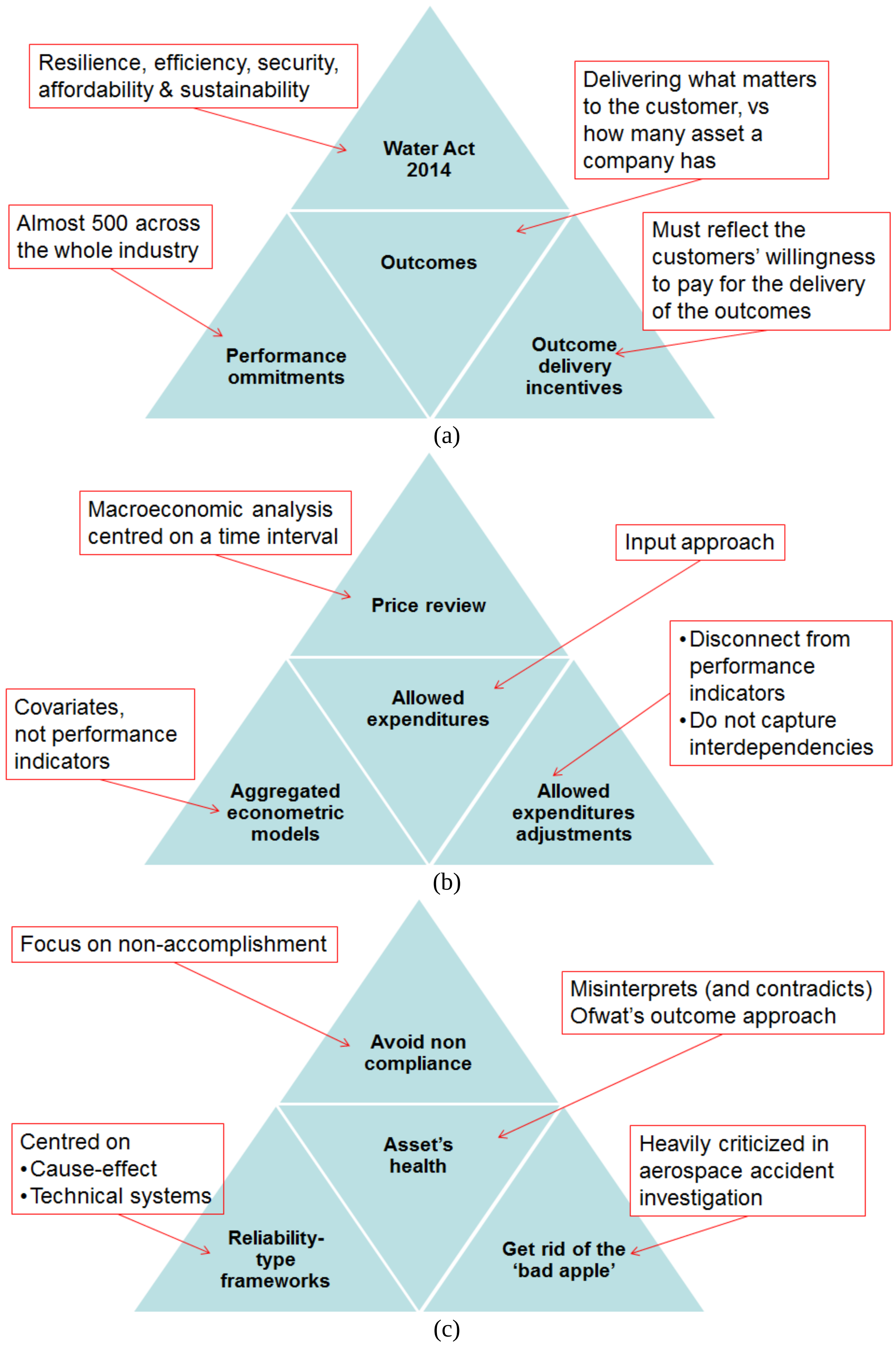


Figure 1 – Perspectives on the outcome approach in the water and wastewater industry regulation: (a) ideal view; (b) regulator's view; and (c) industry's view

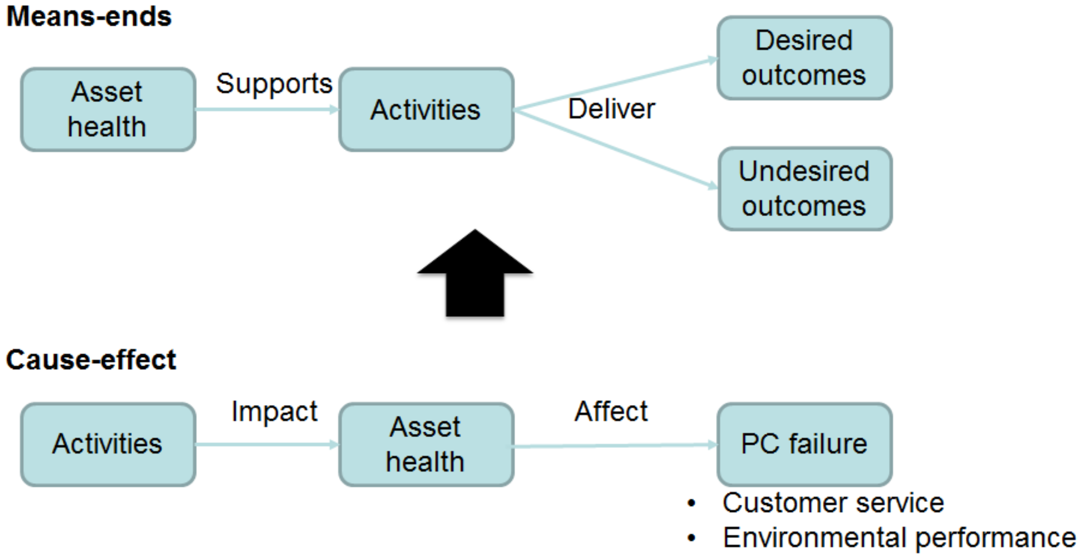


Figure 2 – From 'cause-effect' to 'means-ends' approach to performance in water and wastewater sector. The cause-effect outlook is based on Tynemarch Systems (2014a). PC: Performance Commitment.

Making reference to the water and wastewater industry Figure 2 contrasts a 'cause-effect' outlook centered on what caused failure to meet a PC with a 'means-ends' outlook centered on what enables the achievement of a PC. The former is triggered by one-off non-compliance and proceeds backwards with the purpose of eliminating its causes. The latter is forward-looking because it brings to the fore the purposefulness of everyday activities, and drives attention on the aspects of those activities that may increase the chances of achieving some outcome of interest. In the process industry a means-ends outlook underpins successful approaches to integrate material, energy and cost flow analysis (Möller, 2010).

Proposed approach

In this section the 'input-transformation-output-outcome' structure described earlier is used as the building block for a two-stage model of a system of operations enabling an integrated evaluation of technical, environmental and economic performance. The model encompasses:

- Visualization and conceptual modelling of a system of operations
- Mathematical manipulation of quantitative data about a system of operations.

The system of operations of interest here is a wastewater system, which is a "system providing the functions of collection, transport, treatment and discharge of wastewater" (BS, 2014). As most real-life systems of operations, a wastewater system consists of multiple interdependent transformation stages whereby each activity may be characterized by multiple inputs and multiple outputs (MIMO), including byproducts, that potentially contribute towards multiple and often conflicting outcomes. A technical overview of wastewater systems' operations is beyond the scope of this work and can be found elsewhere (Mihelcic and Zimmerman, 2010; Spellman, 2003).

Each modelling stage is illustrated next, making reference to a hypothetical wastewater system underpinned by a real industrial case.

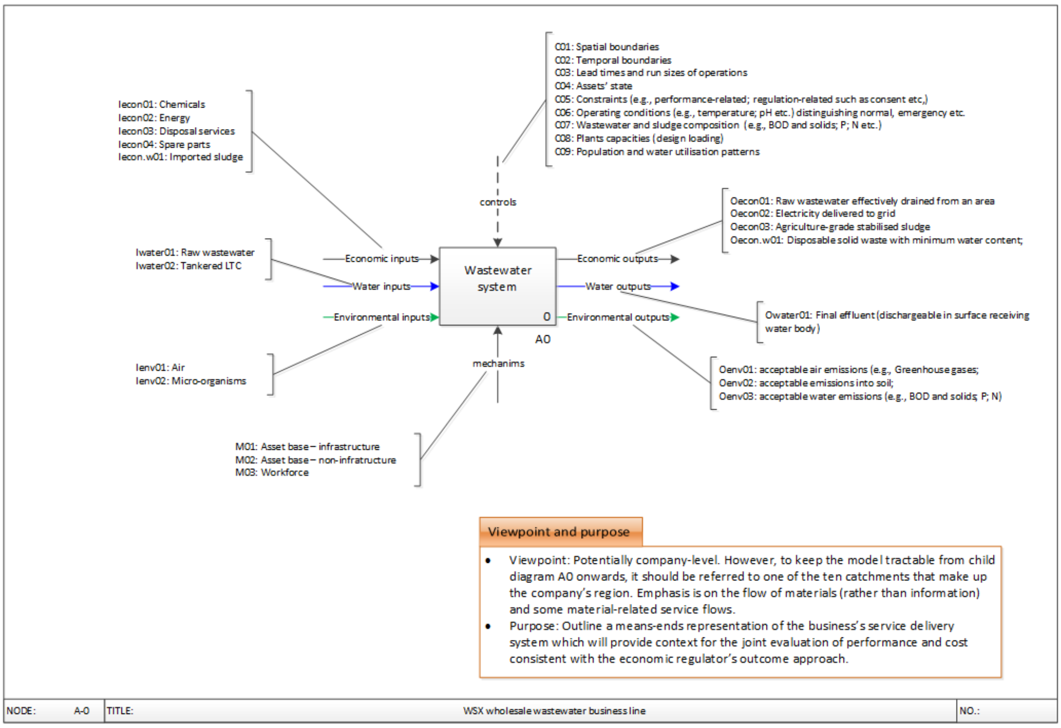


Figure 3 – Context diagram for a hypothetical wastewater system

Visualisation and conceptual modelling

For modelling purposes it is often appropriate to start with a top-level conceptual representation of the subject matter. This allows specifying the boundaries and scope of the analysis as well as the perspective taken by the analyst before going into further detail by pursuing empirical data to add to the picture. For a wastewater system such a top-level view is shown in Figure 3. Following the IDEF0 conceptual modelling language a 'single-box' diagram called context diagram is used (National Institute of Standards and Technology, 1993). The context diagram is detailed later on through child diagrams to capture a snapshot of the wastewater system's configuration with reference to a specific period of time. Both the context diagram and the child diagrams use the building blocks summarised in Table 1.

The outputs of a context diagram are the system's outcomes because they represent final deliverables meeting a demand which is exogenous with respect to the system's boundaries. The outcomes shown in Figure 3 answer the question 'which exogenous demand are the wastewater system's operations meant to meet?' For wastewater systems the answer to this question is likely to change over time. For example, the generation of electricity from wastewater biomass can be viewed as either a mean of reducing the dependency of wastewater treatment works (WwTWs) on the national power grid, or as an opportunity to manage those plants as if they were power generation plants (Logan, 2005).

The wastewater system depicted aggregately in Figure 3 may correspond to the entire portfolio of a company's WwTWs, an individual WwTW, or a network of WwTWs operating within the boundaries of a geographical area. Often it is deemed appropriate to define an area at the river catchment level for the purpose of assessing and managing more effectively the contribution of multiple WwTWs to the eutrophication of surface watercourses (Wessex Water Services Plc, 2012). These different levels are illustrated in Figure 4(a) for an industrial case (with sensible information omitted).

Table 1 – Building blocks of an IDEF0 conceptual model

Building block	Pictorial representation	Description
Functions	Boxes	Purposeful transformations - neither a specific organisational unit, nor a piece of equipment. May correspond to atomic operations or aggregated processes, or the whole subject matter of interest depending on the level of granularity chosen
Inputs	Arrows pointing towards a box	What is being acted upon to produce an effect by executing a function. Can be acquired from other economic delivery systems through market transactions, or provided freely by the natural environment
Outputs	Arrows directed from a box to another	What is meant to be accomplished performing a transformation. Emissions into environmental media and other by-products of a transformation also qualify as outputs
Mechanisms	Arrows pointing towards a box from below	The 'operant' resources employed to act upon the inputs for the transformation to take place. Physical assets and human resources typically fall into this category
Controls	Arrows pointing towards a box from above	Specify under which circumstances a transformation is meant to take place for the intended results to be achieved. Examples include compliance with a specific regulation, the occurrence of physical conditions, or the availability of certain equipment

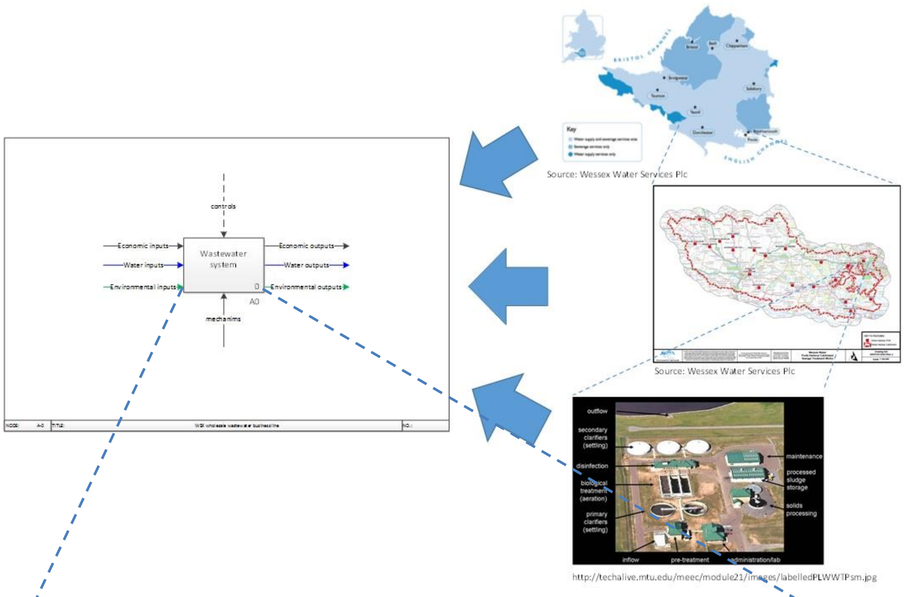
Table 2 Reclassification of PCs for a wastewater wholesale business line according to IDEF0

Outcome category	**Performance Commitment (PC)**	**Input**	**Output**	**Mechanism**	**Controls**
Improved bathing waters	Agreed schemes delivered			X	
	Beaches passing EU standards				X
	EA's rating				X
Rivers, lakes and estuaries protected	Monitored CSO's			X	X
	River water quality improved			X	X
Sewage flooding minimised	Internal flooding incidents				X
	Risk of flooding from public sewers due to hydraulic inadequacy				X
	North Bristol sewer scheme			X	
Resilient services	Collapses and bursts on sewerage network				X
Reduced carbon footprint	Greenhouse gas emissions		X		X
	Proportion of energy self-generated	X	X		X

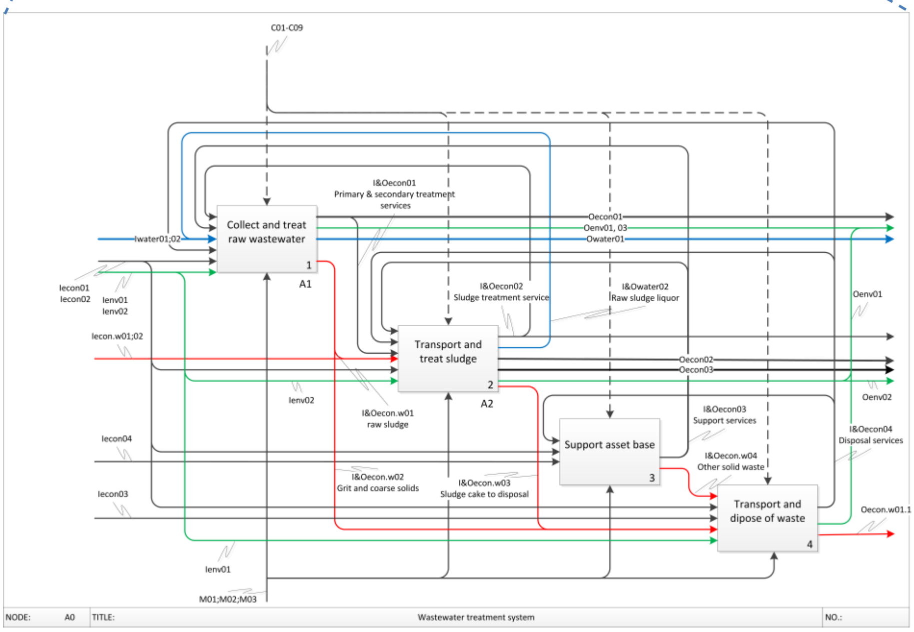
Notes: CSO = combine sewage overflows; EA = environmental agency

A context diagram can be used to categorise the data reported by businesses regarding their PCs. Using a company's publicly available data (Wessex Water Services Plc, 2014) Table 2 reveals that the PCs for its wholesale wastewater line of business mostly focus on controls (e.g., regulatory constraints) and mechanisms (e.g., its asset-base). This demonstrates that distinguishing between genuine outcomes and regulatory constraints can be difficult. By contrast, details about the inputs and outputs of a wastewater system's operations are required by other types of regulatory reporting (OFWAT, 2014a).

From a context diagram the analyst progressively develops a blueprint of the main functions that constitute the wastewater system of interest and the interrelationships between such functions as child diagrams. Figure 4(b) shows the first child diagram, called 'A0' diagram, derived from the context diagram in Figure 4(a). One way of looking at Figure 4(b) is to follow the influents and effluents (blue-coloured arrows) from wastewater collection through different stages of treatment (aggregately represented by box 1). By-products (red-coloured



(a)



(b)

Figure 4 – (a) Example of wastewater systems that may correspond to a context diagram for a company; (b) Main functions of a wastewater system

arrows) such as sludge flow from the functions generating them to the functions downstream (represented aggregately by boxes 2 and 3) which are in charge of treating the effluent using different technologies E.g. biologically, while pollutants (green-coloured arrows) are released directly into environmental media. The labels ‘A1’ and ‘A2’ underneath boxes 1 and 2 indicate that child diagrams exist for those functions, although not shown here. The input flow of by-products to the treatment functions equivalently expresses the output flow of ‘treatment service’ provided. In Figure 4(b) treatment services are represented as black arrows similarly to the goods and services purchased.

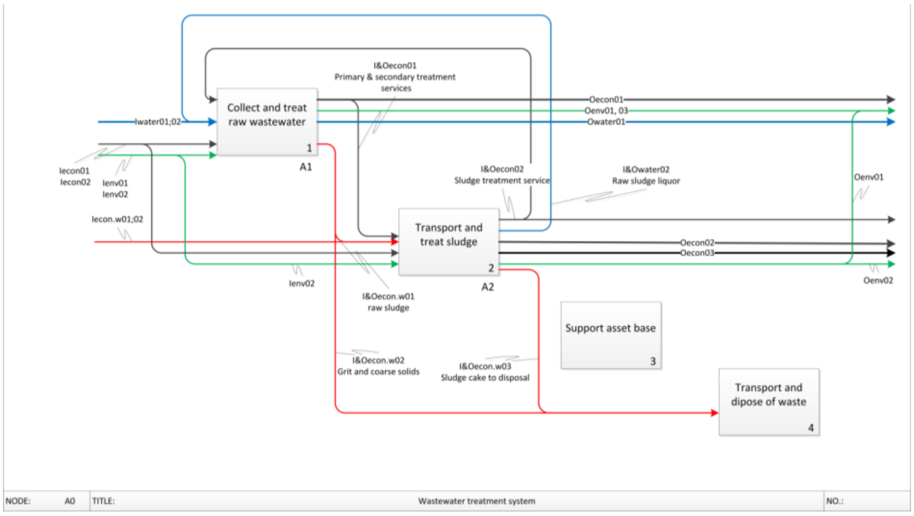


Figure 5 – Subset of the wastewater system defined by the use of mass balance data only

A 'service' perspective on wastewater treatment requires answering, starting from the top-level outcomes shown in the context diagram, the question 'which means are needed to pursue this end?' rather than 'how much influent goes into this piece of equipment?' Thanks to a 'service' perspective it is possible to represent functions such as box 3 in Figure 4(b), which are seldom recognised as part of wastewater operations modelling but are responsible for an asset base being in such a state that the physical flow is as depicted by the analyst.

The analyst's subjective viewpoint shapes what can be seen in a conceptual model so outlined, and so does that of each individual taking part to the construction of the model. Hence, the usefulness of such a model resides in its ability to provide a baseline communication vehicle underpinned by a shared understanding of a system of operations.

Gathering and manipulation of quantitative data

The blueprint in Figure 4(b) provides a starting point to gather quantitative data that can be manipulated mathematically. For the purpose of this research data were gathered through a collaboration with industry for an individual WwTW, which therefore constitutes the relevant wastewater system. The data gathered were complemented by insights form the literature. Detail on the data gathering process, and the specific numerical values obtained are provided elsewhere (Settanni, 2015) and will not be disclosed in this paper for confidentiality.

Quantitative data for WwTW operations were obtained in the form of a mass balance. Mass balances are commonly used for process control in WwTWs (Puig *et al.*, 2008). A recent trend in the process industry is to use mass balances to model networks of alternative processing technologies (also called 'superstructure') for plant synthesis by enterprise-wide optimization (Quaglia *et al.*, 2012). This approach has been applied to WwTWs design (Bozkurt *et al.*, 2015). By using mass balances only a subset of the conceptual model outlined earlier can be investigated quantitatively. Such subset is shown in Figure 5.

The first step is to visualize the data gathered from an existing mass balance. This is achieved by means of the Sankey diagram shown in Figure 6. A Sankey diagram is a quantitative data visualisation approach which follows the requirement of conservation of mass through a system of interdependent operations (Schmidt, 2008).

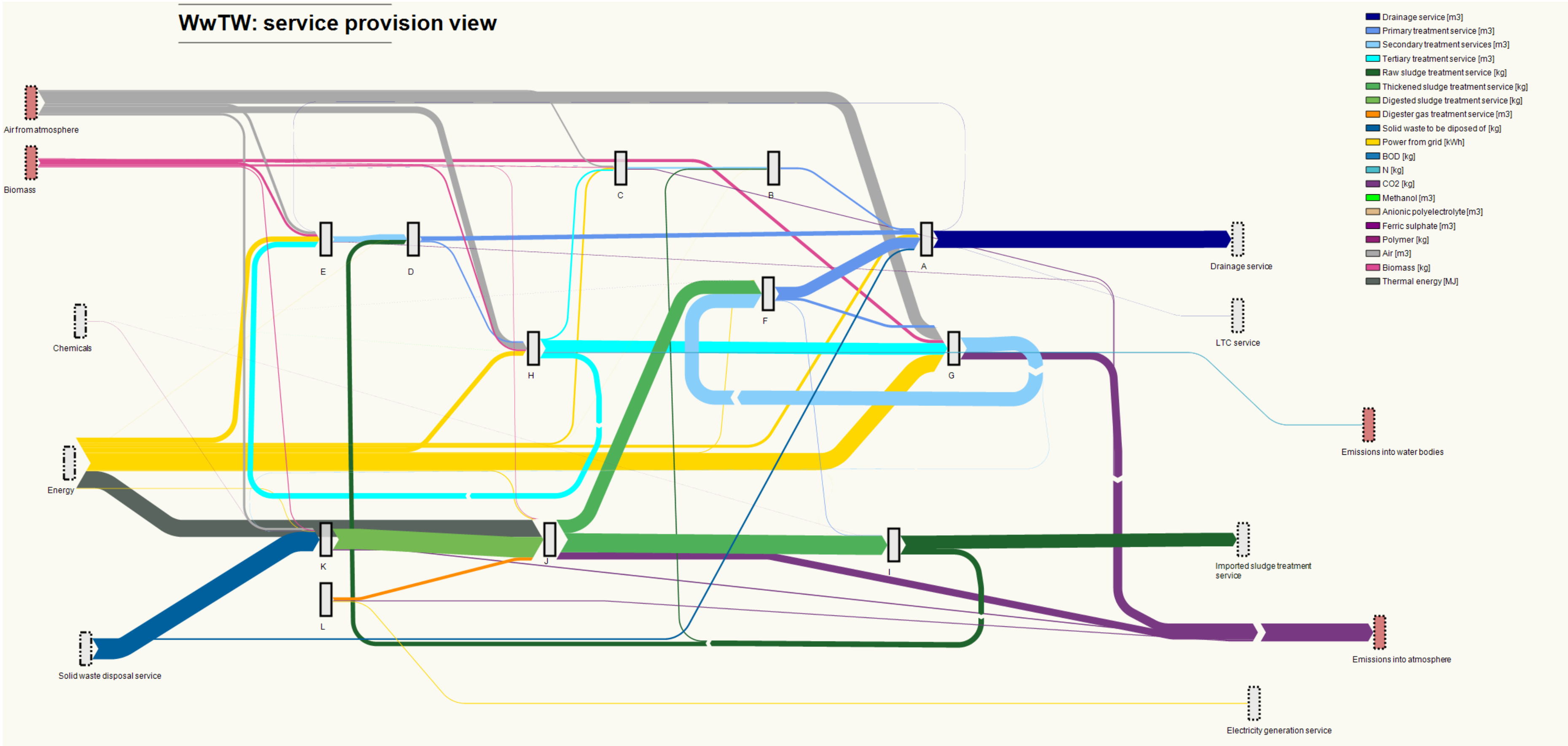


Figure 6 – Sankey diagram of physical flows through a WwTW from a "Means-ends" perspective (service provision). All flows in the legend are expressed in the units indicated per day. Details omitted for confidentiality. The diagram has been realised using e!Sankey (www.e-sankey.com)

Table 3 – Tabular representation of the flows visualised in the Sankey diagram (only non-zero elements shown; formal notation replaces numerical values).

Description	Flow index	Unit of measurement	Production process index												Final demand (net production)	Emissions (+) Purchases (-)
			Wastewater								Sludge					
			A	B	C	D	E	F	G	H	I	J	K	L		
Drainage service [Final demand]	a	[m^3/day]	z_{aA}		z_{aC}		z_{aE}								$\sum_{n=A}^{L} z_{an}$	
Primary treatment services @ Site 1	b	[m^3/day]	z_{bA}	z_{bB}											$\sum_{n=A}^{L} z_{bn}$	
Secondary treatment services @ Site 1	c	[m^3/day]		z_{cB}	z_{cC}					z_{cH}					$\sum_{n=A}^{L} z_{cn}$	
Primary treatment services @ Site 2	d	[m^3/day]	z_{dA}			z_{dD}									$\sum_{n=A}^{L} z_{dn}$	
Secondary treatment services @ Site 2	e	[m^3/day]				z_{eD}	z_{eE}								$\sum_{n=A}^{L} z_{en}$	
Primary treatment services @ Site 3	f	[m^3/day]	z_{fA}					z_{fF}	z_{fG}		z_{fI}				$\sum_{n=A}^{L} z_{fn}$	
Secondary treatment services @ Site 3	g	[m^3/day]							z_{gG}	z_{gH}			z_{gK}		$\sum_{n=A}^{L} z_{gn}$	
Tertiary treatment service	h	[m^3/day]			z_{hC}		z_{hE}		z_{hG}	z_{hH}					$\sum_{n=A}^{L} z_{hn}$	
Raw sludge treatment service	i	[kg/day]		z_{iB}		z_{iD}					z_{iI}				$\sum_{n=A}^{L} z_{in}$	
Thickened sludge treatment service	j	[kg/day]						z_{jF}			z_{jI}	z_{jJ}			$\sum_{n=A}^{L} z_{jn}$	
Digested sludge treatment service	k	[kg/day]										z_{kJ}	z_{kK}		$\sum_{n=A}^{L} z_{kn}$	
Digester gas treatment service	l	[m^3/day]										z_{lJ}		z_{lL}	$\sum_{n=A}^{L} z_{ln}$	
Final effluent	1	[m^3/day]								w_{1H}						$\sum_{n=A}^{L} w_{1n}$
Electricity	2	[kWh]												w_{2L}		$\sum_{n=A}^{L} w_{2n}$
Solid waste disposal service	1	[kg/day]	v_{1A}										v_{1K}			$\sum_{n=A}^{L} v_{1n}$
Polymer consumption	2	[kg/day]									v_{2I}		v_{2K}			$\sum_{n=A}^{L} v_{2n}$
Ferric sulphate consumption	3	[L/day]						v_{3F}								$\sum_{n=A}^{L} v_{3n}$
Methanol consumption	4	[m^3/day]								v_{4H}						$\sum_{n=A}^{L} v_{4n}$
Anionic polyelectrolyte consumption	5	[L/day]						v_{5F}								$\sum_{n=A}^{L} v_{5n}$
Electric energy consumption	6	[kWh/day]	v_{6A}	v_{6B}	v_{6C}	v_{6D}	v_{6E}	v_{6F}	v_{6G}	v_{6H}	v_{6I}	v_{6J}	v_{6K}			$\sum_{n=A}^{L} v_{6n}$
Thermal energy consumption	7	[MJ]										v_{7J}				$\sum_{n=A}^{L} v_{7n}$
Greenhouse gases emission	1	[kg CO_2eq/day]			g_{1C}		g_{1E}		g_{1G}			g_{1J}	g_{1K}			$\sum_{n=A}^{L} g_{1n}$
N emissions through effluent	2	[kg Ntot/day]								g_{2H}						$\sum_{n=A}^{L} g_{2n}$
BOD emissions through effluent	3	[kg BOD/day]								g_{3H}						$\sum_{n=A}^{L} g_{3n}$
Air volume	4	[Nm^3/day]	g_{4A}		g_{4C}		g_{4E}		g_{4G}	g_{4H}			g_{4K}			$\sum_{n=A}^{L} g_{4n}$
Biomass	5	[kg /day]			g_{5C}		g_{5E}		g_{5G}	g_{5H}		g_{5J}	g_{5K}			$\sum_{n=A}^{L} g_{5n}$

A ‘service viewpoint’ on wastewater treatment was taken in constructing the diagram in Figure 6. A fictitious exogenous demand for service outcomes ‘pulls’ the system of operations–namely: to drain an area and receive the tankered wastes imported to site (a Licensed Treatment Center—LTC), and to treat raw sludge imported from other WwTWs. These services are displayed as outcomes on the rightmost side of the diagram. The demand of final deliverables propagates backward, triggering directly and indirectly a demand for intermediate outputs (goods and services) provided within the system, as well as inputs purchased exogenously or provided by the natural environment. The by-products generated while meeting such demand are recycled or treated within the boundaries of the WwTW, thus creating feedback loops (e.g., between functions ‘F’ and ‘G’). By-products which are disposed of are represented as an input of disposal service to the function generating them.

A special case in Figure 6 is electrical energy, which is artfully viewed as the by-product of providing a ‘digester gas treatment service’. This is the result of subjective modeling choices based on assumptions made by the analyst about which outcomes actually ‘pull’ the system. If a purely physical viewpoint was chosen instead of a service viewpoint, the final effluent released into a water body would be the final deliverable in Figure 6 whereas raw wastewater, tankered waste and imported sludge would be regarded as inputs.

A mathematical counterpart of the diagram in Figure 6 is a set of matrices and vectors the elements of which can be arranged in tabular form as shown in Table 3. The elements of the table with non-zero values have been colour-coded to facilitate the connection with Figure 6. Specific numerical values for the WwTW are omitted, hence the link between Table 3 and the diagram in Figure 6 will be expressed only through formal notation as described next.

Table 3 is equivalent to the following matrix equation:

$$\begin{bmatrix} \boldsymbol{Z} \\ \boldsymbol{W} \\ \boldsymbol{V} \\ \boldsymbol{G} \end{bmatrix} \boldsymbol{s} = \begin{bmatrix} \boldsymbol{y} \\ \boldsymbol{w} \\ \boldsymbol{v} \\ \boldsymbol{g} \end{bmatrix} \tag{1}$$

Matrix $\boldsymbol{Z} = \begin{bmatrix} z_{aA} & z_{aB} & \cdots & z_{aL} \\ z_{bA} & z_{bB} & \cdots & z_{bL} \\ \vdots & \vdots & \ddots & \vdots \\ z_{lA} & z_{lB} & \cdots & z_{lL} \end{bmatrix}$ is called the ‘technology matrix’, and corresponds to the 12×12 upper partition of Table 3 defined by rows $a, \dots, l$ and columns $A, \dots, L$ is. It has the following characteristics:

- Material flows are reported row-wise, functions are reported column-wise.
- By convention outputs have positive sign, inputs have negative sign. The sign is not shown in the formal notation.
- At the intersection between the generic row i and column j ($i \neq j$) one reads the amount of i-th material flow employed by the j-th function as an input. For example, the element $z_{bA} < 0$ is the amount of flow b into function A, and corresponds to the arc directed from function B towards A in the diagram (Figure 6).
- The main output of the j-th function is on the j-th row. Hence, the main outputs can be read along the main diagonal, where the column and row indexes are equal ($i = j$). For example $z_{bB} > 0$ is a measure of B’s main output and corresponds to the width of the base of the arc leaving B in Figure 6, regardless its destination.
- No function produces another function’s output (there is no substitution).

The 'final demand vector' $\boldsymbol{y} = \begin{bmatrix} y_a = \sum_{n=A}^{L} z_{an} \\ y_b = \sum_{n=A}^{L} z_{bn} \\ \vdots \\ y_l = \sum_{n=A}^{L} z_{ln} \end{bmatrix}$ is a 12×1 vector which corresponds to the column of Table 3 labelled 'Final demand'. Its elements are greater than or equal to zero, and correspond to the demand of final deliverables that the system must meet.

The 'by-product matrix' $\boldsymbol{W} = \begin{bmatrix} w_{1A} & \cdots & w_{1L} \\ w_{2A} & \cdots & w_{2L} \end{bmatrix}$ is the 2×12 partition of Table 3 defined by rows 13-14 and columns $A, \dots, L$. In the case considered here matrix $\boldsymbol{W}$ has a particular configuration due to the 'service viewpoint' taken: it has non-zero elements that correspond to the treated effluent ($w_{1H} > 0$) and the electricity generated ($w_{2L} > 0$) only.

The 'value added matrix' $\boldsymbol{V} = \begin{bmatrix} v_{1A} & \cdots & v_{1L} \\ \vdots & \ddots & \vdots \\ v_{7A} & \cdots & v_{7L} \end{bmatrix}$ is the 7×12 partition of Table 3 defined by rows 15-21 and columns $A, \dots, L$. Its elements, if non zero, have negative sign and denote exogenously purchased inputs. For example $v_{1K} < 0$ is the input of exogenously purchased services due to the generation of sludge cake if assumed to be disposed of.

The 'environmental intervention matrix' $\boldsymbol{G} = \begin{bmatrix} g_{1A} & \cdots & g_{1L} \\ \vdots & \ddots & \vdots \\ g_{5A} & \cdots & g_{5L} \end{bmatrix}$ is the 5×12 partition of Table 3 defined by rows 22-26 and columns $A, \dots, L$. Its elements, if non-zero, record the total amount of environmental resources utilised (negative sign) and emissions generated (positive sign) by each function.

Finally, $\boldsymbol{w}$, $\boldsymbol{v}$ and $\boldsymbol{g}$ are vectors that correspond to the three partitions under the column heading 'Emissions (+) Purchases (-)' in Table 3; whereas $\boldsymbol{s}$ is a 12×1 vector which specifies the 'activity levels' at which each operation $A, \dots, L$ within the system is required to perform in order to meet the final demand $\boldsymbol{y}$ while sustaining themselves. Since the flows in Table 3 are already balanced, $\boldsymbol{s}$ is in fact a unity vector (all its elements are equal to 1).

Analysis

The WwTW model described by equation (1) and visualised in Figure 6 allows a range of mathematical manipulations. These manipulations enable businesses in the water and wastewater sector to evaluate whether the actions they have undertaken, or will undertake, contribute toward the attainment or non-attainment of their PCs. The following manipulations are discussed next: quantifying resource requirements and environmental aspects; costing; evaluating productivity, effectiveness, efficiency and profitability. A spatial dimension can be added to the analysis but this is left to future research. Detailed numerical examples are provided elsewhere (Settanni, 2015).

Joint evaluation of resources and environmental aspects

The following part of equation (1): $\boldsymbol{y} = \boldsymbol{Zs}$ expresses the fundamental physical balance which governs the net production within the system boundaries, and can be used for planning purposes. Scenarios can be created by changing the demand of some or all the final deliverables in $\boldsymbol{y}$, and then by computing how this affects the demand of inputs and natural resources, as well as the by-products and emissions generated given the interdependencies among the system's elements. This requires specifying a 12×1 vector $\boldsymbol{y}_{\text{scenario}}$ obtained by changing the values in $\boldsymbol{y}$ as desired (or by simulation), and calculating the unknown vector of activity levels $\boldsymbol{s}_{\text{scenario}}$ corresponding to the envisaged scenario as follows:

$$\boldsymbol{s}_{\text{scenario}} = \boldsymbol{Z}^{-1}\boldsymbol{y}_{\text{scenario}} \quad (2)$$

Where $\boldsymbol{Z}^{-1}$, if exists, is the inverse of matrix $\boldsymbol{Z}$ (the mathematical conditions for the existence of the inverse of a matrix are not discussed here). Knowing $\boldsymbol{s}_{\text{scenario}}$ it is possible to obtain:

- The total amount of electricity and final effluent generated as $\boldsymbol{w}^* = \boldsymbol{W}\boldsymbol{Z}^{-1}\boldsymbol{y}^*_{\text{scenario}}$
- The total amount of exogenously acquired goods and services as $\boldsymbol{v}^* = \boldsymbol{V}\boldsymbol{Z}^{-1}\boldsymbol{y}^*_{\text{scenario}}$
- The total amount of environmental resources utilised and emissions generated as $\boldsymbol{g}^* = \boldsymbol{G}\boldsymbol{Z}^{-1}\boldsymbol{y}^*_{\text{scenario}}$

The amount of environmental resources utilised and emissions generated $\boldsymbol{g}^*$ can be used to verify whether emissions into environmental media such as CO_2, Nitrogen etc. are within limits if a certain level of plant activity is pursued. It can also be used as the starting point for environmental impact analysis, but this requires known characterisation factors for the elements in $\boldsymbol{g}^*$. The link between individual plants' operations and broader sustainability analysis in a cradle-to-grave perspective is examined elsewhere (Heijungs *et al.*, 2013).

Costing

Using a similar model, it is possible to jointly evaluate the unit monetary worth of each output within the wastewater system described so far. First, one must know the values taken by the elements of the following vectors:

- $\boldsymbol{p}_v$: purchase prices of exogenously purchased inputs
- $\boldsymbol{p}_w$: charges for by-product disposal, or revenues if by-products are sold instead
- $\boldsymbol{p}_g$: value of tradable permits, environmental taxes etc. associated with emission in the atmosphere (such as CO_2) or into water bodies (such as Phosphorous).

These vectors have the same size as $\boldsymbol{v}$, $\boldsymbol{w}$, and $\boldsymbol{g}$, respectively, and their entries, if different from zero, have a sign such that $\boldsymbol{q} = [\boldsymbol{p}'_v \quad \boldsymbol{p}'_w \quad \boldsymbol{p}'_g]\begin{bmatrix}\boldsymbol{W}\\ \boldsymbol{V}\\ \boldsymbol{G}\end{bmatrix} \geq \boldsymbol{0}$ (superscript $'$ denotes transposition). The unknown unit monetary worth of the output of each function $A, \dots, L$ corresponds to an entry of a 1×12 vector $\boldsymbol{p}$. Each value must cover the known direct costs $\boldsymbol{q}$ and the unknown monetary worth of the outputs transferred-in from other functions:

$$\boldsymbol{q} = \boldsymbol{p}\boldsymbol{Z} \quad (3)$$

Also in this case it is possible to formulate scenarios given by changing $\boldsymbol{p_v}$, $\boldsymbol{p_v}$, and $\boldsymbol{p}_g$:

$$\boldsymbol{p}_{\text{scenario}} = \boldsymbol{q}_{\text{scenario}}\boldsymbol{Z}^{-1} \quad (4)$$

Equations (1-4) are the foundations of Input Output Analysis (IOA). IOA was originally developed in economics to investigate the techno-economic implications of alternative scenarios given a blueprint of the interrelationships among industries within an economic system (Leontief, 1986). Further refinements take into account interdependencies between production and the generation and treatment of waste (Nakamura and Kondo, 2009). The principles of IOA have also been applied for the evaluation of material and energy flows in manufacturing systems, be them individual plants (Xue, 2007) or supply chains (Albino *et al.*, 2002), as well as to develop computational structures underpinning analytical sustainability evaluations in a life-cycle perspective (Heijungs *et al.*, 2013).

Productivity

Productivity is fundamentally an input to output relationship measured as a prescribed output to the resources consumed. The productivity analysis of a multi-stage, multi-input, multi-output production system suing IOA consists of determining the *technical coefficients* which form the 'structural matrix' of such a system (Leontief, 1986). The structural dependencies determined by the technology in use within the techno-economic system being investigated are exposed as ratios or coefficients of each input to the total output of which it becomes part.

Given the notation used above, it is necessary to disaggregate the technological matrix $\boldsymbol{Z}$ into main inputs (off-diagonal elements) and main outputs (on-diagonal elements):

$$\boldsymbol{Z} = \widehat{\boldsymbol{x}} + \boldsymbol{X} = \begin{bmatrix} z_{aA} & 0 & \dots & 0 \\ 0 & z_{bB} & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & z_{lL} \end{bmatrix} + \begin{bmatrix} 0 & z_{aB} & \dots & z_{aL} \\ z_{bA} & 0 & \dots & z_{bL} \\ \vdots & \vdots & \ddots & \vdots \\ z_{lA} & z_{lB} & \dots & 0 \end{bmatrix} \tag{5}$$

Where $\hat{x} \geq \mathbf{0}$; $\boldsymbol{X} \leq \mathbf{0}$; superscript $\frown$ denotes vector diagonalisation. The structural matrix is:

$$\boldsymbol{A} = -\boldsymbol{X}\widehat{\boldsymbol{x}}^{-1} \tag{6}$$

Matrix $\boldsymbol{A}$'s generic element a_{ij} is a technical coefficient and expresses the quantity of the i-th function's output that goes into the j-th function per unit of its total main output j. Additional technical coefficients can be evaluated in a similar way to measure the quantity of exogenously acquired goods, services, and environmental resources that goes into the j-th function per unit of its total output j, as well as the quantity of by-products and emissions into the environment generated by that function per unit of output. An example is given in Figure 7 for the functions *C*, *E*, *G* which correspond to different biological treatment technologies within the WwTW considered here.

In industrial practice most PCs tend to be formulated and reported in absolute rather than relative terms. Examples include the self-generation of electricity from wastewater biomass, greenhouse gases emissions in the atmosphere and of nutrients in water bodies. Hence the technical coefficients approach can be used to improve the current formulation of PCs.

Effectiveness

Effectiveness is the ability of an organization to fulfil its objectives. It implies that the firm consists of multiple transformation stages whereby downstream from intermediate outputs is outcome, which reflects the ultimate achievement of the firm.

Assuming that the elements in the final demand vector $\boldsymbol{y}$ are the 'outcomes' that a system of operations is supposed to pursue, IOA provides a pragmatic insight into the effectiveness of a multi-stage, MIMO delivery system. Using the structural matrix obtained earlier one can determine how much the output of each function would increase to match a variation in the final demand considering that it contributes to the final delivery both directly and indirectly by supplying many or most other functions. To achieve this, the planning problem in equation (2) is reformulated to include the structural matrix $\boldsymbol{A}$ as follows:

$$\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{y} \tag{7}$$

Where the matrix $\boldsymbol{A}^* = (\boldsymbol{I} - \boldsymbol{A})^{-1}$ if it exists, is known as the Leontief inverse. The generic element a_{ij}^* of matrix $\boldsymbol{A}^*$ indicates by how much the output x_i of the i-th process would increase if the quantity of the good or service j absorbed by the final demand, y_j, had been increased by one unit. Such an increase would affect process i directly if $i = j$ and indirectly when $i \neq j$ insofar as the i-th process provides inputs to some or all other processes which, in turn, directly or indirectly contribute to the final delivery (Leontief, 1986).

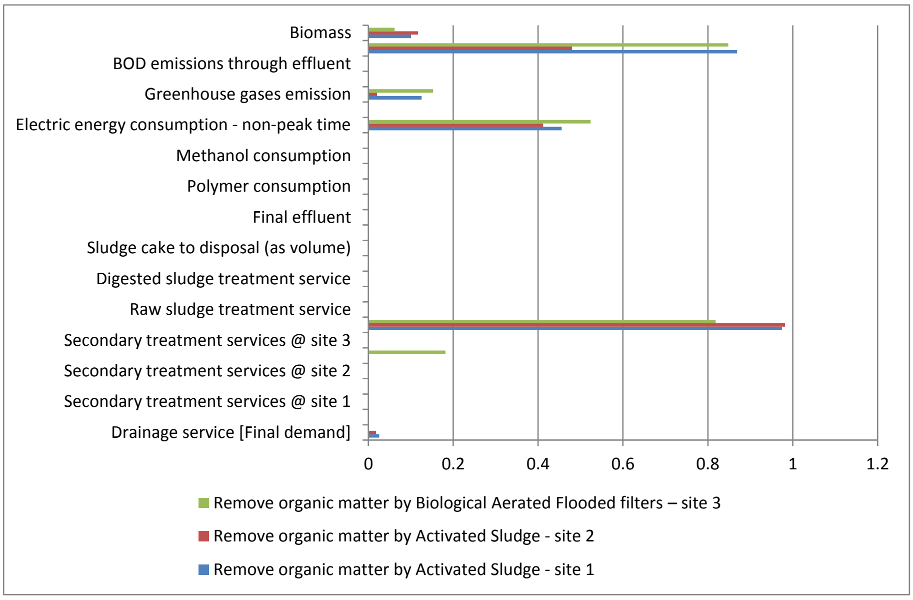


Figure 7 - Coefficients bar chart for three biological treatment technologies in use at the WwTW

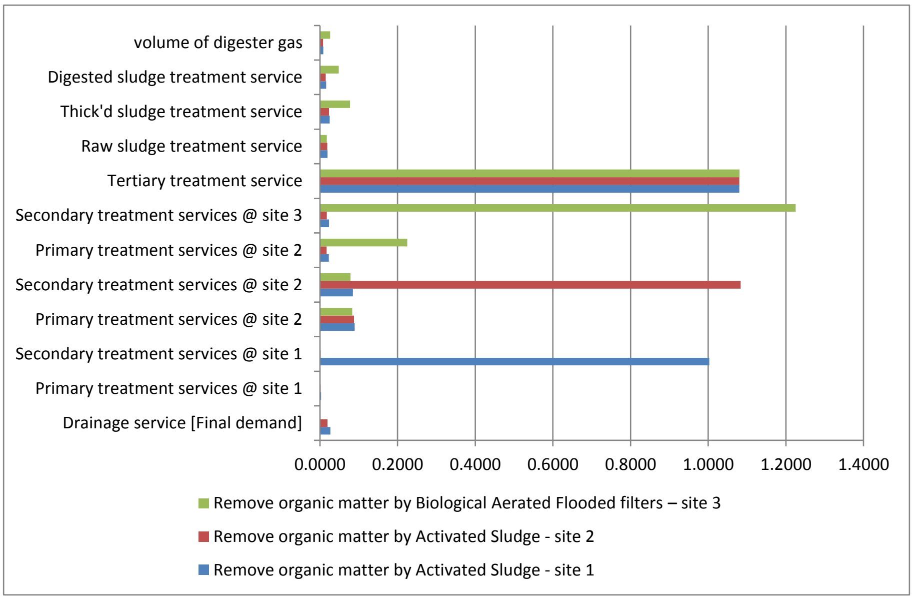


Figure 8 - Leontief inverse coefficients for the biological treatment processes in use at the WwTW

For illustrative purposes, Figure 8 shows the values taken by the Leontief's inverse elements corresponding to the same functions considered earlier.

Efficiency and Profitability

Efficiency is a grade which measures the comparison between actual and standard output for a given array of inputs. For example, a grade of 50% means the firm should be able to double its output given the inputs used and hence it can be said to be output inefficient (Hackman, 2008). Efficiency is therefore an inherently comparative concept, which entails comparing and contrasting expected input-to-output ratios with actuals, or historical actuals over time. Most approaches would look at the firm in an aggregated way, assuming a single production stage. An example is Barbiroli (1996), who presents a detailed set of indicators to addresses manifold aspects of efficiency in production including waste generation, natural resource use, recycling and emissions into the environment. Another example is water use efficiency which tends to be more emphasised in corporate reporting practices than water sources and destinations after use (Sodhi and Yatskovskaya, 2014). Efficiency evaluation in a multi-stage settings being possible, it is problematic and mostly limited to two stages (Agrell and Hatami-Marbini, 2013) and strictly sequential configurations (e.g., Troutt, 2001).

Computing efficiency requires shifting from the multi-stage representation used so far to a single-stage representation. This is achieved by focusing on vectors $\boldsymbol{y}$, $\boldsymbol{w}$, $\boldsymbol{v}$, and $\boldsymbol{g}$ obtained earlier, and corresponding to the totals in Table 3. Using historical values for these vectors one may determine if it is possible to achieve an output equal to or greater than the output observed in a reference time period by employing less than the amount of input observed at that time. The metric thus obtained, called ‘radial input efficiency’, requires setting up a mathematical programming problem which is described elsewhere (Hackman 2008).

Profitability analysis is based on historical, aggregated input-output data, too. Conceptually, it brings together the technical analysis performed in equations (1-2), and the monetary evaluation analysis performed in equations (3-4). Using the same vectors mentioned above, a series of indexes can be computed to figure out how well a firm performed between two time periods in both technical and monetary terms and to verify if a productivity gain has occurred. Details about how to calculate the indexes are given elsewhere (Hackman 2008).

In the case considered here realistic efficiency and profitability analysis could not be conducted. In the absence of historical data a simulation was carried out on the data gathered one-off to generate an artificial history. Existing procedures for efficiency and profitability analysis were then applied for illustrative purposes. Details about computations and results are provided elsewhere (Settanni, 2015).

Spatial analysis
As mentioned earlier, a wastewater system may involve a multitude of WwTWs operating over a geographical area, e.g. a catchment. Businesses often respond to regulatory requirements by ‘sweating’ existing assets while spreading the risk of compliance across multiple sites. Hence, it has practical relevance to extend the previous analysis to include multiple locations.

Extensions of IOA have been developed for regional analysis in macroeconomics (Leontief, 1986), and for the exploration of the effects of spatial variables on the economic and environmental performance of multi-locations supply chains (Yazan et al., 2011). However, the exploration of such extensions of IOA to scale up the approach presented above in order to deal simultaneously with more WwTWs within a region is left to future research.

Concluding remarks
This paper has considered some implications of the *outcome*-orientated approach promoted by the regulator of the water sector in England and Wales for the evaluation of the multi-faceted performance of wastewater systems operations. The use of concepts such as input, output and outcome for business performance evaluation were reviewed critically, including evidence from other sectors (defence, healthcare, etc.) and existing frameworks. An approach to reconcile performance measurement with a genuine outcome orientation for use in the water and wastewater service industry was outlined. To achieve this, a two-stage model covering both the conceptual stage, and the quantitative data collection and analysis stage

was applied to a simplified wastewater system underpinned by real company data. A range of performance evaluations allowed by the proposed model of the wastewater system of interest was illustrated, although details were not disclosed.

On a practical side, the research has highlighted the potential to systematise blueprinting of a wastewater system's operation by managing existing mass balances of individual WwTWs while avoiding overly complicated mathematics. However, the focus on quantitative physical flows is at the same time a major limitation of this research because it neglects insights about what happens 'behind the scenes' to enable those flows to occur as depicted. For example, the system of equipment support activities which ensures asset availability was captured in the conceptual model, but not in the quantitative model. Future research should look beyond physical flows to capture service operations. It should also explore spatial analysis, which is becoming increasingly important as industry considers spreading the risk of meeting their performance commitments across multiple plants and locations.

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Improving resource efficiency through the adoption of 3DCE throughout the product life cycle

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Abstract
Changes in one aspect of three-dimensional concurrent engineering (3DCE) can have marked impacts on the other related areas. These effects change over the four phases of the production life cycle: conceive, design, realise, service. The relative importance of each pillar of the 3DCE process can change over the lifecycle as it influences the resource efficiency and usage. This perspective has the potential to become a key competence in manufacturing companies that desire efficiency and effectiveness in their operations. The question guiding this research is how can the adoption of 3DCE improve resource efficiency across the product lifecycle? Specifically, what is the role of each of the pillars of 3DCE, individually and holistically, in helping to increase resource efficiency by developing better ways to do more with less and creating more value with less impact on the environment?

Keywords: Three-Dimensional Concurrent Engineering (3DCE), Resource Efficiency, Resource Scarcity, Product Life Cycle, Manufacturing.

1. Introduction

Materials and natural resources are the lifeblood of a number of sectors from agri-food and high-tech to manufacturing, however recent resource crises (e.g. related to food scarcity, energy production, and water availability), have highlighted the vulnerability of both countries and companies. Recently published reports (McKinsey Quarterly, 2014) suggest that in order to meet global demand in the next two decades an annual improvement of resource efficiency of 1.3% for materials, 1.5% for food, 3.2% energy and 3.7% for water is needed. All these demonstrate the urgent need for improved resource efficiencies and the very simple realisation that the inefficient use of natural resources contributes to resource scarcities. The term scarcity, with regard to resources, refers to an observed shortage of natural resources and a perceived dependency on natural resources due to their global depletion (Passenier and Lak, 2009).

The growing global concerns over the long-term availability of secure supplies of natural resources have been also reflected in recent initiatives taken by a number of organisations. For example, the European Commission launched in 2011 (European Commission, 2011) a new strategy for the Raw Materials Initiative with the mission to offer high-level guidance to Members States and private actors on innovative approaches to the challenges related to raw materials (European Commission, 2012). In a similar vein, a number of legislative efforts have taken place to address the rare earth supply in US (e.g. in the House, H.R. 761, the National Strategic and Critical Minerals Production Act of 2013 or in the Senate, the Critical Minerals Policy Act of 2013-S. 1600). Businesses operating in resource intensive sectors need to carefully consider how they obtain, use, recycle and reuse these resources. Unlike the previous decade and the previous century where resource prices declined continuously businesses today face not only increased prices (e.g. due to either the increase of demand for these resources or due to their reduced productivity), but also a growing risk of supply (McKinsey Quartetly, 2012). In either case businesses need to rethink how resources might affect their profitability (e.g. in the manufacturing sector resources account for 40% of the manufacturer's cost) and the operational challenges for risk management which result from the increased price volatility and from scarcity concerns (EEF, 2014).

In this paper, we explore how three-dimensional concurrent engineering (3DCE), the simultaneous design of product, process and supply chain, can be used to improve resource efficiency across the production lifecycle. The term resources in this paper, covers the natural renewable or depletable resources (e.g. water and oil) as well as the raw materials processed in the supply chain to produce consumer products. Subsequently, resource efficiency in supply chain terms is not just about natural resources, but highlights also firm's material, energy efficiencies, and the generation and impact of waste over products' full life cycles (United Nations Environment Programme, 2012). In this research, although our emphasis is on new product launches, at the same time we recognise that in practice during the production lifecycle of a product there is often the need to change the product (e.g. due to market changes) or the process (e.g. due to new, better processes being developed) or the supply chain configuration (e.g. due to supply chain disruptions as a result of a supplier going bankrupt) or all three aspects. By taking this life cycle perspective, the aim of this research is to explore how and to what extent the implementation of 3DCE practices across different phases of the lifecycle can lead to improvements in resource efficiency. More specifically, the overarching question leading this research is the following:

RQ. How can the adoption of 3DCE improve resource efficiency across the product life cycle?

The article is organised as follows: Section 2 presents the characteristics of 3DCE and unpacks the concept of resource efficiency particularly in the context of manufacturing supply chains. The section also provides an overall description of the key characteristics in manufacturing sector followed by an overview of New Product Development (NPD) and of the four production lifecycle phases. In Section 3, the intersection of 3DCE and resource efficiency across the different production lifecycle phases is illustrated using examples and also referring to best practices from a range of companies from the manufacturing sector. Section 4 concludes with a discussion of the research and managerial implications of 3DCE.

2. Literature review

2.1 3DCE

Traditional NPD literature focuses specifically on the product. Concurrent engineering (CE) focuses on both product and process design using cross-functional teams (Koufteros et al. 2001). Starting in the 1980's, CE gradually became more widespread, being picked up by many organisations, more enthusiastically by the automotive industry, to achieve competitive advantage in the market place. However, that advantage quickly diminished when companies realised that it was important to incorporate supply chain issues along with product and process design (Ellram, et al. 2007). Indeed, the concurrent development of design and in-house manufacturing became more routine, but integration of the supply chain was more limited. It may be a reflection of the vertical integration of the automotive industry at this time, that there was not a more coordinated integration of external suppliers into this process (Gao et al., 2000).

In any case, the result was a 3DCE structure that moved organisations forward in seeking competitive advantage (Fine, 1998). The 3DCE mindset has been linked to numerous issues where there is potential conflict among objectives for example environmental and resource issues across a product life cycle (Ellram et al., 2008). Consider for example the selection of a low-price component, often associated with low quality and long lead times versus the product design aspects with higher quality components, or the process designer wanting short and realisable lead times (Marsillac and Roh, 2014). Companies are realising that even though product and process design are well developed, incorporating the third dimension, the supply chain, can be relatively haphazard. Supply chain design issues to consider include: make versus buy, sourcing and location decisions, contracting decisions and relationships with other supply chain members (Ellram, et al. 2008). There are also many logistical and coordination concerns that need to be incorporated for example, inventory, delivery, lead time, and information systems and sharing (Ellram, et al. 2007). Without considering supply chain aspects, higher costs and reduced performance will occur throughout the life cycle of the product.

3DCE provides an opportunity to address all these challenges and to improve performance which is something that has been manifested in previous research already (e.g. Rungtusanatham and Forza; 2005; Huang et al. 2005; Pulkkinen et al. 2008; Gan and Grunow, 2013; Marsillac and Roh, 2014). In addition to the typical, yet crucial and well-identified, benefits related to cost and time-to market improvements, we argue that 3DCE could be also a very useful tool to improve resource efficiency and resource utilisation.

2.2 Resource efficiency

Resource efficiency is about ensuring that natural resources are produced, processed, and consumed in a more sustainable way, reducing the environmental impact from the consumption and production of products over their full life cycles (United Nations Environment Programme, 2012). A definition of what resources and efficiency are is important in order to establish clear links with 3DCE. According to Dewulf et al. (2007) resources can include fossil fuels, minerals, metals, nuclear energy, water resources, land resources, abiotic renewable energy and atmospheric resources.

In addition to these natural resources, also industrial resources and waste-as-resources should be considered (Huysman et al. 2015). From a purely quantitative and measuring perspective resource efficiency can be linked not only to the derived benefits (i.e. useful outputs) per inventoried flows (Heijungs, 2007), but also to intended effects (or benefits) per environmental impacts (Huysman et al. 2015). In the context of supply chains resource efficiency entails four major characteristics: resource awareness, resource sparing, resource sensitivity and resource responsiveness (Matopoulos et al. 2015).

Resource awareness refers to being able to quantify the resource usage and the environmental impact caused along the supply chain. Resource sparing is about continuously improving the operations, reducing the use of resources along its various stages. For example, it may include product design and production processes adaptations and creation of closed-loop supply chains so as to recollect and re-use resources. Resource sensitivity is about being capable to capture any changes in the availability of natural resources and raw materials with the help of suppliers and customers. The changes may be due to price variations and changes in the supply of the resources (e.g. depletion or natural disasters, changes in demand patterns, population growth, geopolitical activity). Finally, the fourth characteristic, resource responsiveness is about mitigating the effects of natural resource scarcity by actively responding to resource usage challenges.

2.3 Manufacturing sector

The need to coordinate the activities of design, manufacturing and supply chains is as old as the manufacture of products. In a linear system, the design of products is dictated by the needs of the end customer and the marketplace. Products would be designed for a specified usage life, which would influence the design selection for materials, construction and manufacturing process. The design would then be passed on to production, possibly with elements outsourced to sub-suppliers. Considerations of production life i.e. how long the product would be in production, were often based on prior knowledge and manufacturing expertise in tool life and the reliability of production to meet market demands. Discussions between design, marketing, manufacturing and the supply base were limited and informal.

Current trends in manufacturing are still, quite rightly to some extent, placing emphasis on lean techniques, first popularised by Toyota in the 1990's, but these have been developed over time from the initial Toyota production systems and are now widely adopted. A central tenet of Toyota's production system is the elimination of waste in all forms (Womack and Jones, 2010). In considering waste in manufacturing and the supply chain, we also need to consider the utility of excess capacity. Berndt and Hesse (1986) have measured and assessed the manufacturing capacity of a range of firm types across Europe. Their findings correlate well with other studies and other recent reports (e.g. Eurostat) to show remarkably consistent unutilised capacity within each industry. The level of this excess capacity varies by industry, but in Europe in the manufacturing industry it is typically 15-20% of available capacity (Eurostat, 2015). This buffer is often used to manage the dynamics of demand and supply within the system. Design plays an important role in determining the limit of decisions that can be made in terms of manufacturing options and supply chain choices. Increasingly, sustainability of the products being designed, including cradle to grave energy and waste consumption, are important factors in design configuration decisions. Design for the environment incorporated into Life Cycle Analysis is becoming a common process, with product and process design on new and existing products being considered (Bevilacqua et al., 2007).

The new challenges for manufacturing are not only the market's desire for mass customisation, globalisation of demand and supply, combined with reduced lifecycles of products in the marketplace, but also stricter industry regulations and public pressures for minimising environmental impact and waste generation. A recently published report by the UK Government Office for Science (Foresight, 2013; p. 26-27), highlighted the profound changes that environmental sustainability will have on manufacturing in the next four decades identifying three major phases in the shift to sustainable manufacturing. The first phase, *Efficiency and Resilience*, where the emphasis will be on minimising material inputs, waste management, increasing energy efficiency, reducing water usage. The second phase, *Experimentation with new systems,* where the focus will be on products reused, remanufactured, recycled and redesigned with recovery in mind and on spare capacity built into supply chains to ensure resilience. The third phase in the shift will be related to *Resource Constraints*, where the products will be using smaller amounts of materials and energy, materials will be kept in a 'productive loop' and supply chains will have spare capacity at all stages.

2.4 The life cycle perspective

The concept of lifecycles for products is well established within the product design community. Usually this has been applied to the in-use life of products, but has also been used in planning the production life of the products and its various componentry. An inherent challenge to the supply chain is in dealing with uncertainty in demand and production life.

Work by Lee (2002) has sought to align product design and supply chains to have some degree of robustness to uncertainty through the use of a framework to plan supply chain design. Shorter product lifecycles are driving the need for a more dynamic supply chain needed, with Lee (2002) once again drawing out the need to transparency and information sharing through the system.

Adopting lean techniques to product lifecycle management has been described by several researchers (Hines et al. 2006). However, the concept of Product Lifecycle Management (PLM) can become confused between lifecycle of the design information, sometimes referred to a PLM, the production lifecycle (the management of the product through its manufactured life, including supply chain involvement), and the in-use product life once it is in the hands of the end user. All of these product lifecycles need to be planned and optimised to ensure efficiency of operations and materials, and ideally would also be coordinated – a primary objective of 3DCE.

Gmelin and Seuring (2014) have established a linkage between NPD and sustainability through the lifecycle planning process. Given the collaborative nature of much current product development they identify cross company and departmental information sharing and activity coordination as key to successful control of the lifecycle process. Felekoglu et al. (2013) look into effective interactions across the NPD process. One of their main findings is that the formality of NPD hierarchy influences the quality of the interactions that result. Roh et al. (2014) suggest that it is not clear how to build an appropriately responsive supply chain for the demands of modern dynamic markets. After investigating the drivers, strategies and practices of supply chains through an empirical study, giving consideration to the frequency and innovativeness of product changes, they determined that a ‘pull’ system is the most responsive to market dynamics.

3. An overview of the implications of 3DCE for Resource Efficiency in Manufacturing

3.1 3DCE and Resource Efficiency links

In this section, we map the links between 3DCE and resource efficiency across the production lifecycle. We use the classical four phases categorisation of the production lifecycle: Phase 1- Conceive (Imagine, Specify, Plan, Innovate) refers to the requirements definition based on customer company, market, and regulatory viewpoints, Phase 2- Design (Describe, Define, Develop, Test, Analyze, and Validate) covers detailed design, product development, prototype testing, Phase 3- Realize (Manufacture, Make, Build, Procure, Sell and Deliver) includes the pilot release, product launch and full operations, and Phase 4- Service (Use, Operate, Maintain, Support, Sustain, Phase-out, Retire, Recycle, Disposal). In the following tables an overview of the implications of 3DCE for the four characteristics of resource efficiency across the four phases of production lifecycle is presented supported by indicative examples of specific companies of more generic best practices.

Table 1. 3DCE implications for Resource Efficiency in Manufacturing at the Conception phase

Production Lifecycle phases	**Characteristics of Resource-Efficient Supply Chains**	**3DCE implications**	**Examples**
Conceive (Imagine,	Resource aware	Understanding of material/ resource	Ford works with suppliers to understand

Specify, Plan, Innovate)		requirements. e.g. specifications based on supply market changes, energy usage, recycling.	the water intensity of raw materials. VW design for recycling initiative.
	Resource sparing	Consider using new/ improved production methods. e.g. select critical suppliers based on their environmental superiority and cooperativeness.	Use of material minimisation software in design, such as Optistruct.
	Resource sensitive	Capture current situation and prospective changes. e.g. understand specifications based on regulatory viewpoints and legislations	Ford identifies and engages suppliers in water-stressed regions where the company operates, sharing water stewardship practices, and supporting actions to implement improvements. Minimising catalytic loading of precious metals on catalysts.
	Resource responsive	Understanding of customer/ channels' requirements. e.g. consider changing customer/consumer preferences with regards to specific materials or customer feedback.	Ford works with its network of dealers on water-saving technology opportunities. VW design for disassembly to aid low energy, fast recycling.

Table 2. 3DCE implications for Resource Efficiency in Manufacturing at the Design phase

Production Lifecycle phases	**Characteristics of Resource-Efficient Supply Chains**	**3DCE implications**	**Examples**
Design (Describe, Define, Develop, Test,	Resource aware	Determination of resources usage and related impact. e.g. integrate	Ford filters and prioritises projects, and the engineers are using LCA to help select one

Analyze, and Validate)		environmental & resource efficiency criteria in process design.	material or design alternative over another
	Resource sparing	Integrate processes in order to reduce resource usage; change processes to adapt to be more resource friendly. e.g. use lifecycle design to identify improvement opportunities; change width of tooling.	Test to failure to determine product life and minimize material redundancy. JCB designs products in conjunction with suppliers and optimises machine design to minimise impact of shipping.
	Resource sensitive	Consider alternative materials; look to standardise materials with other existing products. e.g. use materials with high recycling rate or add reused or recycled resource in the products.	Jaguar Land Rover's strategic emphasis on aluminium bodies, which brings improved fuel efficiency, lower emissions. The aluminium sheets used to form the body panels are made of recycled material. The weight reduction has an impact on the environmental footprint of the cars when it comes to their shipping.
	Resource responsive	Consider alternative design strategies; standardise, platforms, modules e.g. adopt modular design to enable for supplier flexibility.	Use of standardised components from Tier 1 suppliers. Standardized fasteners and fixings, bearings, seals etc.

Table 3. 3DCE implications for Resource Efficiency in Manufacturing at the Realisation phase

Production Lifecycle phases	Characteristics of Resource-Efficient Supply Chains	3DCE implications	Examples
Realise (Manufacture,	Resource aware	Evaluate accurately the environmental	Secondment of manufacturing and

Make, Build, Procure, Sell and Deliver)		load of the entire supply chain. e.g. use life cycle assessment to understand where usage is occurring, identify “hot-spots”, focus on resource intensive areas/processes for improvement.	purchasing engineers to product development teams to embed best practices for product and process concurrent design (e.g. Toyota).
	Resource sparing	Identify full spectrum of supply chain improvement opportunities e.g. consider mode of transport, routing, and scheduling to minimise the use of resources. Look at location decisions to minimise supply side impacts (supply footprint)..	Ford reduces GHG and other emissions from their facilities and vehicles by developing cleaner and more energy-efficient production processes, also improving packaging and transportation (e.g. cleaner and more fuel-efficient vehicles).
	Resource sensitive	Consider potential trade-offs. e.g. purchasing low-cost raw materials may have negative environmental impacts; or purchasing from low costs countries may have excessive total environmental costs.	Sustainability factor built into cost/benefit analysis for change decisions.
	Resource responsive	Proactively mitigate the use, inventory and waste of resources. e.g. consider stock levels that should be maintained and in which locations to address resource scarcity risks; perform network modelling to determine optimal locations and levels.	Monitoring of scrap and waste in manufacturing process for improvement opportunities.

Table 4. 3DCE implications for Resource Efficiency in Manufacturing at the Service phase

Production Lifecycle phases	**Characteristics of Resource-Efficient Supply Chains**	**3DCE implications**	**Examples**
Service (Use, Operate, Maintain, Support, Sustain, Phase-out, Retire, Recycle, Disposal)	Resource aware	Monitor customer usage and provide service support to understand issues with scarce resources. e.g. customer continues to have issues with one particular component, redesign and change while also considering resource scarcity.	Mercedes oil condition monitoring to determine vehicle service interval (service on demand).
	Resource sparing	Design and facilitation of reverse flows. e.g. collecting back used products from customers, disassembly, returning back to suppliers where appropriate.	Honda established process to reuse rare earth metals extracted from nickel-metal hydride batteries for new nickel-metal hydride batteries to recycle precious resources. VW remanufactures parts such as engines and gearboxes (major components) and restores to as-new quality using leading-edge technology to recover noble metals such as platinum, palladium and rhodium.
	Resource sensitive	Determine what levels of scarce resources currently exist in this phase and what the impact is on the scarcity level. Schedule capacity for retire, recycle, disposal of end products. e.g. measuring the requirements of all existing clients within the product life cycle.	Harley-Davidson strategic resource availability assessment for lifecycle support. Product life forecast considers material availability and market volatility in design and purchase decisions.

	Resource responsive	Watch scarce resources and changes in material offerings. e.g. due to a need to resource items mid-life (supplier issues, new contract negotiation, etc.), as products are redesigned, new products are introduced, incorporate these changes into existing products.	BMW alternative design options to allow mid-life change to material specification to conform to legislation (asbestos free gaskets).

3.2 Key issues for further exploration

In the previous section we provided examples of how the 3DCE paradigm can affect resource efficiency across the production lifecycle. In this section we highlight some of the issues that we have identified with regards to the adoption and benefits of 3DCE.

- Integration of stakeholders

Integration of stakeholders possibly beyond design, process and supply chain, to consider whole lifecycle management is important for maximising resource efficiency improvements. This is particularly the case regarding supplier and customer (user) involvement. Traditionally, suppliers and customers are involved in the early phases of the production lifecycle (i.e. conception or design) with initiatives such as Early Supplier Involvement. However, we believe that there are many opportunities to improve resource efficiency by also involving them in the later phases of the production lifecycle (e.g. realisation and service).

- Product and supply chain design in relation to resource efficiency.

In Fine's (2005) terms in modular supply chains the relationships among suppliers, customers, and partners are relatively flexible and interchangeable. Previous research by Feng and Zhang (2014) has shown that the modular approach reduces the cost to the manufacturer and the supply chain, which explains the prevalence of modular assembly from the perspective of inventory management. The design of modular products architectures and supply chains could improve resource efficiency due to the increased flexibility for the company in selecting partners (e.g. suppliers) and this is something that needs to be further explored. From the three elements of 3DCE, supply chain design may play a key role in minimising or collecting scarce resources particularly at the end of the product's useful life. Unlike modular product architectures and supply chains, integral product architectures typically link subsystems with tightly coordinated relationships. The cross-company links are strong and the barrier to entry for newcomers is relatively high. Because of the geographical, organisational, cultural, and/or electronic proximity and the tight links we posit that such designs can help companies to mitigate resource scarcity risks.

- 3DCE benefits across the production lifecycle.

The benefits of 3DCE on resource efficiency are greatest during conception. It is much easier and more effective to consider issues of product, process and supply chain during while ideas are being generated and designed. Over seventy per cent of costs and resource issues can be reduced before the product is launched (Asiedu and Gu, 1998). It is very difficult after launch to remove resources or make changes and these changes will have less influence.

- 3DCE and resource scarcity

Resource scarcity is currently debated in the literature but 3DCE could proactively focus on potential scarcity concerns and optimise product, process and supply chain design to limit the consumption of energy, water and other materials. 3DCE can also help reducing output and process waste.

- The inter-connected nature of 3DCE.

Actively managing information as a product in itself is coming under increasing scrutiny from legislators. Particularly when it comes to issues of product liability, intellectual property and the legal processes of discovery, the structures and processes for creating, disseminating, storing and disposal of information need to be planned (Volonino et al., 2007). The lifecycle of the information used in 3DCE becomes even more crucial to control when it is dispersed across different entities in different locals and jurisdictions. Therefore, 3DCE requires transparency and greater degrees of information sharing that previously has been the norm. This increased level of information sharing is essential for the use of tools such the Environmental Profit and Loss account statement, which can help producing, with the help of stakeholders, more accurate estimates.

4. Conclusions

The 3DCE paradigm emerged in the late 1990s as a result of the growing recognition that supply chain issues can be a large determinant of the total cost of producing and delivering products and therefore need to be incorporated with product design and process planning. However, the practice of 3DCE is underdeveloped in industry, as is research on the implementation. Research so far on 3DCE has attempted to provide insights on the low adoption rate of 3DCE in practice or has looked at its impact on new product development outcomes, such as reduced time to market and costs, and improved customer acceptance. In this paper we tried to expand the discussion on 3DCE implementation by considering the link between 3DCE and resource efficiency. We argue that the adoption of 3DCE can have also significant implications for resource efficiency and we identified a number of key themes that require further research.

From a managerial/practitioners perspective whilst there is much to be gained from evaluation of sub-parts to the whole 3DCE process, it is in the coordinated management of the complete system that the greatest gains can be achieved. This requires the combined specialist inputs of planners from several disciplines, and a thorough review of trade-off decisions by careful analysis of sensitivities to change. This was quite evident also from the tables presented in section 3.2 where the initiatives presented were covering a very broad and diverse spectrum of disciplines.

Product lifespans are reducing for both in-service life and production life and therefore extending the life of products through designing for refurbishment, remanufacture and second life is a preferred strategy for reducing environmental impact (Bakker et al. 2014). This is gaining increased attention from both legislative bodies and manufacturers. A product strategy of extended life products has profound effects on manufacturing and supply chains and is not something that should be left to chance. In essence, product lifecycle and manufacturing should drive supply chain design selection (Wang et al. 2004).

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A Framework for a Smart City Production System

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Abstract

This paper is a first step to understand the role of a smart city in production and supply chain management contexts, with a specific focus on supplier chain design and its reconfiguration. We pose the question: how will smart city characteristics and types of production technology for distributed manufacturing change supply chain configuration? We develop a conceptual framework for understanding the interplay of smart city characteristic, production technologies and supply chain configuration. Following Scott and Davis' (2006) argumentations that supply chains are "open systems" mutually dependent on the surrounding environment and constantly adapting to it, we posit the existence of different synergies between smart cities distributed manufacturing and supply chains. These effects occur in both sides, i.e. from smart cities-distributed manufacturing to supply chain and from supply chain to smart cities-distributed manufacturing. Moreover, the structuration theory argues that agent and structure co-evolve and interact mutually in complex social interactions (Giddens, 1984). Considering that smart cities production systems are based on the collaboration between firms, end-users and local stakeholders (Manville et al, 2014), we add to the present knowledge by recognizing a coevolution approach, in which the social interactions are also considered. The objective is to identify the key elements driving integration and their influence on smart city production and associated supply chains.

Keywords: Framework; Smart city, production technology, supply chain configuration

Governance in Global Value Chains based on Digital Platforms: the Importance of Network Effects and Volume of Participants

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Abstract

Global Value Chain (GVC) Governance has evolved in the last 20 years, since the first comparison of buyer-driven and producer-driven chains. Digital Platforms have some characteristics that are not focused on GVC literature, including high network effects, complementary players/sides management, and lock-in strategies. Based on Multi-Sided and Industrial Platforms literature and GVC governance as driving, coordination, and normatization; this paper aims to expand GVC Governance to analyse Digital Platforms. The analysis shows that Volume of Participants (VP) and Network Effects can be important variables to understand the GVC Governance of Digital Platforms. It proposes Platform as a different type of value chain coordination and reinforces the importance of normatization's additional worth and quality conventions (civic, inspirational, and opinion) that were not considered in coordination approach.

Keywords

Global Value Chains, Governance, Multi-Sided Platforms, Industrial Platforms, Network Effects

1 INTRODUCTION

Global Value Chains (GVCs) theory studies a variety of industries, from commodities to information technology, with considerable contributions to the understanding of industry dynamics and governance, value creation and capture, and geographic distribution. Recent research includes institutional, social, cultural, sustainability, and other dimensions. The influence of this approach goes beyond the Academy, and is very strong on multilateral organizations, as shown by their publications - World Bank (Cattaneo, Gereffi, & Staritz, 2010), OECD (OECD, 2007, 2008; OECD & WTO), ILO (Stephanie Barrientos, Gereffi, & Rossi, 2011; S. Barrientos, Mayer, Pickles, & Posthuma, 2011; Carr & Chen, 2004; Milberg & Winkler, 2011; Nadvi, 2011), Inter-American Development Bank (Pietrobelli & Rabellotti, 2006), and others. Three aspects are central in GVC analysis: governance, economic and social upgrading, and geographic setting. This paper will focus on the first dimension.

The research on GVC Governance has evolved in the last 20 years, since the first comparison of buyer-driven and producer-driven chains. Although the large range of industries studied, the research on platform-based industries and the impact of the internet on GVCs governance is limited. In the beginning of the 2000s, new types (internet, technology and alliance driven chains) were proposed to analyse the an emerging type of governance; but the debate decreased after the Gereffi, Humphey and Sturgeon (2005) fivefold coordination typology (market-modular-relational-captive-hierarchy) was largely adopted. Additional contributions included new worth and quality conventions; and larger integration with institutional and regulatory environments (Gibbon, Bair, & Ponte, 2008).

Sturgeon and Ponte (Ponte & Sturgeon, 2013; T. Sturgeon, 2009) propose modular theory-building to incorporate elements and connect theories to improve GVC governance theory. This paper aims to connect industrial and multi-sided platforms literature to GVC, and expand GVC Governance to analyse Digital Platforms. It proposes the Volume of Participants (VP) and Network Effects as variables to analyse the Governance of GVCs. Platform as a governance type can clarify and synthesize part of GVC governance debate of how to incorporate new drivers and configurations from the knowledge economy, especially information goods and services.

Public and social interest in platforms increased as platforms disrupt different kinds of industries. First wave focused on digital goods, digital services, and electronic commerce. Now Uber and AirBnB show how digital platforms can disrupt physical services industries. Platforms in Industry Level have been studied by different approaches, under concepts such as Industry Platforms (Cusumano & Gawer, 2002; Gawer, 2009; Gawer & Cusumano, 2014) Two/Multi-Sided Platforms/Markets (Eisenmann, Parker, & Alstyne, 2006; Hagiu, 2013; Rochet & Tirole, 2003) and Platform-Mediated Networks/Markets (Eisenmann, Parker, & Van Alstyne, 2007, 2011).

GVC literature does not focus some key Digital Platform characteristics, such as high network effects, complementary players/sides management, and lock-in strategies (Shapiro & Varian, 1998). Digital Marketplaces and Auctions, Credit Cards, Operational Systems, Digital Games and Mobile Applications are some examples of industries that have platform providers, who mediate suppliers and consumers interactions. Platform leaders do not mainly buy products and services from suppliers to manufacture/ provide their own product/ service. Their nature is different from traditional value chains/ production networks, and this difference has not being emphasized even on GVC studies these industries. The increasing digitalization of all processes of the value chain - research, development, production, operations, distribution, consumption, and post-services – has changes all industries, especially platform-based industries.

To understand the potential contributions that Platforms, this paper is organized in the following sections: (i) Introduction, (ii) Global Value Chains' Governance; (iii) Platforms Overview (iv) Discussion; and (v) Final Remarks.

2 GLOBAL VALUE CHAINS' GOVERNANCE

In 1994, the Global Commodity Chain (GCC) approach started to bring a new perspective to understand Globalization, focusing on inter-firm networks, and breaking the traditional commodity chain research based on world-systems approach (Bair, 2008). The original GCC concept was:

"A GCC consists of sets of interorganizational networks clustered around one commodity or product, linking households, enterprises, and states to one another within the world-economy. These networks are situationally specific, socially constructed, and locally integrated, underscoring the social embeddedness of economic organization" (Gereffi & Korzeniewicz, 1994, p. 2)

Despite the critics, the GCC approach always considered the industries as complex networks (not linear chains) that produced different products (not only commodities); on which location, social, and institutional aspects were important. Later the term GVC was chosen as the concept to provide the common language, and actually started another tradition of research while some researchers continued to use GCC. A group of researchers preferred Global Production Networks (GPNs) to differentiate their approach, which included action-network theory and some critics to GVC.

GCCs, GVCs and GPNs' research have common ground (i) on ontological level - variants of chain/ network approaches, and (ii) on epistemological level - study social and development dynamics of contemporary capitalism at global-local nexus, especially governance structures, firm-level upgrading and regional development opportunities. The differences are on (i) relative emphases/ coverage on (sub-) national/ regional institutions and dynamics, (ii) the role and agency of non-firm actors, and (iii) the relative impact of territorial development on firms´ competitiveness (Coe, Dicken, & Hess, 2008). Between the three complementary/ competitor approaches, GVCs concept is the most used on all ISI, Scopus and EBSCO databases (Sakuda & Fleury, 2012).

Governance is originally defined as "authority and power relationships that determine how financial, material and human resources are allocated and flow within a chain" (Gereffi, 1994, p. 97). A historical/ critical perspective of GCC/GVC governance was summarized in the three approaches of governance: (i) driving, (ii) coordination/linking, and (iii) normatization (Gibbon et al., 2008; Ponte & Sturgeon, 2013).

2.1 Governance as Driving

Governance as Driving is the first approach. Assuming that governance is a function of the lead firm, two basic types were proposed: Buyer-Driven and Producer/Seller-Driven (Gereffi, 1994). Later Internet-oriented chains (Gereffi, 2001a, 2001b), Technology-driven (Ó Riain, 2004) and Alliance-driven (Birch, 2008; Birch & Cumbers, 2010).

To understand the globalization process, GCCs changed the focus from the countries to the lead firms of the commodity chains. Producer-Driver Commodity Chains (PDCCs) are led by transnational manufactures seeking vertical integration to ensure ownership and control. Representative industries are natural resources (oil, mining, agribusiness), capital goods and consumer durables. Buyer-Driven Chains (BDCCs) are led by retailers and marketers seeking network integration to have better logistics and manage trusted relationships. Examples include Sears, Nike, Gap, and Wal-Mart (Gereffi, 1994).

Many studies were conducted on early 2000s affirming or disputing the relevance and utility of PDCC/BDCC. Three types of criticisms were made: (i) two ideal types were not enough, and some chains had more than one leader/pole; (ii) a buyer-driven dynamic emerging in industries that were (formerly) producer-driven made the typology redundant, and lead to the re-conceptualization of governance as coordination; and (iii) many important dimensions such as product sub-types, institutional configuration and external actors were not properly analysed, and lead to the elaboration of governance as normalization (Gibbon et al., 2008).

The Internet-oriented chains are introduced to help to understand the impacts of the digital globalization on GVCs, as well as emerging players and industries (Gereffi, 2001b). Led by internet infomediaries, brokers or intermediaries who help customers maximize the value of their data (Hagel III & Singer, 1999), their examples include online retailing, online brokerage, and autos and computers B2B Intermediaries.(Gereffi, 2001a).

Technology-driven focus on production networks where control over technological design, standards and trajectories is the central element of business power; instead of economies of scale and production efficiencies as PDCCs, and control of marketing and distribution to BDCCs (Ó Riain, 2004).

Alliance-driven governance was proposed applying a global commodity chains approach (as a critique to the cluster view) to the biotechnology industry, a knowledge-based industry with very particular characteristics which entail high asset specificity and reliance on the protection of intellectual property to encourage innovation, and shows a different type of leadership to be able to conduct innovation in a high risk industry (Birch, 2008).

Although this approach is more cited as a historical framework than applied in recent publications, analysis of Digital Platforms shows that the contributions proposed by internet-oriented, technology-driven and alliance-driven to GVC governance can be summarized by connecting GVC with platforms literature.

2.2 Governance as Coordination

Governance as Coordination is the most influential approach inside and outside GVC studies. Sturgeon (2002) integrates the debate between transaction costs theory and network theory to GVCs, and identified some national alternatives to the vertical integration of the modern corporation: the Japanese Model, the hierarchical, captive network; the German Model, self-reliant network; the Italian Model, the egalitarian, cooperative network; and the New American Model, with shared manufacturing capacity in the modular network. In 2005, the typology of five governance types was proposed: market, modular, relational, captive and hierarchy. These types came from the combinations of the three key determinants of governance: (a) complexity of information and knowledge transfer, (b) complexity of to codify transactions and (c) capabilities is the supply-base. It is important to stress that the dynamics of the governance and how it changes from one type to another according to changes on the variables cited is as much or even more important than the typology itself (Gereffi, Humphrey, & Sturgeon, 2005). Later proposed the inclusion of the variables (d) requirement of explicit coordination, (e) tolerance of distance, (f) switching costs/ asset specificity, and (g) coordination mechanism to the model (Ponte & Sturgeon, 2013).

Digital Platforms analysis confirms the importance of the four variables proposed by Ponte and Sturgeon (2013), and proposes volume of participants and network effects as additional variables.

The shift from driving to coordination implied in two interrelated changes: (i) the scope narrowed to inter-firm transaction at a specific node of the chain (lead firm and first-tier suppliers), and (ii) organizational forms emerge from transaction-efficient solutions. Criticisms to this approach include (i) the narrowing discarded the conceptualization of economic relations in terms of chains, (ii) that some variables (complexity and codifiability of transactions, suppliers capacities) are not so objective as the model assume, rather they are socially constructed, and (iii) the exclusion of external constrains such as regulatory systems (Gibbon et al., 2008).

2.3 Governance as Normalization

Governance as Normalization was raised from the criticisms described above, and used convention theory to account the normative environment and the broader normative frameworks, in order to include "external" variables to GVC governance. Forms of co-ordination were distinguished from overall modes of governance (Ponte & Gibbon, 2005). Three quality conventions (market, industrial, domestic) can be related to coordination typology (market, modular/relational, relational captive), but other three (civic, inspirational, opinion) can not. These other dimensions expand the scope of the model and enhance the comprehension of GVC dynamics on micro, meso and macro levels (Ponte & Sturgeon, 2013).

The analysis of Digital Platforms illustrates how this expansion is important to understand the dynamics of emerging GVCs.

In Discussion section, these governance types are detailed according to comparison and applicability to platforms.

3 DIGITAL PLATFORMS

The term “Platforms” is used in different areas with different conceptualizations. Baldwin & Woodard (2009) distinguish three traditions: (i) product development research, who introduced the term “platform product” in early 90s, (ii) technology strategists, who focus on the points of control and platform competition dynamic since late 90s, and (iii) industrial economists, who after the 2000s adopted the term to study two or more sided markets and emphase network effects (Baldwin & Woodard, 2009). For GVC governance study, the second and third traditions are more relevant. Gawer (2014) compared the main differences of the two groups on the following table:

LITERATURE	ECONOMICS	ENGINEERING DESIGN
CONCEPTUALIZATION	Platforms as markets	Platforms as technological architectures
PERSPECTIVE	Demand	Supply
FOCUS	Competition	Innovation
VALUE CREATED THROUGH	Economies of scope in demand	Economies of scope in supply and innovation
ROLE	Coordinating device among buyers	Coordinating device among innovators
EMPIRICAL SETTINGS	ICT	Manufacturing and ICT

Table 1: Platforms in economics and engineering design (Gawer, 2014)

To prepare for the discussion of Digital Platforms governance, this section has three parts: platform types, network effects and digital business.

3.1 Platform Types

Gawer (2009) proposes a platform typology according to their context: internal platforms (within firm), supply chain platforms (within the supply chain), industry platforms (industry ecosystems) and multi-sided markets or platforms (industry). A detailed comparison in Table 2. The literature on industry platforms and two/multi-sided markets/platforms interact; but the emphasis of the first is on the relationships of production and development, while the other relies on distribution.

It is possible to identify the GVC governance of each type: internal platforms (Hierarchy), supply chain platforms (Producer-Driven, Modular), industry platforms (Technology-driven, Distinct relationships with first-tier suppliers/complementors - more relational, and other tiers - more modular or captive) and multi-sided markets or platforms (Internet-oriented, Distinct relationships with first-tier suppliers/complementors - more relational, and other tiers - more modular or captive).

TYPE OF PLATFORM	INTERNAL PLATFORMS	SUPPLY CHAIN PLATFORMS	INDUSTRY PLATFORMS	MULTI-SIDED MARKETS OR PLATFORMS
CONTEXT	Within the firm	Within the supply chain	Industry Ecosystems	Industries
NUMBER OF PARTICIPANTS	One firm	Several firms within a supply chain	Several firms who don´t necessary buy or sell from each other, but whose products/services must function together as part of a technological system	Several firms (o groups of firms) who transact with each other, through the intermediary of a double-sided (or multi-sided) market
PLATFORM OBJECTIVES	- To increase the productive efficiency of the firm - To produce variety at low costs - To achieve mass customization - To enhance flexibility in the design of new products	- To increase productive efficiency along the supply chain - To produce variety at lower costs - To achieve mass customization - To enhance flexibility in the design of new products	For the platform owner - To stimulate and capture value from external, complementary innovation For complementors: - To benefit from he installed based of the platform, and from direct and indirect network effects complementary innovation	- To facilitate the transactions between different sides of the platform or market
DESIGN RULES	- Re-use of modular components - Stability of system architecture	- Re-use of modular components - Stability of system architecture	- interfaces around the platform allow plugging-in of, and innovation on, complements	- Not usually addressed in economics literature. Exception: Parker & Van Alstyne (2005) and Hagiu (2007), who address questions that are central to the literature of Industry Platforms
END-USE OF THE FINAL PRODUCT, SERVICE OR TECHNOLOGY	- Is known in advance and defined by the firm	- End-use is defined by the assembler/ integrator of the supply chain - End-use is known in advance	- Variety of end-uses - End-uses may not be known in advance	- Not usually a variable of interest in the economics literature
KEY QUESTIONS ASKED IN THE LITERATURE	- How to reconcile low cost and variety within a fim?	- How to reconcile low cost and variety within a supply chain?	- How can a platform owner stimulate complementary innovation while asking taking advantage of it? - How can incentives to create complementary innovation be embedded in the design of the platform?	- How to price the access to the Double-sided (or multi-sided) market to distinct groups of users, to ensure their adoption of the market as an intermediary?
GVC GOVERNANCE TYPE	**Hierarchy**	**- Producer-Driven** **- Modular**	**- Technology-driven** **- Distinct relationships with first-tier suppliers/ complementors (more relational) and other tiers (more modular or captive)**	**- Internet-oriented** **- Distinct relationships with first-tier suppliers/complementors (more relational) and other tiers (more modular or captive)**

Table 2: GVC Governance and Typology of platforms (Expanded from Gawer, 2009)

In order to organize the Platform research, key researchers addressed questions about platform definitions, platform control, network business model, and platform evolution in 2006/ 2007 (Eisenmann, 2006; Eisenmann et al., 2007).

Platform Mediated Networks (PMNs) are defined as “networks with a triangular pattern of relationships in which two parties to a transaction – network users – each access a common platform that facilitates their transaction” (p.20). They encompass the common (i) components, including hardware, software, services, and the architecture of the components; and (ii) rules employed by network users in most of their interactions, including standards, protocols, policies, and contracts. The interactions are subject to network effects. There are three main roles in PMNs: (i) platform providers, mediators of network users´ interactions; (ii) platform sponsors, holders of platforms´ technology that can determine who may participate in which role; and (iii) platform component suppliers, offers of products and services. Based on these roles, many structures can be set. The platform may have one or more providers; as well as one, more than one or no sponsors. They can be more “open” or “closed”, and different levels of compatibility and interoperability. The degree of openness/ closeness may vary on each role (Eisenmann, 2006).

Multi-Sided Platforms (MSPs) have a related, but different definition: “an organization that creates value primary enabling direct interactions between two or more distinct types of affiliated customers.” (p. 2). This definition does not include network effects, what has many implications. The authors that use this concept argue that the presence of network effects on previous definitions of two/ multi-sided platforms/ networks suffer from over-inclusiveness, when consider just cross-group network effects in at least one direction; or from under-inclusiveness, when require cross-group network effects in both directions. It is important to note that many intermediaries with significant cross-group network effects are not multi-sided platforms. Cable TV, department/ retail stores, supermarkets, movie theatres and retail service firms aren´t MSPs as they take over control over exchange. Stock photo companies (e.g. Getty) aren´t MSP for a different reason: the exchange is not directly between the parties, but both with the intermediary (Hagiu & Wright, 2011).

The definition presented in the previous paragraph stresses different aspects of the platforms. MSPs´ “organization” can be identified with PMNs´ sponsors, not with traditional concept of private firm, government or NGO. As their primary source of value comes from the direct interactions (e.g. dating websites), some business that may promote direct interactions but are not on of their core activities (e.g. sports clubs). Direct interactions are combinations of communication, exchange, and consumption between members of different sides of the platform. The enabling role is also key, as the interactions happen on or through the MSP. Finally, affiliation is defined as “conscious decision to participate that is specific to the platform and that is strictly necessary in order to be able to direct interact with the other customers types on the platform” (p. 13). Affiliation may demand investments (access fee, opportunity cost in time of inconvenience), be costless or even carry rewards, depending on the structure, role and strategy that the platform sponsor has to attract and retain members for each side of the platform (Hagiu & Wright, 2011).

3.2 Network effects

According to the traditional network effects concept, they exist when "the value of the membership to one user is positively affected when another user joins and enlarges the network" (p.94), and technology adoption, product selection and compatibility decisions (Katz & Shapiro, 1994). Network effects are studied since 1974, but seminal works were produced only on the mid-80s, focused mostly on technology adoption decisions with an economics approach. A new wave of research started to be published on the beginning of the 2000s, with strategy and organizations approaches (Eisenmann, 2006).

The network effects don´t rely only on size and number or participants on each side. Structure (number of possible connections, centrality, structural holes, network ties, number of roles played by each actor, and distinctive capabilities) and conduct (opportunistic behavior, reputation effects, and trust) (Afuah, 2013).

3.3 Digital Platforms

The impact of ICTs, especially the Internet, on business and society is a subject studied by several disciplines with different concepts and theories. As organizations of different industries and governments incorporated these impacts, terms like e-business became less emphasised. Still, some characteristics of pure digital business are important to understand the dynamics of their value chains.

Information goods are any information that can be codified and transformed in bits. Information goods have high costs to be produced, but cheap to reproduce. This characteristic makes digital industries very different from traditional industries in many aspects, including pricing and creation of versions, right management, lock-in strategies, market dynamics (winner takes all), cooperation, compatibility, and standards (Shapiro & Varian, 1998). Digital platforms are based in software: personal computers, video game console, and mobile phones are classic examples. (Evans, Hagiu, & Schmalensee, 2008)

Value chain analysis, Schumpeterian innovation, resource-based view, theory of strategic networks and transaction cost economics have different approaches to value creation. Amit and Zott (2001) identified four **new sources of value creation** that these theories give more or less importance: (i) **efficiency** (search costs, selection range, symmetric information, simplicity, speed, scale economies, etc), (ii) **complementarities** (between products and services for consumers, online and of-line assets, technologies, activities, etc), (iii) **lock-in** (switching costs – loyalty programs, dominant design, trust, customization, etc-, direct and indirect positive network effects) and (iv) **novelty** (new transactional structures, new transactional content, new participants, etc) (Amit & Zott, 2001).

For this paper, Digital Platforms are Multi-Sided or Industrial Platforms that connect different sides based on a digital infrastructures (e.g. application stores, internet auctions) and/or digital standards, languages and tools (e.g. operational systems, development kits).

4 DISCUSSION

In this section, digital platforms are put in context of the three governance approaches (driving, coordination and normatization).

4.1 Digital Platforms and Driven Governance types (Buyer, Producer, Internet, Technology and Alliance)

Digital Platforms can be viewed as synthesis of internet and technology driven types, as shown in table 3. As there were some similarities and distinctions between buyer-driven / producer-driven and platforms that can be important for further analysis.

Buyers and Producers make the transaction (buy or sell) usually physical products or not digitally reproducible services (with its cost of production and operations) with the previous/next player of the chain. Digital Platforms deal mainly with bits, not atoms. Their relationship with the suppliers/components is not as a buyer, but as representative of the buyers; as well as they represent the sellers, but do not have a physical product on stock that they had to buy and stock.

Platforms have economies of scope and scale simultaneously, and can customize multiple front-ends according to their diversity of the customers. The unlimited shelve space (but limited consumer attention) posed new challenges about the gatekeeping/curator role of the platform leader. As costs and complexity to affiliate to a platform decreases, managing the infrastructure needed to serve the participants and manage the community of suppliers and consumers is anos another challenge, very different from the challenges of traditional buyer or producer-driven chain leaders.

Alliance-driven chains type was not included in this comparison, as it focus on other dimensions. Still, its main idea – the leader has to share the risk and the gains in turbulent markets – is also true in some digital markets. As platform markets tend to have extreme market share concentration (the winner takes all), standards are subject to intense negotiation between the players involved, and alliances explain the success or failure of several technological/market battles (e.g. VHS versus Betamax). Past performance does not guarantee future performance: Microsoft was very successful in PC, at a point of being accused of monopoly behaviour; but was not able to be a relevant third player in mobile devices (yet).

AUTHORS	Gereffi 2001b, 2001a	Gereffi 2001a	Gereffi 2001a	Gereffi 2001b	Gereffi 2001b
GOVERNANCE TYPE	Leading industries and timing, main drivers / Economic sectors, typical industries	Core competencies, barriers to entry and main rent types	Ownership of manufacturing firms and main network links	Institutional an organizational innovations	Form and dominant principles of chain integration
PRODUCER-DRIVEN (GEREFFI, 1994)	Natural resources: late 19th & early 20th centuries Capital goods and consumer durables: 1950s and 1960s Transnational manufacturers Consumer durables, intermediate goods, capital goods Automobiles, computers, aircraft	R&D, Production Economies of scale Technology rents Organizational rents	Transnational firms Investment-based	Vertically integrated TNCs with international production networks Mass production Lean production	Vertical Integration (ownership and control)
BUYER-DRIVEN (GEREFFI, 1994)	Consumer nondurables: 1970s and 1980s Retailers and Marketers Consumer nondurables Apparel, footwear, toys	Design, marketing Economies of scope Relational rents Trade-policy rents Brand name rents	Local firms, predominantly in developing countries Trade-based	Growth of export processing zones Global sourcing by retailers Rise of pure marketers Rise of specialty retailers Growth of private labels (store brands) Lean retailing	Network Integration (logistics and trust)
INTERNET-DRIVEN (GEREFFI, 2001)	Services (B2C) online – online retailing, online brokerage / Intermediates (B2B) – autos, computers 1990s &2000s Internet infomediaries (B2C market) and some established manufacturers (B2B Market)			Rise of e-commerce Mass Customisation Disintermediation: direct sales (skip retailers), online services (e.g. brokerage) New internet navigators	Virtual Integration (information and access)
TECHNOLOGY DRIVEN (Ó RIAIN, 2004)	Information and Communication Technologies (ICTs) Software, video games, computers	R&D, Design, marketing Control over technical standards Technology rents Organizational rents Relational rents Brand name rents		Increasing returns over dominant design Coordination of increasingly complex networks.	
PLATFORMS	**Platforms for development and distribution 2000, 2010s. Both internet and technology driven economic sectors**	**R&D, Distribution Economies of scope and scale, IP/standards**	**Firms with links with both producers and consumers**	**Industry Ecosystems, Multi-Sided Makets/Platforms**	**Platform Integration (control, logistics, trust, and access)**

Table 3: Platform Governance versus Producer, Buyer, Internet and Technology Driven Governance Types (adapted and expanded from Gereffi 2001a, 2001b and Ó Riain, 2004)

4.2 Digital Platforms and Coordination Governance types (Market, Modular, Relational, Captive, and Hierarchy)

Digital Platforms have mixed characteristics of the other types:

- Complexity of transactions: High (as Modular).
- Ability to codify transactions: High (as Modular) for most of the participants, Low (as Relational) for key partners/complements, especially during R&D before commercial launching.
- Capabilities in the supply-base: Low barriers allow micro and small participants with low level of capabilities to explore small and very specific needs of the leaders (as Captive) or the market (long tail). Most players have medium or high level of capabilities.
- Degree of explicit coordination: To deal with a
- Power asymmetry: standard process are necessary to deal with the large number of participants. Power asymmetry is High (as Modular) for most of the participants, Low (as Relational) for key partners/complements, especially during R&D before commercial launching.
- Tolerance of distance: High (as Modular) for most of the participants, Low (as Relational) for key partners/complements, especially during R&D before commercial launching. Distance in platforms is not necessary geographical, is more related with the maturity of the clusters on a particular industry.
- Switching costs: platforms are designed to lock-in high volumes of participants, having different strategies to bring and capture volume and value. High switching costs are part of the design, sometimes in a relationship more like relational (with key partners), but mostly like captive. The participant will always try to lower switching costs make them more like modular.
- Volume of participants: platforms are designed to be able to deal with high volumes of participants (as Market and Modular), but maintain a high degree of explicit coordination and power asymmetry.
- Network Effects: high network effects is the reason why platforms attract and lock-in participants. In other governance types, network effects are not important.

The role of "Platform Leader" is cited in modular type governance (T. J. Sturgeon & Kawakami, 2011), but it is more on a supply-chain platform context than an industry ecosystem context.

Platform as a new governance type has characteristics of other five types, but simultaneously; and distinctive characteristics on volume of participants and network effects. Platform value chains are not multi-polar, with different kinds of governance in different nodes along the chain: the platform leader is clearly the lead firm, and has different kinds of relationship with different players.

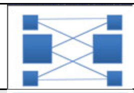
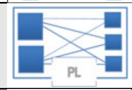
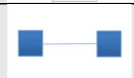
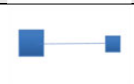
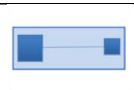
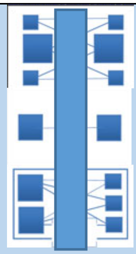
AUTHORS	GHS	GHS	GHS	GHS	GHS	PS	PS	PS	PS	**New**	**New**
GOVERNANCE TYPE	Complexity of transactions	Ability to codify transactions	Capabilities in the supply-base	Power asymmetry	Stylized network form	Requirement of explicit coordination	Tolerance of distance	Switching costs/ asset specificity	Coordination mechanism	**Volume of participants**	**Network Effects**
MARKET	Low	High	High	Low		Low	High (global)	Low	Price	**High**	**Low**
MODULAR	High	High	High	Medium		Low-Medium	High-Medium	Low	Standards	**Medium**	**Low**
RELATIONAL	High	Low	High	Medium-High		Medium	Medium	High	Trust and Reputation	**Low**	**No**
CAPTIVE	High	High	Low	High		High	Low	High	Buyer Power	**Low**	**No**
HIERARCHY	High	Low	Low	High		High	Low (co-located or internalized)	High	Management Hierarchy	**Very Low**	**No**
PLATFORM	**High**	**High (Operations) /Low (R&D)**	**High**	**Medium (R&D); High (Operations)**		**Medium (Operations); High (R&D)**	**Medium (R&D); High (Operations)**	**High**	**Standards, trust, reputation, access to other sides of the platform**	**High (Operations) /Low (R&D)**	**High**

Table 4: Platform Governance versus Market, Modular, Relational and Hierarchy Governance Types (adapted and expanded from Sturgeon, 2002; Gereffi, Humphrey and Sturgeon, 2005 -GHS and Ponte and Sturgeon, 2013 - PS)

The following figure positions Platform in relation to other four types according to complexity of the value addition process and the number of participants of the chain. Hierarchy was not included, as the focus is on the relationship of the lead firm with the other organisations. Still, it is important to remember that Platform leaders do maintain several core activities internal for the same reasons already studied in governance literature.

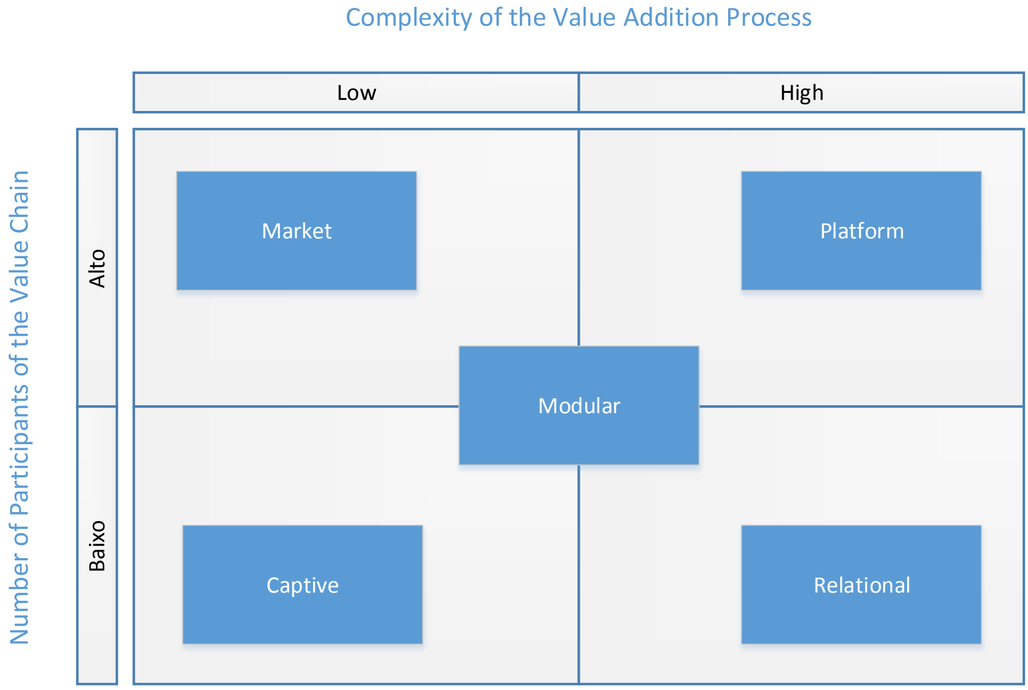


Figure 1: Coordination typology including Platforms according to complexity of value addition process and number of participants

4.3 Digital Platforms and Governance as Normatization

There are six main worth and quality conventions (market, industrial, domestic, civic, inspirational, and opinion), and it is possible to relate the first three to existing coordination types (Ponte & Sturgeon, 2013). On Digital Platforms, the value created on market, industrial and domestic conventions are easier to relate with the new sources of value: transparency and huge volumes of suppliers and buyers enhance market value; standards and modularity enable high productivity; and trust is needed to deal with tacit knowledge and medium/long term projects.

Civic, inspirational and opinion conventions are very important to Digital platforms. As transparency is one of the most increased characteristics of the digital platforms (compared to traditional markets), the "power of crowds" also increases. Crowds of all sides: customers, non-customers, suppliers, general public. New business models, consumer-created innovations and a series of not planned initiatives can arise and the role of regulator/gatekeeper/curator become the main role of the leader. On Table 7, Key features of worth and quality conventions are applied to platforms.

CONVENTION	MARKET	INDUSTRIAL	DOMESTIC	CIVIC	INSPIRATIONAL	OPINION
ORGANIZATIONAL PRINCIPLE	Competitiveness	Productive	Loyalty	Representation	Creativity	Reputation
FOCUS OF JUSTIFICATION	Product units	Plans, systems, controls, forecasts	Specific assets	Negotiation, consultation, distributional arrangements	Innovation, creation	Public relations, media coverage, brand reputation
KEY TESTING QUESTIONS	Is it economic?	Is it technically efficient, scalable, functional?	Does it follow tradition? Can it be trusted?	What if the impact on society? Is it healthy, environmental sound?	Is it new? Is it a breakthrough?	Is it accepted by the public?
MEASURE OF PRODUCT QUALITY	Price	Objective technical measurement	Trust, repetition, history	Social, labour, environmental, collective impact	Spirit, personality, osmotic process	Opinion poll, social media coverage, subjective judgement by expert
EASE OF TRANSMISSION ALONG VALUE CHAIN	High	High	Low	Medium	Low	Medium
RELATION WITH COORDINATION TYPE	Related to market governance	Related to modular governance	Related to relational/captive governance	Not related to a specific form	Not related to a specific form	Not related to a specific form
CHARACTERISTICS IN INDUSTRY PLATFORMS	**Highly transparent, powered by network effects**	**Standards and procedures are key to manage high volumes of participants**	**Trust is key to coordinate complements and first tier suppliers**	**Community management on all sides of the platform (components suppliers, complementors and consumers) develop and maintain relationships**	**Possibility of consumer-created innovations.**	**Social**

Table 5: Industry Platforms and Key features of worth and quality conventions (adapted and expanded of Ponte & Sturgeon, 2013)

5 FINAL REMARKS

As the Internet in central to Digital Platforms, Industrial and Multi-Sided Platform studies can bring substantial contribution to GVCs debate about the impact of internet and related ICTs to GVCs governance, which didn´t evolve significantly since the proposal of the Internet-driven ans technology-driven value chains types. It goes beyond the traditional criticism of chains, regarding the network/ grid nature: the multi-sided characteristic of being the facilitator, not the traditional intermediary, of relationships of different parties.

Few GVC studies were conducted on digital business (offshoring services, digital games, animation, computers), but most of them did not considered the platforms characteristics. One exception (Parker, Cox, & Thompson, 2014) studied the console and mobile game industry and included platform literature to analyse the industry, but didn't expand the coordination model to explain the particularities of digital platform dynamics.

The Platform Leadership dynamics may benefit governance dynamics and how the GVCs change from one governance type to another. An envelopment movement done by the leader of one platform may lead to verticalization of the chains and a more hierarchical mode of governance. There are almost no platform studies on geographic impact of the platforms. One exception (Tatsumoto, Ogawa, & Fujimoto, 2009) has a very interesting analysis of technological architecture (modular versus integral), decoupling and a new collaboration model between the platform leader (and close partners) and the platform-based finished products suppliers. This approach may be useful to future studies of social and economic upgrading in Digital Platforms.

To continue the connection between GVC and Platforms, studies on digital platforms from different industries must be conducted; and there are a lot of cross-fertilization potential to be realized.

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How do some Emerging Multinationals Become Global Leading Innovators

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Abstract

Emerging multinational corporations (EMNCs) have become increasing popular in IB research, with the focuses on (1) FDI patterns of EMNCs, (2) strategy and operations of EMNCs and (3) comparative analysis between EMNCs and MNCs from developed countries. Yet, little is known about how EMNCs have become innovative during its international expansion. Even, the mutual interaction between global strategy and organisational learning is neglected topics for studies on established MNCs (Hotho et al, 2015). This paper seeks to bridge the gap by case studies on two Chinese EMNCs with world leading innovation capabilities. Based on traditional international R&D network (IRDN) theories, the case studies provide frameworks on the establishment, operations and evolutions of EMNCs' IRDN and their paths of development to become global innovators. Combining with organisational learning literature as well as catching-up theory, I provide several propositions on the interaction between innovation strategy and global strategy of EMNCs, which can contribute to both innovation theory and IB literature

Keywords:

Evaluation of global manufacturing networks – a matter of perspective

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Abstract

To remain competitive in an environment of emerging markets and increasing globalization, many companies in the manufacturing industry are facing challenges. Adding new production capacities or adapting existing production capacities of their manufacturing network becomes necessary to realize local production advantages and for serving new markets. In this regard, network configuration alternatives need to be evaluated according to the decision maker's perspective. Thereby, the goal-orientation of each perspective has a fundamental influence on the design of manufacturing sites and their connections. The objective of this paper is to demonstrate the influence of different perspectives on design decisions of manufacturing networks. Therefore, seven relevant perspectives are identified based on current trends in literature. In addition, more than 70 key performance indicators (KPIs) were identified and assigned to the different perspectives. Based on the reference point method and the analytical hierarchy process, a comprehensive approach is developed enabling the evaluation of manufacturing network alternatives according to different perspectives and related KPIs. The KPI-based approach allows for adjustment to manufacturing network and target system specifics using weightings on perspective level and KPI level. The paper is concluded by demonstrating the functionality of the approach using an example.

Key words: manufacturing network, evaluation perspectives, assessment, analytical hierarchy process, reference point method

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1. Introduction

Globalization of markets is an important trend of today's business activities. Especially the manufacturing industry has to adapt to changing business environments to remain competitive (Wirth, 2002). Production capacities are increasing globally, leading to saturated markets. Therefore, customers become more and more selective and develop high requirements towards future products (Witthaut & Hellingrath, 2009). However, globalization also offers many opportunities for the manufacturing industry such as the realization of cost advantages by producing in or outsourcing to low-wage countries. Furthermore, companies can get access to new markets and secure resources such as raw materials and know-how (Blecker & Liebhart, 2006). In addition, economic and political risks can be managed and distributed better by increasing production capacities globally (Spur, 1986). Therefore, companies especially in the manufacturing industry are establishing international production networks and are focusing on their core competences by looking for external partners and suppliers offering production activities which are not related to their core business (Chao et al., 2009). This way, more complex interconnections and manufacturing networks arise (Gehle-Dechant et al., 2010).

Design and management of manufacturing networks is becoming more important for the success of globally operating companies. Depending on the company's targets, related industries, and customers a manufacturing network can be designed and evaluated according to different perspectives such as the shareholder-value or the customer-orientation perspective. No matter which perspective is in the company's focus, a universal approach is needed which allows for perspective-based evaluation and comparison of manufacturing networks.

The aim of this paper is to demonstrate the influence of different perspectives on the manufacturing network configuration. This way, network alternatives can be compared from different perspectives' points of view. Additionally, the orientation towards certain perspectives can be monitored and improvement potential can be identified.

Based on a literature review concerning the evaluation of companies and especially manufacturing networks, seven perspectives as well as related key performance indicators (KPI) are identified which enable the comprehensive assessment of each perspective's target achievement. By integrating the perspectives and KPIs into a hierarchical approach, KPI values are aggregated over perspectives to one goal value which enables the comparison of different manufacturing network alternatives regarding selected targets. To consider the application of this universal approach in specific situations, such as a rapid change of customer requirements, the hierarchical approach allows for adjustments in two ways: adjusting weightings on KPI- and perspective-level to shift the focus on certain KPIs and perspectives as well as adjusting target values for each KPI.

2. Foundation

The main area of application of the approach is on company networks producing tangible goods. According to Zahn (1996) production is defined as a process which transforms inputs into outputs. Skinner (1996) broadening this definition by summarizing all business activities which enable production such as logistics, planning, sales, purchase, research etc. For this paper, the broader definition of production according to Skinner (1996) is used to ensure an assessment not only of processes directly related to production but also of aspects which have an indirect influence.

For enabling production nowadays, many companies design complex manufacturing networks. A network consists of at least two production locations which are connected by material and information flows and were costumer value is added to the final product gradually (Rudberg & Olhager, 2003). Comprehensive evaluation approaches should allow for comparison of diverse manufacturing network alternatives which may differ from each other regarding their number of production sites or locations. Looking at a single production site, differences may exist in capacities, technologies, configurations or other features (Neuner, 2009).

According to Küting & Weber (2006), KPIs are high-density benchmarks to monitor numerically ascertainable facts in a concentrated form in terms of ratios or absolute values. Therefore, KPIs have to meet several requirements; essential are high significance, intelligibility, comparability, as well as a clear definition and assignment. Moreover, the hierarchical structure within a KPI system is a crucial criterion. (Dietrich et. al., 2007; Syska & Böhnisch, 2006; Alicke, 2005)

A KPI system is defined by Reichmann & Lanchnit (1976) as an ordered set of ratios, with each individual element correlating to another (logical and/or computational link), complementing each other and altogether being aligned to a common primary target, which is the goal value in the presented evaluation approach.

To identify relevant perspectives for manufacturing network evaluation, a literature review was performed on production and supply chain evaluation publications using Elsevier's Scopus.com.

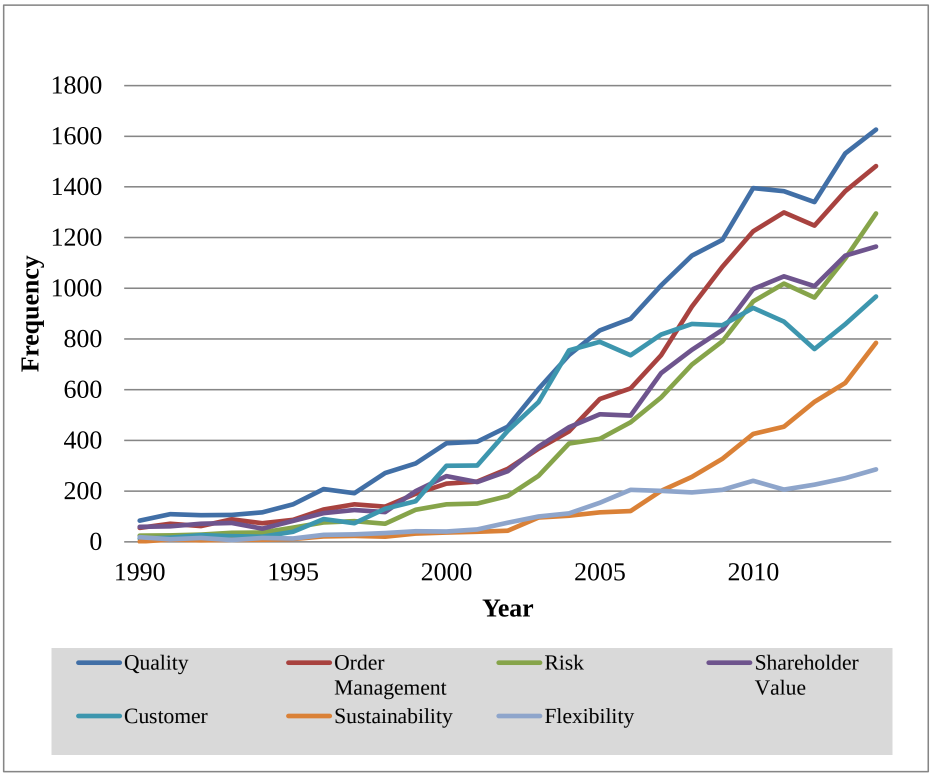

Figure 1: Frequency of term usage perspectives in supply chain and production related literature (Scopus, 2015).

As a result, seven perspectives were identified, namely **quality**, **order management**, **risk**, **shareholder value**, **customer orientation**, **sustainability**, and **flexibility**. The search included all types of documents and was specified for title, abstract and key words. In Figure 1, the frequency of these terms used in a supply chain or production context in the last 25 years is illustrated. Their relevance can be derived from the steady increase of usage until today, which is why these seven perspectives are used as the base of the presented evaluation approach. Other candidates for perspectives, such as "outsourcing" or "robustness", did not feature significant counts featuring publication numbers below 200 in recent years. Furthermore, 75 meaningful KPIs were extracted from the identified publications of the literature review and serve as the basis for the developed hierarchical approach.

3. Multi-criteria decision making problems

To incorporate identified perspectives and related KPIs into a hierarchical evaluation approach for manufacturing networks, a multi-dimensional decision problem is to be solved. According to Geldermann (2015), multi-criteria decision problems can be divided into two groups, namely multi-attribute-decision-making (MADM) and multi-objective-decision-making (MODM) problems. The main difference between both groups is the solution space. While MADM-problems feature discreet solution spaces, MODM-problems feature continuous ones. MADM-problems consist of a number of attributes which can realize a certain number or range of values. MODM-problems are usually formulated as an optimization problem and constraints restrict the potential solution space. All relevant KPIs in this approach can be represented by discrete features and thereby this manufacturing network evaluation problem can be classified as an MADM-problem.

4. Research gap

There is need for complementing existing literature and research state in the following aspects. One important feature of this approach is the focus on manufacturing networks. Many evaluation approaches are developed only for companies as a whole and thereby do not consider interactions with external stakeholders (cf. Werner, 2014). Those approaches mainly include also indicators which do not feature a clear orientation towards production but rather a purely financial orientation. Secondly, the connection between performance indictors and aggregation methods is mostly neglected. On the one hand, approaches such the ones presented by Hanne (1989) and Ude (2010) only focus on aggregation and comparison methods and are neglecting clear definitions of comparison parameters; on the other hand, approaches such as the one presented by Werner (2014) only focus on the definition of performance indicators without making connections between them. Third, several approaches in literature are orientated towards optimization means (cf. Moser, 2014). Thereby, complex systems of equations are needed to describe manufacturing networks in a mathematical way. These approaches are difficult to use and are mostly developed to solve specific problems. Minor changes on the optimization model are rather complex and are not suitable for practical use without the help from experts. Finally, many evaluation approaches only focus on one perspective. For example, Georgoulias et al. (2009) mainly focus on flexibility aspects, Medini et al. (2014) analyse sustainability aspects, whereas Harland et al. (2003)'s approach manly considers risk aspects. The presented approach is contributing to the research field of manufacturing network evaluation by addressing these four identified gaps in literature.

5. Basics about perspectives

In this chapter, each identified perspective is motivated and defined according to the underlying literature. Additionally, the perspectives are structured in dimensions which are used as an intermediate step in the hierarchical approach for better understanding. Detailed definitions and illustrations of all 75 KPIs are omitted since this would go beyond the frame of this paper. However, the hierarchical structure is exemplarily demonstrated for the shareholder value perspective in Figure 2.

5.1 Quality

The quality perspective has become increasingly important during the last two centuries. Meanwhile in the western society, quality aspects are an important success factor for companies leading to competitive advantages (Holger, 2004). The term quality can be defined as the comparison of the actual performance of a company, resulting in a product or service, with customer requirements towards that product or service (Geiger & Kotte, 2008). In this paper, quality aspects regarding material, components, and products are measured by comparing requirements with the performance of manufacturing network entities. Therefore, quality is to be measured internally (i.e. for internal production processes) and externally (towards customers and suppliers). This perspective consists of the following three dimensions:

- The quality of inputs into the manufacturing network is measured in the input dimension (e.g. *material defect rate*).
- In the output dimension, the quality of outputs and therefore, the results of production processes, are assessed (e.g. *scrap rate*).
- The general dimension focuses on indirect factors which can influence the quality of the output (e.g. *employees' education level*).

5.2 Order management

The order management perspective became more important due to today's need of fast and efficient processing of orders. This perspective's main focus is not on the strategic design of manufacturing networks but rather on its operations in terms of the execution of actual customer orders (Wiendahl, 2011). Therefore, the following four dimensions are identified as relevant:

- The focus in the production dimension is on fast, high quality, and efficient production processes (e.g. in terms of *lead time*).
- Fast and cheap delivery without damages or delays is relevant in the transportation dimension (e.g. in terms of *delivery time*).
- In the storage dimension, the focus is on high storage capacity utilization (e.g. *turnover rate*).
- The procurement and sales dimension provides information which goes beyond the borders of the internal manufacturing network. However, there are external influences on the network which are considered within the order management perspective such as *order processing time of suppliers*.

5.3 Risk

Due to the development of highly interconnected manufacturing networks and supply chains, more dependencies between entities exist and thereby accompanying risks occur (von Haaren, 2008). These risks, especially being generated by outsourcing large shares of value adding processes to suppliers and partners, have to be managed and controlled (Clemons, 2000). According to Harland et al. (2003), risk can be defined as the possibility of danger, damage, loss, hurt, and other negative consequences resulting from activities in the manufacturing network. In this perspective, internal risks (e.g. in terms of production downtimes) and external risks (e.g. in terms of supplier shortfalls) are considered and subdivided in the following three dimensions:

- The input dimension covers risks related to input factors (e.g. *material shortage*).
- The output dimension focuses on risk with are related to outputs (e.g. *price development*).
- In the general dimension, all other risks are summarized which are relevant for production purposes.

5.4 Shareholder value

In this perspective, interests of the company's shareholders are considered whose aim is to maximise the monetary value of the manufacturing network.

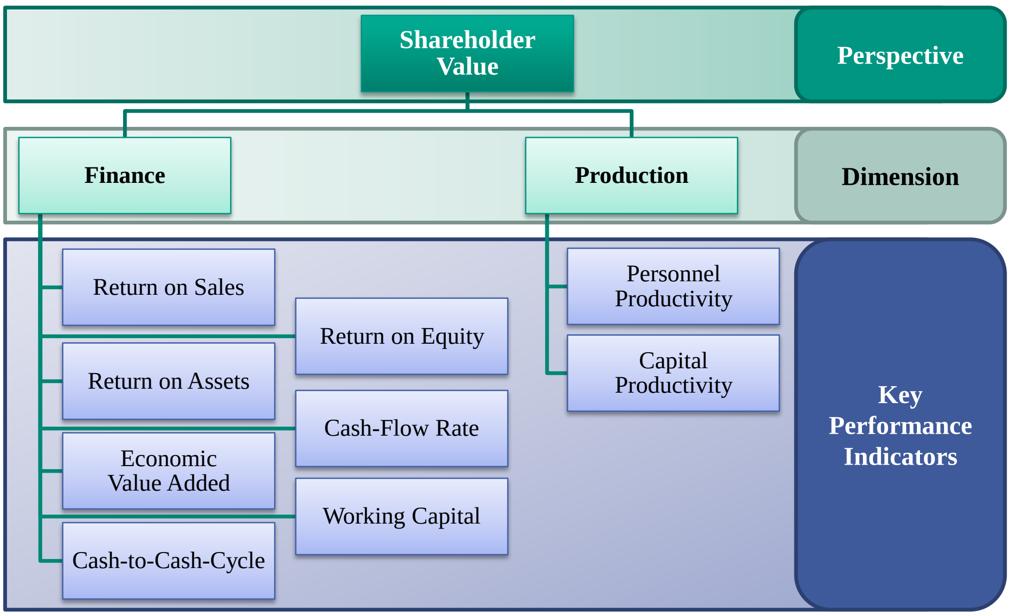

Figure 2: Hierarchical structure of the shareholder value perspective.

To assess shareholder value relevant KPIs, this perspective consists of two dimensions as illustrated in Figure 2:

- The finance dimension focuses on aspects such as profitability and liquidity which can be assessed by several KPIs such as *return on sales* and *cash-flow rate*, respectively.
- In the production dimension, productivity measures of the manufacturing network regarding capital and deployed personnel are assessed.

5.5 Customer orientation

In the 1990s, the change of the customer's position in many markets led to so called buyer markets. This means that customers feature a dominant position due to excessive supply of products and therefore sellers are competing for customers. This development can be seen as main driver for today's importance of company's customer orientation (Varian & Buchegger, 2004). Customer orientation can be defined as a strategy according to which managers and employees are focusing on the needs and requirements of customers (Accounting Dictionary, 2015). In the manufacturing industry, production network design and operation has a strong influence on meeting customers' needs. As illustrated in Figure 3, the following dimensions are used to assess KPIs in the customer orientation perspective of the manufacturing network:

- In the customer dimension, KPIs are characterizing the direct relationship between the company and the customer (e.g. *customer integration* into product development and production processes).
- The market dimension focuses on the appearance of the company as a whole in the market and therefore, also describes the relationship to competitors (e.g. in terms of *market share*).
- In the performance dimension, mainly time and quality aspects are assessed which are relevant for the customer (e.g. *delay rate*).
- In the innovation dimension, opportunities for the company's future success are assessed based on the development of products (e.g. in terms of *innovation rate*).

5.6 Sustainability

Due to stricter legal requirements, sustainability aspects gained more importance during the last decades. Additionally, customers' perception of sustainability aspects is on a rise and can therefore be used to attract customers and to differentiate from competitors by sustainably interacting with stakeholder and the company´s environment (Hon, 2005). According to Medini et al. (2014) sustainability can be assessed by looking at indicators in the following three dimensions:

- The Focus in the economic dimension is on future-orientated aspects which enable the long-term existence of a company (e.g. *rate of continuous improvements*).
- In the environmental dimension aspects such as production input and output as well as by-products are considered (e.g. in terms of *emissions*).
- In the social dimension the relationships to stakeholder such as employees, customers, and suppliers are taken into consideration. Therefore, internal and external relationships are relevant (e.g. *staff fluctuation rate* and *social engagement*, respectively).

5.7 Flexibility

Dynamic markets and increasing uncertainty due to more complex supply chains and market conditions give reasons why flexible manufacturing networks are required (Heger, 2007; Nyhuis et al., 2008). Flexibility aspects have to be considered in an early stage of production planning and product design and therefore are of high strategic importance. Chryssolouris (2005) indicated that 'flexibility of a manufacturing system is determined by its sensitivity to change' and it can be evaluated by calculating the expected cost of accommodating possible changes in the operating environment. The smaller the expected change cost is, the less sensitive the system is to changes in its operating environment and thus, the system is considered as more flexible. According to D'Souza (2000), the term flexibility can be divided into four dimensions:

- Process flexibility can be defined as adaptability of single process steps (e.g. *setup times*).
- Handling flexibility can be defined as flexibility in connections of production processes or single process steps (e.g. *connectivity*).
- Volume flexibility can be defined as adaptability of quantities and lead times according to technical restrictions (e.g. *level of automation*).
- Variant flexibility describes under which conditions production outputs can be changed completely or partly (e.g. *flexibility of staff*).

6. Design of the approach

The design of the approach is based on the analytical hierarchy process (cf. Medini et al., 2014) and the reference point method (cf. Hanne, 1998). As illustrated in Figure 3, the hierarchy of the presented approach consists of four levels.

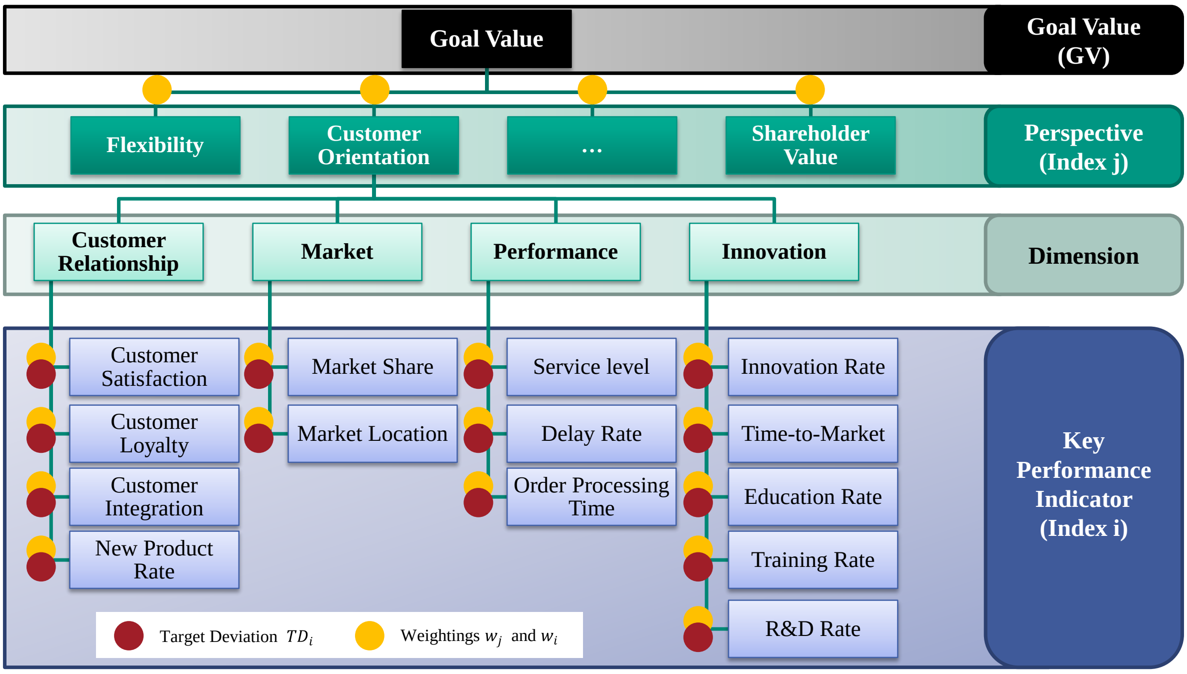

Figure 3: Hierarchical structure of the evaluation approach.

The Goal Value (GV) represents the result of the mechanism on the highest level which can be used to compare different network alternatives. The second level is containing $j\epsilon\{1,\dots,m\}$ perspectives which represent the target according to which a manufacturing network can be designed and operated. The third level holds the formerly introduced dimensions which represent logical groups of $i\epsilon\{1,\dots,n\}$ KPIs for each perspective j. Respectively, these KPIs are feeding in the dimensions and form level four.

On the second and forth level, weightings (w_j and w_i respectively) are applied which are represented by yellow dots in Figure 3. These levels are called weighting levels and allow for adjustments of the approach according to the decision maker's preferences.

By applying this approach, five steps have to be executed which are illustrated in Figure 4.

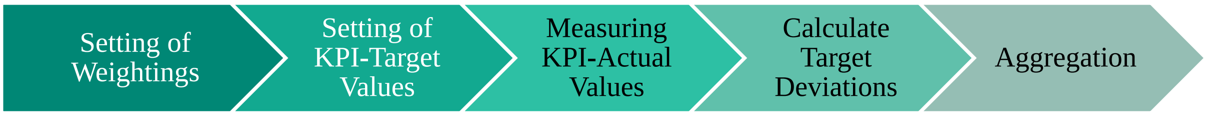

Figure 4: Application steps of the evaluation approach.

First of all, the weightings on perspective- and KPI-level have to be chosen. This way, the company can focus on certain aspects according to their preferences. A simple method which can be used for determining weightings is the pairwise comparison method (cf. Deng, 1999). However, weightings on perspective- and KPI-level have to fulfil the following conditions:

- weightings are chosen in an interval between 0 and 1:

$$w_i \epsilon\ [0;\ 1]$$
$$w_j \epsilon\ [0;\ 1]$$

- sums of weightings on perspective-level and on each perspectives' KPI-level equal 1:

$$\sum_{i=1}^{n} w_i = \sum_{j=1}^{m} w_j = 1$$

A perspective or KPI is called "relevant" if the corresponding weighting is set > 0.

In the second step, target values for KPIs have to be determined. In many cases companies are using KPIs for controlling purposes and therefore already existing KPI targets can be used accordingly. Subsequently, actual or expected KPI values have to be measured which may also be part of the company's common controlling processes. Based on target and actual/expected KPI-values, target deviations (TD_i) can be calculated for each KPI in the fourth step according to the following characteristics:

- If a KPI is to be maximized, the following formula is applied:

$$TD_i = \left| \frac{Target\ Value_i - min\{Actual\ Value_i, Target\ Value_i\}}{Target\ Value_i} \right| \epsilon\ [0;\ 1]$$

- In case a KPI has to be minimized, the following formula holds:

$$TD_i = \left| \frac{Target\ Value_i - max\{Actual\ Value_i, Target\ Value_i\}}{Target\ Value_i} \right| \epsilon\ [0;\ 1]$$

Market share serves as a typical example for a KPI which is to be maximized; an example for a KPI which is to be minimized would be time-to-market. This part of the approach is inspired by the reference point method. In Figure 3, the target deviations are represented by red dots. The precentral target deviation can be interpreted as distance which is used in the reference point method (cf. Hanne, 1998). To ensure that overachievements do not have a negative effect in both cases, the minimum and maximum functions are used.

In the last step, the percentage target deviation TD_i is transformed to a scoring scale, e.g. a target deviation of 5% is transformed to 5 scores. The transformed target is indicated as TD_i^t. Subsequently, scores are multiplied with the respective KPI-weighting and added up to the Sum of All Weighted Target Deviations (*SAWTD*) of perspective *j*. In this sum all *n* relevant KPIs of perspective *j* are considered.

$$SAWTD_j = \sum_{i=1}^{n} TD_i^t \cdot w_i$$

Finally, the *GV* is calculated by adding up the products of $SAWTD_j$ and the corresponding weighting w_j for each perspective *j*.

$$GV = \sum_{j=1}^{m} SAWTD_j \cdot w_j$$

After performing the five steps, a *GV* is the result of the approach which enables comparisons of different network alternatives. It is to be mentioned that the alternative with the lowest *GV* is in favour, since its aggregated weighted deviation of all target values is the lowest.

7. Industrial application

In this chapter, an exemplary application of the presented approach at an international manufacturing company is outlined whereby two different network alternatives are compared. Traditionally, the company is focusing on financial performance indicators which are important for their shareholders. Nowadays, the management recognized that market conditions are changing and therefore, customer orientation should be of higher importance for their business model. The existing network configuration as well as an alternative configuration, which is allowing for higher integration of the customer into the production process, will be compared from the customer orientation perspective. However, the shareholder value was guiding all business activities in the past and therefore is still important for long-term decisions. Therefore, both relevant perspectives will be compared separately to evaluate alternative network configuration from the point of view of a shareholder and a customer driven company.

In the following, chosen weightings are explained in detail to understand the company's situation better. The weightings in the production dimensions in Figure 5 illustrate, that a high *usage of capacities* (15%) is relatively important due to high fix costs which are to be covered. In addition, the *productivity of* the main input factors *capital* (20%) and working *personnel* (20%) are focused on. Both KPIs are compounded by the value of capital (e.g. equity capital) and personnel (e.g. labour costs) in relation to the value of outputs (e.g. turnover) in the defined time period, respectively. To satisfy shareholders, financial targets have to be met in terms of profits compared to sales (weighting of *ROS*: 15%) and to equity (weighting of *ROE*: 10%) as well as a certain *return on investment* (12%). Therefore, respective weightings are set relatively high in comparison to weightings of liquidity related KPIs.

Dimension	Key Performance Indicator	Weighting	Target Value	Actual Value		Goal Value	
				Network 1	Network 2	Network 1	Network 2
Production	Capacity Usage	15%	96	90	96	0,158	0,247
	Capital Productivity	20%	90	85	50		
	Personnel Productivity	20%	95	90	93		
Finance	Return on Sales (ROS)	15%	6	5	6		
	Return on Equity (ROE)	10%	8	5	4		
	Return on Investment (ROI)	12%	5	3	2		
	Cash Flow Rate	8%	5	4	3		
	Economic Value Added	0%	0	0	0		
	Working Capital	0%	0	0	0		
	Cash-to-Cash-Cycle	0%	0	0	0		
		100%					

Figure 5: Industrial application of the approach with shareholder value focus.

The evaluation results for the customer orientation perspective are illustrated in Figure 6. Due to increasing competition, *customer satisfaction* and *customer integration* become more important in the considered manufacturing industry represented by a relatively high weighting of 12% and 15%, respectively. Because of long order processing times for the considered product it is important for customers to have the possibilities to adapt features of an order according to new market conditions or technical developments which can be seen as high level of integration. In addition, management aims to increase *service level* (10%) and to avoid penalties for delivery delays (weighting of *delay rate*: 15%) since issues in both fields are are causing lower profitability. Furthermore, shorter processing times are desirable due to increasing demand and fast changing customer requirements (weighting of *Order Processing Rate*: 13%). To remain competitive from a technological point of view, a sufficient amount of earnings has to be reinvested into research (*R&D-Rate* weighting: 7%) for innovations (*Innovation Rate* weighting 7%).

Dimension	Key Performance Indicator	Weighting	Target Value	Actual Value		Goal Value	
				Network 1	Network 2	Network 1	Network 2
Customer Relationship	Customer Satisfaction	12%	100	95	97	0,713	0,677
	Customer Loyalty	8%	100	90	95		
	Customer Integration	15%	15	5	14		
	New Customer Rate	0%	0	0	0		
Market	Market Share	8%	60	51	53		
	Market Location	0%	0	0	0		
Perfor-mance	Service Level	10%	100	100	100		
	Delay Rate	15%	1	4	5		
	Order Processing Rate	13%	3	5	3		
Innovation	Innovation Rate	7%	70	60	60		
	Time-To-Market	5%	3	4	4		
	Education Rate	0%	0	0	0		
	Further Education Rate	0%	0	0	0		
	R&D-Rate	7%	3	2	2		
		100%					

Figure 6: Industrial application of the approach with customer orientation focus.

Both, Figure 5 and Figure 6 list the KPIs of each perspective, corresponding weightings, and target values. In addition, actual values for both network alternatives are provided, representing the actual status of the manufacturing network (Network 1) as well as a planned alternative configuration (Network 2). As the perspective weighting is 100% for each perspective, the *SAWTD* equals the *GV* for both evaluation sheets. Looking at both figures, one can identify that network 1 is preferred from the shareholder value perspective (0,158 < 0,247) and network 2 is favoured from the customer orientation perspective (0,677 < 0,713). With these result in mind, the international manufacturer needs to determine the appropriate weighting w_j for both, shareholder value perspective and customer orientation perspective, to come to a final conclusion which alternative is to be preferred.

8. Sensitivity analysis

Resulting from the Scopus-analysis, customer orientation especially in terms of customer integration becomes more important.

However, other KPIs should not be neglected entirely and therefore a sensitivity analysis of the customer orientation perspective regarding the KPI *customer integration* is carried out for the example of the international manufacturing company since their management is not entirely sure how customers would respond to a higher level of integration into the order fulfilment process. Therefore, different weightings for this KPI are applied in the following and the effect on the GV is analysed. By increasing the weighting for *customer integration*, all other weightings have to decrease, so that the total sum of weightings remains at 100 percent. However, to analyse the influence of one KPI's weighting on the result, target values and actual values of all KPIs as well as the proportion of the all other weightings are remaining the same.

According to Figure 7, one can identify that with the initial weighting of 15% network 2 is preferred over network 1. By increasing the weighting of the *customer integration* KPI, the GV of network 2 becomes even more favourable. By decreasing the weighting of the customer integration KPI, network 2 becomes worse. If the weighting of the KPI is lower than 9.62% network 1 is favoured over network 2.

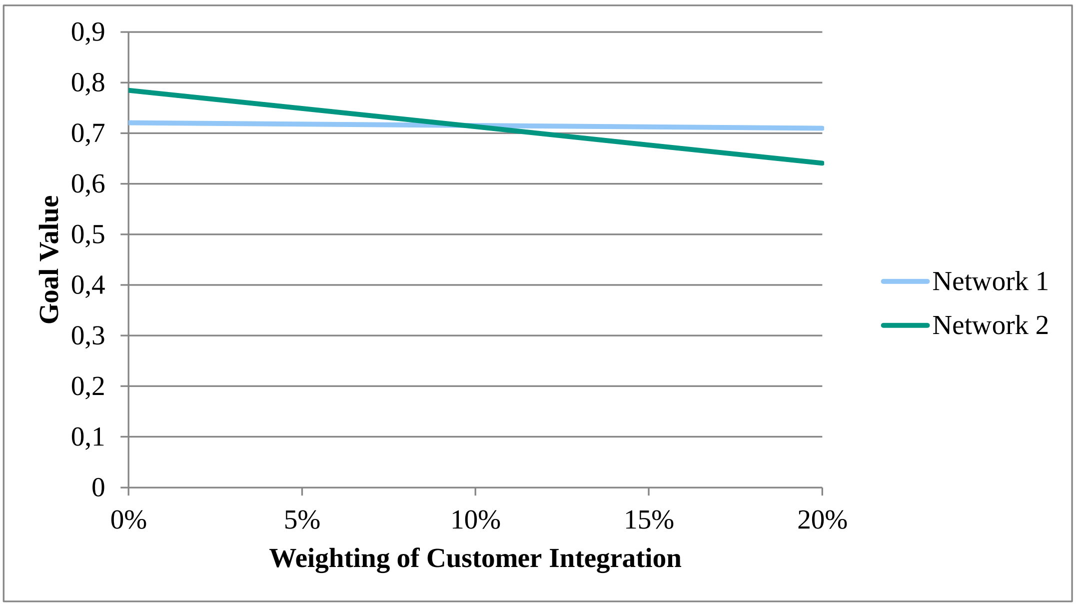

Figure 7: Sensitivity analysis changing the weighting of the customer integration KPI.

9. Conclusion

In this paper an evaluation approach for manufacturing networks is presented which enables the comparison of different network alternatives. Seven targets, so called perspectives, and 75 related KPIs were identified by means of a literature review and serve as the basis for this approach. Based on the analytical hierarchy process and the reference point method, this approach provides a mathematically simple aggregation method of KPIs. Adjustment spaces in terms of weightings and target values enable the application of this approach for a wide range of different industries as well as company sizes. The functionality of the approach and the effects of changes regarding the target deviation were shown in an example of an international operating manufacturing company.

This way, the presented approach fills existing gaps in literature. The approach focuses on manufacturing networks and takes the interaction with external stakeholders into account. Thereby, many aspects which are currently relevant for manufacturing companies are considered in a comprehensive hierarchical approach based on seven perspectives. The hierarchical structure of the approach ensures a clear connection between meaningful KPIs and valuable comparison methods which are presented separately by many authors. Furthermore, the presented approach is mathematical simple and thereby easily applicable. The approach was applied in an example of an international manufacturing company by evaluating two possible manufacturing network alternatives. Furthermore, a sensitivity analysis was executed for demonstrating the effect of weighting changes on the KPI-level. For further research an analysis of further perspectives and related KPIs would be interesting.

10. Acknowledgement

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Green Planet Strategy

- How Social Responsible Multinational Manufacturers Can Create Shared Value Strategies

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Abstract

International manufacturers are facing increased pressure from key stakeholders such as customers, policy makers and investors for adopting more sustainable and social responsible business processes (Gonzalez-Perez 2013). Historically, multinational manufacturers have sought to meet this demand by engaging in various types of corporate social responsibility (CSR) activities (Chen and Bouvain 2009). While CSR might be effective in building stakeholder relationships (Park, Chidlow et al. 2014), the literature on the relationship between CSR and competitiveness is far less convincing. Social responsibility itself does not necessarily bring competitive advantage. On the contrary, most multinational manufacturers view social responsibility exclusively as a cost element (Christman and Taylor, 2006).

More recently, many scholars, and maybe most notably Porter and Kramer (2006), has brought attention to firms that has been successful in devising strategies that create value for the firm *and* society. Porter and Kramer (2006) call this shared value creation (SVC) and advocates for the significant business potential that exists by aligning value creation in firms and the society as a whole.

Even though plenty of examples of SVC, there is still an open question of how, and under which conditions, social responsibility and sustainability strategies can build profitability and competitiveness for international manufacturers.

This study seek to address this question by studying two multinational manufacturers that are reaping significant international competitive advantage from deploying a sustainability strategy. The first company – Stormberg – is a relatively new, fast-growing manufacturing firm in the sports and outdoors industry. The second company – Marine Harvest – is the largest salmon farmer in the world.

Both companies have intentionally chosen their shared value creation strategy from a range of viable alternative options with comparable, or even better, profit potential in the short run, but remains confident that their choice will render them superior international competitiveness in the longer run.

We call this Green Planet Strategy and, inspired by the Blue Ocean Strategy framework (Kim and Mauborgne, 2005), we offer strategic tools that other multinational manufacturers can use if they want to follow their example and create strategies that are not only beneficial for the firm's international competitiveness, but also create significant value for the global society and environment.

Introduction

Despite the fact that the global economy has experienced extraordinary growth over the past few decades, we face multiple challenges related to the sustainability of this growth. Many of these challenges are materialized through environmental issues such as unsustainable use of natural resources, carbon emissions or pollution, or social issues such as unsustainable use of social and human resources (Engle 2007, Dam and Scholtens 2008).

International manufacturers, like all other firms, need legitimacy for their activities (Wood 1991), and they increasingly experience pressure from key stakeholders to address sustainability challenges (Gonzalez-Perez 2013). Historically, multinationals have sought legitimacy and social licenses through various Corporate Social Responsibility schemes. These schemes might create great value for society, but often contribute little to increased competitiveness of the firm.

Recently, Michael E. Porter and Mark R. Kramer have argued that this does not need to be the case (Porter and Kramer 2011). On the contrary, they argue that sustainability challenges should be regarded as a great opportunity from which proactive firms can create values for themselves as well as for society.

Even though Porter, Kramer and others have presented many examples of firms that have successfully implemented shared value strategies, we can hardly say we experience a SVC revolution among international manufacturers. That might be due to the newness of the concept, but it is also likely that it is due to lack of managerial tools combines with the effect that top managers in typical manufacturing firms feel estranged by high-flying examples of philanthropic firms that, for them, are unrealistic. In order to explore the real potential of SVC we need more mainstream examples of typical manufacturers that are doing good and development of managerial tools that they can use.

This study investigates two international manufacturers – Marine Harvest and Stormberg - that has built a shared value strategy and building significant international competitiveness by addressing the most pertinent challenges in their respective industries. Based on Blue Ocean Strategy (Kim and Mauborgne 2005) we develop a strategic tool for international manufacturers that wish to develop sustainability strategies. Inspired by Kim and Mauborgne, we call this Green Planet Strategy.

Theory

Some argue that International manufacturers are a major source of global environmental and social problems. According to anti-globalizers, the globalized manufacturing industry moves resources and labor demanding industrial processes that mine into social and natural resources in low cost regions. And to a certain degree they seem to be right (Dam and Scholtens 2008).

However, from another perspective, multinational companies must be viewed as a part of the solution to the same problems. Arguably, the increased mobility of industry has created enormous growth in less developed regions. The UNCTAD World Investment Report consistently has found the majority of foreign direct investment going from developed to developing countries (UNCTAD 2015), contributing to the extraordinary and consistent economic growth we have witnessed in developing countries over the past few decades. More than that, international manufacturers are better equipped than any citizen, governments or NGOs as they are closer to the problem. MNCs normally have significant impact on local communities in which they operate because of their size, resources, international experience and direct interaction with the community.

As we can see, international manufacturing firms may represent the source of many problems, but also the solution to them. However, in order make them the part of the solution we need to change focus from CSR to SVC.

From Corporate Social Responsibility to Shared Value Creation

External stakeholders increase pressure and impose regulations on the actions of international manufacturers – especially in developing countries – in order to control activities and increase accountability social and environmental impact (Chen and Bouvain 2009). Consequently, CSR has emerged as an inescapable priority for managers all over the world, and has even become a part of some firms' business strategies (Porter and Kramer, 2006). However, the perception of CSR varies and the term CSR has evolved over the past six decades (Gonzalez-Perez 2013). The meaning of the term depend on factors such as demography, culture, economy, firm size, and the character and values of leaders and top management teams (Waldman, Sully de Luque et al. 2006, von Weltzien Hoivik and Melé 2009, Laudal 2011). A common denominator seems to be that CSR always includes some charity and responsible stewardship of natural and social resources (Gonzalez-Perez 2013).

Even though the CSR literature is old and established (Carroll, 1999), the role of CSR in international business is fairly new with only a handful of studies published before 2006 (Aspelund, Fjell et al. 2015). This is in close correlation with the increased attention put on the actions of international firms the recent years and it suggests that most firms engage in CSR activities to satisfy external stakeholders or simply to improve firm reputation (Christman and Taylor 2006). Indeed, a recent literature review (Aspelund, Fjell et al. 2015) reveals that there is a significant lack of literature on the relationship between social responsibility and competitiveness among international firms.

The most influential work on social responsibility and competitiveness comes from Michael E. Porter and Mark R. Kramer (2006), which introduced the concept *shared value creation*. Shared value creation implies that, when used strategically, both firm and society can gain advantages from engaging in socially responsible actions. That said, not any given social responsible action will contribute to a competitive advantage. Most often, the effort taken by firms to act responsible is not particularly productive, financially speaking. In fact, most firms consider CSR as an unwanted cost (Christman and Taylor 2006). The concept of shared value creation seeks to describe how firms can incorporate CSR activities to their overall business strategy, so that they not solely represent a cost, but also create value for the firm in terms of increased competitiveness.

The shared value creation approach differs significantly from how the majority of firms engage in CSR today, but it is arguably not a completely new concept (Crane, Palazzo et al. 2014). Previous research has also provided evidence for firms that are able to draw considerable competitive advantage from social responsibility. The unsolved problem though, that discourage managers, is to what extent does these examples transfer to the typical manufacturing firm. In other words, how, and under which circumstances, can a company use social responsibility to create competitive advantage? We argue the answer may lie in adopting a strategic framework specially designed for firms that are locked up in fierce competition and perceive their competitive landscape as set.

Blue Ocean Strategy

Blue Ocean Strategy was introduced by Kim and Marborgne in 2005. They argue that traditional strategic thinking – often adopted by international manufacturers – lead them to *red oceans* – an over-crowded market place characterized by fierce competition were actors see their profits dwindling because industry logic constantly force them to "deliver more for less" (Kim and Mauborgne 2005).

Blue Ocean Strategy explains how firms can break out of the bloody competition of *red oceans* and create *blue oceans* where industry competition is less relevant (Kim and Mauborgne 2005). The perspective presents a range of strategic tools for firms that seek to break reigning industry logic, reconstruct industry barriers and create a new marketplace where new demand can be created, and hence, existing competition becomes irrelevant. We think this type of logic fits well with shared value creation logic and especially for international manufacturers that seek to build a sustainability strategy, but feel constrained by reigning industry logic based on fierce cost competition.

The core of *Blue Ocean Strategy* is called *value innovation.* The defining characteristic of a value innovation, according to Kim and Marborgne (2005), is that it breaks the value – cost inference of traditional strategic thinking. *Value innovations* seeks to simultaneously increase customer value and reduce operation costs (Figure 1).

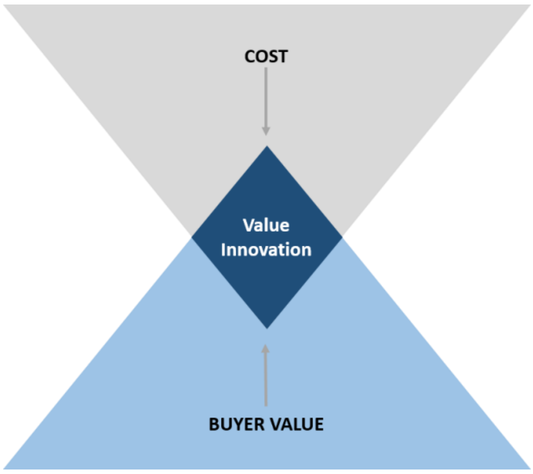

Figure 1: Value innovation

Value innovation – the simultaneous increase in customer value and cost reduction – might seem like an oxymoron, but Kim and Marborgne make a convincing argument that it is those kinds of strategic moves that historically has changed the nature of competition in industries, and consequently triggered new growth.

Now, changing industry's logic, its nature of competition and trigging new growth is an ambitious task for any manager. To help, Kim and Mauborgne presents various strategy tools including the *Strategy Canvas*, the *Four Actions Framework* and the *ERRC Grid*.

The *Strategy Canvas* is both a diagnostic and an action framework to be used to develop a compelling blue ocean strategy. The horizontal axis shows the factors that the actors in an industry compete on. The vertical axis shows the offering level for each competitive factors. The strategy canvas can be used understand the current competitive situation and where competition currently invests. For example, the canvas visualizes which strategic investments that will lead to more competition as coinciding value curves indicate *red oceans*. On the other hand, the strategy canvas can also be used creatively to help the firm reorient its focus into *blue oceans* by looking eliminating, reducing, raising and creating competitive factors. Figure 2 below illustrates an example of a strategy canvas. The bold blue line exemplifies a distinct competitive profile of a firm in a blue ocean.

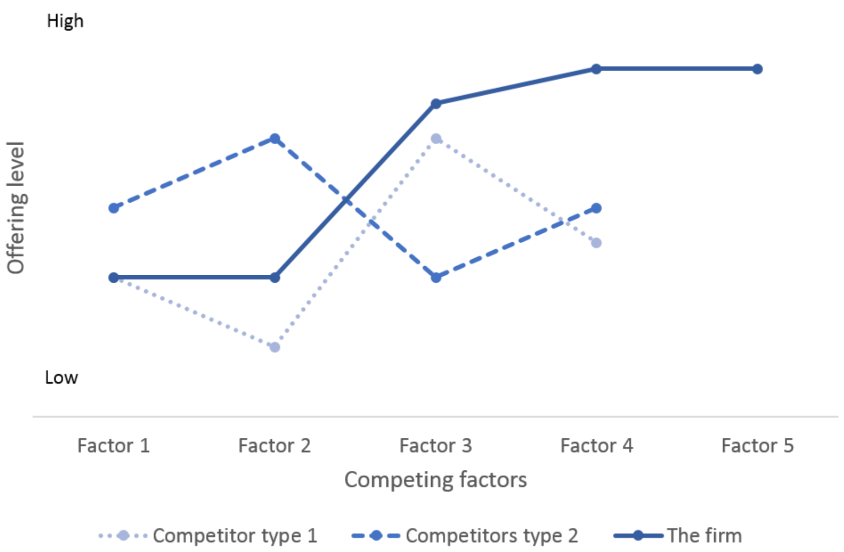

Figure 2: Example of a strategy canvas

The Four Actions Framework intends to help the firm reconstruct the value offering and the cost structure by analyzing existing competitive factors, and hence, which to eliminate, reduce, raise and create (see Figure 3).

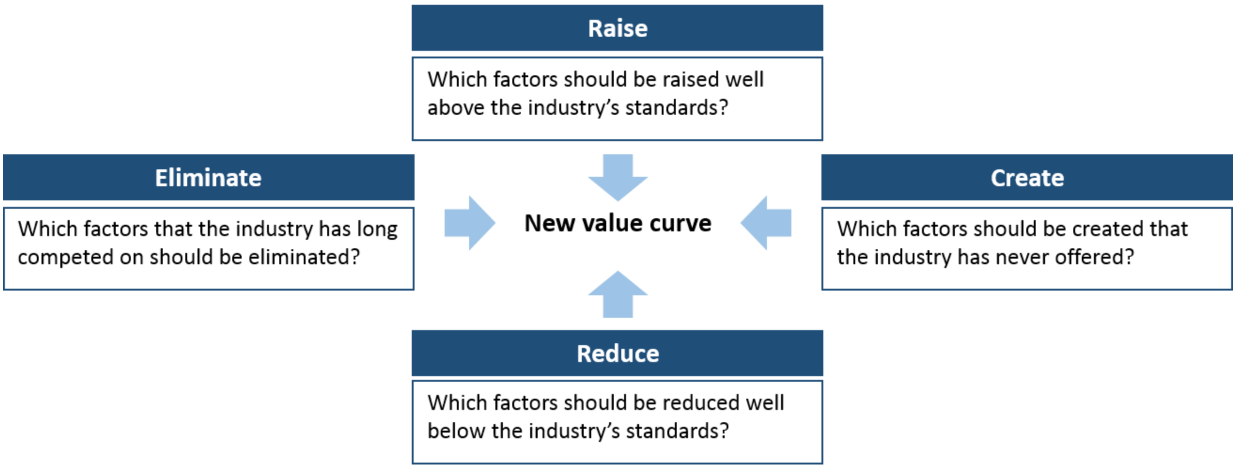

Figure 3: The Four Actions Framework

As figure 3 illustrates, the firm should identify competitive factors that have low value for the customers, and consequently can be reduced or eliminated. Reducing and eliminating elements will help the firm to lower costs in areas that are not highly valued by customers. Furthermore, , the firm must identify the competitive factors that do in fact represent great value for customers, and that should be raised well above industry level. Additionally, the firm should create and offer new elements to customers that have previously not been offered by the industry. Raising and creating elements contribute to increased customer value. Consequently, a value innovation is created.

Finally, the *Eliminate-Reduce-Raise-Create (ERRC) Grid* (see Figure 4) forces the firm to take their thoughts into actions. The grid pushes the firm to pursue both differentiation and low costs, as it becomes evident in the grid if the firm pursues only the one or the other. Creating a compelling blue ocean strategy is difficult, but the grid makes the firm evaluate every competitive factor, helping them to discover implicit and maybe wrong assumptions about industry competition.

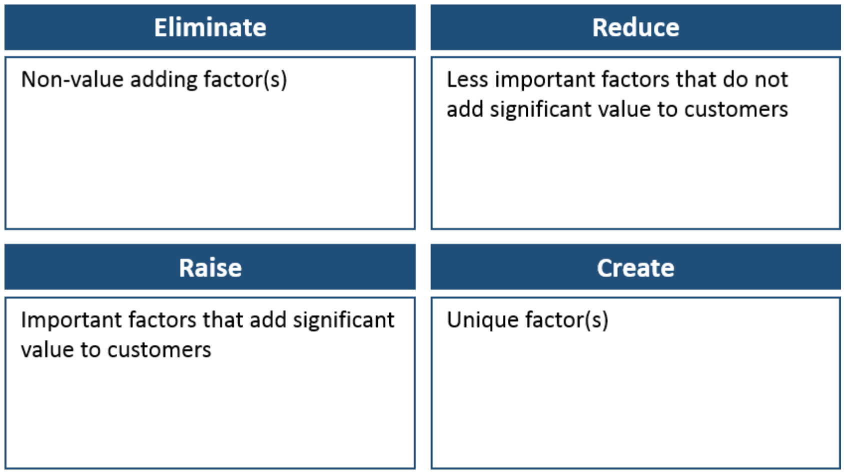

Figure 4: Example of an ERRC grid

Blue Ocean Strategy has become popular in the management literature and widely adopted in firms that are operating typical *red ocean* markets as international manufacturers often are. However, there are few examples where blue ocean strategy has been linked with other managerial perspectives such as CSR or shared value creation. That is our intention in this study.

Method

The research questions of this study is how, and under which conditions, can international manufacturers use social responsibility to create competitive advantage. In order to explore the research question we have used an instrumental case study approach, which is appropriate when we seek to build general theory from case insight. This approach requires an intensive and detailed examination of case data in order to obtain an in-depth understanding. We depend on extensive insight to case firms' business strategy and mindset, operations, market characteristics, motivations and drivers of responsible engagements, their competitive environment, as well as other relevant elements.

We have selected two case firms from convenience sampling (Eisenhardt 1989). A *multiple case study* design was chosen because of its distinct advantages (Yin 2014). A multiple case study is more robust and provides an opportunity for replication, examining whether the different cases have similar or deviating results, or perhaps constitutes a pattern. Further, the method provides the opportunity to investigate under which conditions we can generalize findings. This is especially important for our study as our research question relates to "under which conditions" a given concept may occur.

We selected the cases based on three criteria:

1. An international manufacturer with international activities both upstream and downstream
2. Clear strategic business decisions related to social responsibility

3. The strategy should not be forced on the firm from governmental regulations or other powerful external stakeholders, but rather a strategic option chosen from other viable alternatives.

Based on these criteria we approached the Norwegian sports and outdoor clothing company Stormberg. Stormberg stood out as an obvious choice considering the firm's profile in both social and environmental responsibility. By looking at a completely different industry, we found Marine Harvest to be a suitable case. Marine Harvest is the world's largest salmon farmer, representing one fifth of the global supply of farmed salmon, and one of the largest seafood companies in the world. The fact that these firms represents industries that have received a considerate amount of public criticism for environmental or social irresponsibility added to their appropriateness for this study.

Data was collected through online sources, archival records and interviews with top management in each of the companies. Concerning online sources and archival records, we collected relevant press releases and mass media outputs, company websites, annual reports, reports to shareholders, and policy and mission statements, company blogs, and online presentations. More archival data was available for Marine Harvest than Stormberg as Stormberg is a privately held company and does not need to report to the same degree as Marine Harvest, which is listed on the Oslo and New York stock exchanges. The interviews were semi-structured and open-ended including Global Director R&D and Technical and COO Sales and Marketing at Marine Harvest and Chief Corporate Responsibility Manager and Chief Communication Manager at Stormberg. Interviews were recorded, transcribed and returned to the interviewees for fact and quality check.

Empircal Background - Stormberg

Stormberg is a sports and outdoor clothing company established in 1998 with headquarters in Kristiansand, Norway. They have the vision of "Outdoor fun for all", and aim to manufacture clothes that are functional and good-looking, with a sensible price tag (Stormberg 2015). In the very beginning, Stormberg differentiated little from their main competitors – a strategy they perceived as little sustainable in an industry characterized by *red ocean* competition. Consequently, Stormberg initiated a process to create a new strategy that clearly differentiated them from existing competition.

The Sustainability Strategy

In the strategy process, the firm eagerly sought factors that the entrepreneur and top management was passionate about and simultaneously distinguished them from competition. The sports and outdoors clothing industry has for a long time been characterized as one of the worst industries when it comes to certain environmental and social factors. Intense price competition has seen most actors leave the strict governmental regulations and high costs of Europe and North America and establishing almost all production capacity in less regulated low-cost countries in Asia. Hence, the obvious choice for strategic differentiation, based on the values and mindset of the founder and CEO Steinar J. Olsen, was sustainability and social responsibility. In addition to deliver reasonably priced clothing with good quality, he wanted differentiate the firm based on its environmental and social responsibility.

The Sustainability Innovation

Stormberg's differentiation strategy is explicitly illustrated in their corporate mission "Making the world a better place" (Stormberg 2015) and is based on four corporate responsible elements (see figure 5) - Environmental Care, Fair Trade, Charity, and an Inclusive Working Environment.

Figure 5: Stormberg's four corporate responsible elements.

Environmental Care

Stormberg has put in place various measures to ensure environmental care. First of all, they are a climate neutral company. Even though great environmentally measures are taken, Stormberg has not yet reached their zero vision, so remaining CO_2 emissions are compensated by UN approved carbon offsets. They thoroughly keep track of the carbon footprint of the firm and work continuously to improve throughout their value chain. Second, Stormberg strives to use more environmentally friendly materials and production processes to avoid the use toxic and toxins, which is widely used in the manufacturing of technical outdoors clothing. Furthermore, in all parts of their value chain that they control they have a guarantee of origin of their power consumption using only renewable energy. In order to certify their efforts and work with continuous improvements of their environmental policies Stormberg they partake in several certification schemes – like the Norwegian Government's Climate Campaign, the Green Dot Partnership and the Environmental Lighthouse – to mention a few. Concerning environmental issues Stormberg's *Climate Action Plan* guides the firm at any time, in the aim of achieving their environmental goals (Stormberg, 2015).

Fair Trade

Stormberg emphasises fair trade meaning manufacturing abroad to a healthy social, and economic development for foreign manufacturers and the society they live in. Since 2002 Stormberg has been a member of The Ethical Trade Initiative, which assists Stormberg in facing the challenges of operating in little regulated countries such as China and Myanmar. Ethical guidelines are developed for the firm's upstream activities, which imposes strict requirements for suppliers and manufacturers in terms of working conditions, wages, human rights and anti-corruption. Random factory inspections are carried out several times a year in ensure compliance. Stormberg is also a member of the UN Global Compact Initiative, which obligates the firm with respect to human rights conditions in the workplace, working environment, and anti-corruption (United Nations Global Compact 2015).

Inclusive Working Environment

Stormberg also has a great focus on having an inclusive working environment. This element of the responsible business profile has been evident from the inception, and has been important for the firm's entrepreneur. When Stormberg is recruiting, 25 percent of new employees should be people who have, for various reasons, difficulties getting a job. This 25 percent rule applies to recruitment in all of Stormberg's departments and concept stores. Stormberg has a close collaboration with organizations such as NAV (The Norwegian Labor and Welfare Administration) and Wayback (an organization that helps former convicts back to a normal life) and together they seek to help people with disabilities, psychological health problems, people with drug problems, former convicts and school drop-outs back into work life.

The One Percent

One percent of Stormberg's yearly turnover (exclusive VAT) is reserved for humanitarian and socially beneficial projects (Stormberg, 2015). The donation goes to projects that address social challenges Stormberg feel is relevant for them, but that they are not suited to address them due to lack of resources, competence, or knowledge.

Stormberg's business strategy has since the beginning of the 2000s primarily remained unchanged. However, the activities that constitute the sustainability innovation are continuously evolving and shaped over time. The work to find new measures to include is continuously ongoing, as they find new elements that are affected by the firm's production processes or operations. However, it is what the customers care about, which is the primary criteria for what the firm engages in. Consequently, over time, Stormberg enjoys significant goodwill from aware customers.

Marketing and Competitive Advantage

In 1998, the Scandinavian market for sports and outdoor clothing was considerably smaller than today and dominated by a few high-end brands whose focus was on delivering supreme quality clothing, often for extreme weather conditions and expeditions. Low-end brands existed, but they did not play a significant role in the market. Worth mentioning is also the fact that no other actors in the market emphasized social responsibility in their business strategy.

Stormberg is marketing their products through retail stores, concept stores and through the Internet. These channels provide Stormberg with full control over information flow to customers and they use this opportunity extensively to inform customers about the distinguishing features of their products. Consequently, Stormberg often stands out to be the preferred brand because, all other product features similar, they offer something more.

The response from customers and consumers in Norway has been exceptional. Many customers and consumers in the sports and outdoor market have embraced the brand, both for their reasonable priced clothing, as well as for their social and environmental efforts. Since the start in 1998, Stormberg has grown from four employees and a turnover of 3.8 million NOK to over 400 employees in 2015 and with 377 million NOK turnover in 2013.

Customers of the brand are often very engaged and some feel proud of carrying Stormberg products, especially if it coincides with their own environmental or social engagement. These "Stormberg Ambassadors" are valuable as an active communication channel for the firm. Communication Manager Petter Toldnæs states:

> *"...We have many customers that are important ambassadors for us. There are a lot of people that wear our clothing with pride because they feel that it is important to support someone that shows that they care, and that speak very warmly about us." - Communication Manager Petter Toldnæs*

Advocates of Stormberg are often active on social media and often both promote and defend the firm if subject to skeptical or negative media coverage.

Stormberg themselves also use the Internet and social media extensively to push their message. Through their web site and web shop the firm can to a great extent control the communication that goes out to all customers and consumers. This makes it easier to shift and vary the messages that are sent, and it makes it easier to promote campaigns and create personalized messenges such as: "Thank you! 1% of this purchase is donated to a humanitarian or socially beneficial project. You have now made the world a better place". Additionally, the firm can turn around very quickly to focus on issues currently in the media.

In addition to their own web sites, Stormberg actively uses social media. Facebook and Twitter are most actively used, but they also use Instagram, Google+, Flickr, LinkedIn, YouTube and Pinterest. Facebook and Twitter have daily activity, and these channels serves as the primary communication channel with customers.

Furthermore, Stormberg strives to be as transparent as possible, both upward and downwards the value chain. The firm actively uses their website to shed light on every corner of the organization, such as showing their list of factories in China and Myanmar, which chemicals that are found in their clothing, and numerous other aspects of the firm and products. Such information is not promoted on the front page, but easy to find for those who seek it, and serves as an excellent argument whenever the industry is subject to public scrutiny.

Stormberg has great success in Norway, but is still working on getting the same effects abroad. Their sustainability strategy has proven to be successful and they believe the core of is right, but acknowledge the need for adjustments to each market. For example, they perceive their Swedish customers to be more concerned about design and the German market more concerned about environmental issues.

The socially responsible part of Stormberg's business strategy has been crucial for the firm's development in Norway. Communication Manager Petter Toldnæs notes:

"... Yes, it has (the strategy ref.) differentiated us from other brands. It has not only been profitable, I think it has been absolutely essential for our development. And if you start looking at how our turnover has increased in comparison to others', then it is no doubt that this has been an obvious contributory factor." - Communication Manager Petter Toldnæs

However, the sustainability strategy has brought Stormberg other advantages in addition to loyal and supportive customers. Stormberg's responsible business strategy, with all it environmental and social requirements, compels them to enter long-term agreements and contracts with manufacturers and suppliers. These strong relationships bring with them several benefits, especially in terms of reliability in the supply chain. For example, during the financial crisis, Stormberg did not have one single delay, which is extraordinary in this industry. This is, says CR Manager Jan Halvor Bransdal, exclusively due to the relationships that have been built through the extensive manufacturing and supplier contracts.

"...During the financial crisis, a time of uncertainty and disturbances in the market and where there were delays, people lost money, etc. Then we could make a mark in the roof; we did not have one single delay in that period. That I mean is, and I think that is easy to document, solely a result of good relations to the suppliers. We had been with them for long, they knew they could trust Stormberg. (...) Ergo they could help us with our situation the same way as we had helped them before."
- CR Manager Jon Halvor Bransdal

Marine Harvest

Marine Harvest is the world's leading producer of farmed Atlantic salmon, satisfying one fifth of the total global demand (Marine Harvest 2015). The firm has been in operation for over 50 years, but has changed significantly along the way as a result of several mergers and acquisitions. Today, Marine

Harvest has over 11,600 employees and is present in 26 countries. The headquarters is located in Bergen, Norway, and listed on the Oslo and New York Stock Exchange. Marine Harvest delivers salmon to more than 50 markets worldwide, and is present in all major salmon farming regions around the world (Marine Harvest, 2015). More than 50 percent of their products are sold directly to retail chains or food services such as restaurants and cafeterias. Marine Harvest operates the entire value chain, all the way from fish feed to value adding process, and distribution of the processed farmed salmon. The firm is the first large producer of farmed salmon to have its own in-house fish feed plant, which was opened in Bjugn, Norway in June 2014. With time, Marine Harvest aims to fully integrate fish feed production in their value chain and it is that strategic decision that will be focused in this analysis.

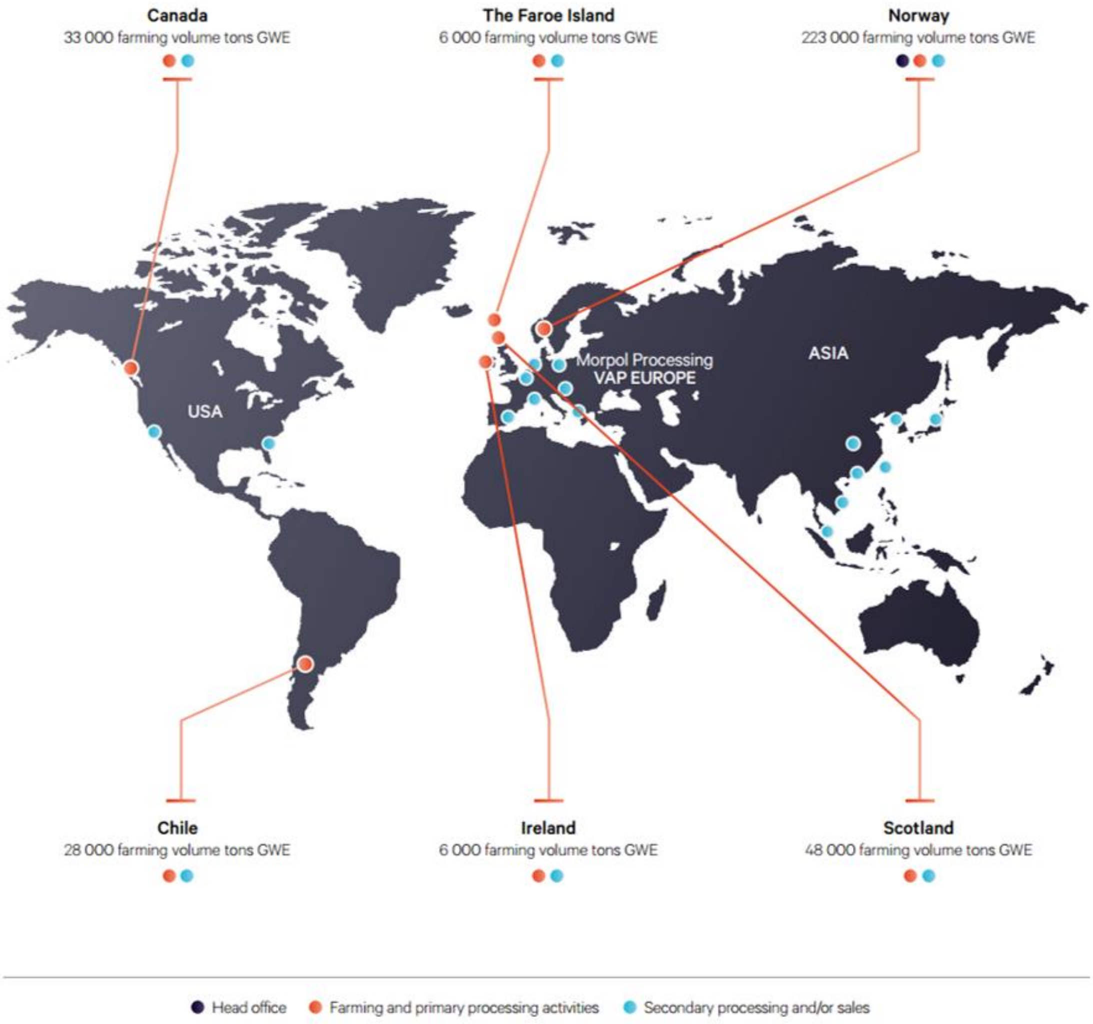

Figure 6: Marine Harvest's global operations (Marine Harvest, 2014).

Fish farming is arguably influencing the natural environment - with issues related to sea floor pollution, diseases and lice, fish escape and genetic blending frequently debated. Arguably, this discussion rages in various forms in all food producing industries, but another debate, which makes salmon farming vulnerable to critique is food safety. Salmon is a fat fish and fish fat accumulates pollutants from the fishes' feed. This process is arguably similar with wild salmon, or any other fat fish, which often has even higher levels of pollutants. Even though farmed salmon shows levels of pollutant far below the governmental nutrition guidelines, many customers are skeptical to eat farmed salmon as they are uncertain about food safety. This perception stems from environmentalist groups that has a tendency to confound the arguments regarding food safety with sustainability in the public debate. Marine Harvest experience that this debate reduces demand for their products in global markets, especially towards alternative protein sources such as poultry, pork and beef.

In the years 2007-2009, the industry was hit by a major crisis. In Chile, salmon farming had grown over a long period without any notable regulatory control. With an uncontrolled outbreak of the viral disease ISA, all actors in the Chilean salmon industry, Marine Harvest included, suffered severe financial losses and had to cut most of the production in Chile. The crisis was a consequence of a production system where best practices for biological principles were not applied, and where the industry grew too fast without sufficient biological control. The crisis in Chile both sparked more awareness among global customers and triggered more responsibility and sustainability awareness in actors like Marine Harvest.

The same trend has occurred regarding food safety. It first became an issue in media in 2004 and the discussion has been recurring ever since. In 2014, the media attention regarding food safety of Atlantic salmon reached a peak and the media took a rather offensive approach. The massive negative attention created uncertainty amongst the consumers. This media attention that started in Norway found its way to the French market, which is one of the most important markets for Marine Harvest. In France, this negative media coverage affected the demand in the market in a way that the firm had never experienced before.

"What happened was that you had the newspaper articles in Norway first (...) which created massive disturbance in the market. Then it started to spread to France and we experienced a real effect on the demand in a way that we had never seen before." - COO Sales and Marketing Marine Harvest

In the beginning, Marine Harvest and others tried to convince customers that media was wrong and the salmon was safe to eat as pollutants were far below nutrition guidelines. However, once the ball started to roll, it was hard to stop. Marine Harvest decided something had to be done differently.

"We experienced that we were continuously in a defensive position, even though we had all possible scientific approvals from the Norwegian authorities. But it was not enough." - COO Sales and Marketing Marine Harvest

The Sustainability Strategy

Marine Harvest has a vision of "Leading the Blue Revolution". The firm seeks to develop the industry by being in the forefront of technology development and transformation of industry practices (Marine Harvest, 2015). Through this work, Marine Harvest seeks to ensure a sustainable food supply to the world's population. They are engaged in a broad range of sustainability activities and cooperate both with competitors and NGOs in order to improve the environmental footprints of their global production. Examples of this is the certification of their production plants from the Aquaculture Stewardship Council (ASC), cooperation with WWF Norway to improve the conditions of Norwegian aquaculture and the Global Salmon Initiative, which unites 15 international farmed salmon producers, to improve the sustainability of aquaculture by reducing environmental impact, increase social contribution and maintaining economic growth (Global Salmon Initiative 2015).

The Sustainability Innovation

Apart from what Marine Harvest is doing in cooperation with other actors in the industry, they also take sustainability measures of their own from which they seek international competitive advantage. The biggest such the past few years in the internalization of feed production and the new approach of cleaning the fish oils used in production of fish feed, thus removing pollutants by about 90 percent from the fish feed.

By cleaning the fish oil in the feed, the extremely low levels of pollutants accumulated in the fish meat renders the official guidelines irrelevant and consumers can eat farmed salmon practically as much and as often they want. Marine Harvest chairman points out that this is not something they do because they have to, but rather because they want to (Lerøy 2014). The first fish feed facility opened in Bjugn, Norway in June 2014 and by fall 2015 or winter 2016, all of Marine Harvest's farmed Atlantic salmon will be fed on diets with oils cleaned for environmental pollutants, with the most effective methods available, as the only farmed Atlantic salmon farmer on the market.

Marketing and Competitive Advantage

The global salmon market is in growth and the global demand is typically higher than the output. However, increases in production comes slow due to biological restrictions and the fact that new production sites and production volumes are subject to licenses provided by national governments. New licenses are often subject to sustainability measures and competition for new licenses are fierce. For example, all new licenses issued in Norway in 2014 had specific requirements for new sustainability technologies.

The consumer market is also characterized by fierce competition. There is little differentiation between suppliers and to the consumer "a salmon is a salmon" regardless of supplier - a typical *red ocean* market place.

As the new generation of salmon from Marine Harvest is still growing in the net cages and has yet to reach the market, we cannot decisively conclude what the market reaction will be. What we know is that no competitors have followed suit, so when the fish reaches the market it will be distinctive.

However, Marine Harvest will be in a very good position to defend themselves against allegations of uncertain food safety the next time the discussion comes to the surface. This competitive advantage does not only apply within the salmon industry, but maybe even more towards alternative protein sources such as poultry, pork and beef. Marine Harvest does not only sees the new clean product as a way to differentiate themselves from competition and being socially responsible, but also as an opportunity to collect higher prices through differentiation.

"We have customers that are concerned about this issue (food safety ref.), and by initiating this measure it is clear that for us it was also an opportunity to create an advantage towards those customers. (…) So it was not only a decision we took because we felt like a responsible corporate citizen, it was also a commercial decision…" - COO Sales and Marketing Marine Harvest

The new strategy included internalization of feed production making Marine Harvest the only large salmon farmer with a fully integrated value chain. Marine Harvest could make this strategic move because of their size and the fact that they – as one of very few - could get economies of scale out of their feed production. Strategically it means lower costs through internalization of feed production, but also reduced dependency of suppliers, ensured reliability and improved cost control. More than that, by controlling the whole value chain Marine Harvest could increase their flexibility to create value adding products, which competitors that still depended on external feed producers can not. COO Sales and Marketing points out:

"So what we are thinking is that by controlling the entire value chain we will have more leeway in order to differentiate ourselves, and to take positions which you cannot take if you do not own the entire value chain." - COO Sales and Marketing Marine Harvest

Marine Harvest is confident that the internalization of feed production and the new products will serve as a distinctive competitive advantage in the years to come. They have developed the new products in close collaboration with their large international customers so they feel confident that food safety products will gain a price premium and create more demand for salmon in general.

Discussion and Green Planet Strategy

Stormberg and Marine Harvest represents good examples of international manufacturers that through sustainability measures can increase thein international competitiveness, and hence, create shared value as proposed by Porter and Kramer. This is arguably not a new finding (Crane, Palazzo et al. 2014). The interesting question remains – how and under which conditions can a sustainability strategy create competitive advantages for international manufacturers?

The first observation that seems to bear great impact on the top management's commitment and ability to back sustainability thinking throughout the organization. Top management commitment differentiate symbolic versus substantive implementation (Christman and Taylor 2006) and substantive implementation is a precondition for actually creating competitive advantage from changes in value creating processes in international manufacturing (Netland and Aspelund 2013).

More than that, it takes a strategic philosophy of either differentiation or focused differentiation (Porter 1985). As we have seen from our cases, even though the sustainability transition in itself might lead to lower overall costs of production, and indeed decreased risk through more reliable production, a pure price leadership strategy would not allow firms to harvest increased customer value that comes from the sustainability shift. On the bright side, a differentiation strategy might help you achieve the ultimate goal, namely to take you out of pure cost competition of *red ocean* markets and into more profitable *blue oceans* if the transition is done well and in the right direction.

Sustainable Value Innovation

The sustainability transition in the firms has come through the introduction of an innovation. The innovations in question has similar characteristics as Kim and Mauborgne (2005) labeled value innovations, except for the fact that they clearly states a direction towards either social or environmental responsibility. Three characteristics seems to be common for sustainable value innovations (see figure 7). First, it targets one of the great challenges of the industry. Hence, it is not an act of charity targeting less relevant challenges of the industry. Secondly, it also targets challenges that are perceived by key stakeholders – especially consumers – as valuable to solve. Finally, the sustainable value innovation should provide both increased buyer value and either reduced cost or risk (or both). Failure of the latter will probably just lead the firm into even redder oceans as thay only offer more for less. All these features were salient in our cases. Stormberg and Marine Harvest target major challenges in their industry, which coincide with relevant consumer worries. Indeed, both companies made sure that solving these challenges where something that contributed to increased buyer value. Furthermore, in both cases the sustainable value innovation contributed with either lower cost or risk. This is most salient in the Marine Harvest case, were internalization of fish feed production in their own value chain contributed to both, but also Stormberg experienced lower risk in supply as a result of stronger ties with main suppliers.

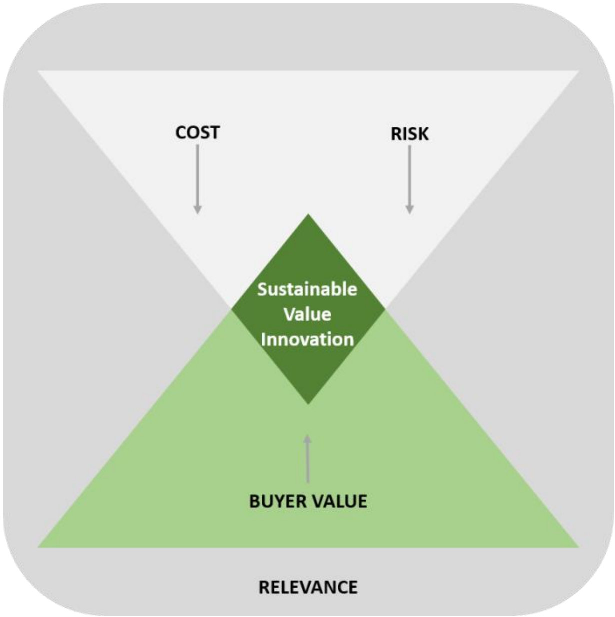

Figure 7: Sustainable value innovation.

Another Blue Ocean Strategy tool that helps to visualize the competitive strength of the strategic change is the strategy canvas. As a consequence of the sustainability value innovation, Stormberg and Marine Harvest have changed their competitive profile by following Blue Ocean logic of eliminating, reducing, raising and creating key competitive elements – predominantly raising and creating factors related to social or environmental challenges. Figure 8 shows Stormberg's strategy canvas. Arguably, the sustainable value innovation has left Stormberg with a distinct competitive profile that renders them competitive with low-end and high-end competitors.

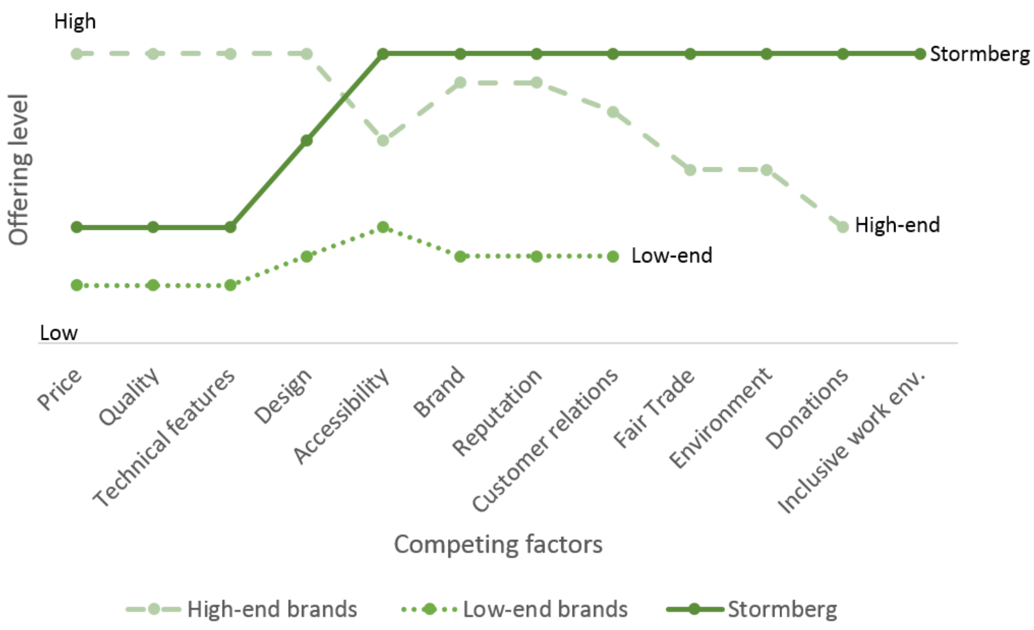

Figure 8: The strategy canvas and value curve of Stormberg.

Similarly, we can draw a strategy canvas of Marine Harvest before and after the internalization of feed production and cleaning of fish oils. We also see here that the factors raised and created are factors related to social or environmental sustainability as well as their increased control of the value chain. Also, in this case the sustainability innovation renders a distinct competitive profile, which raises the general level of competitiveness as well as making Marine Harvest product preferred for a large customer group with food safety concerns.

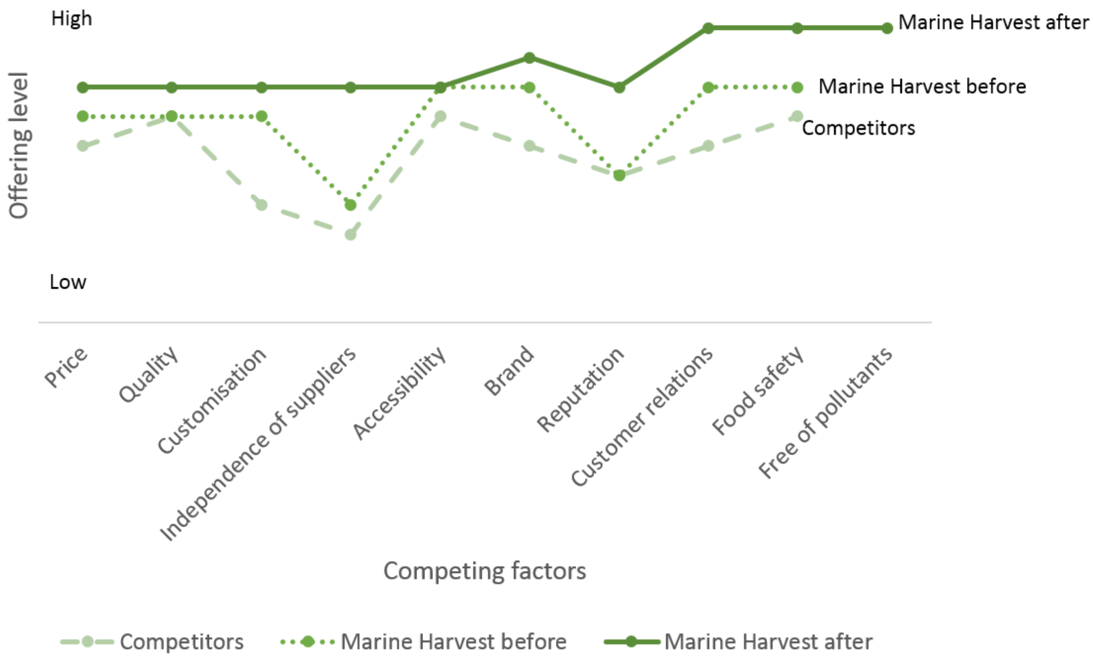

Figure 9: The strategy canvas and value curve of Marine Harvest.

We suggest that the sustainability value innovation model and the strategy canvas could be excellent tools for firms that seek to create a green planet strategy. The sustainable value innovation model delivers guidelines of what characteristics an innovation need to have in order to form the basis of a shared value creation strategy. Furthermore, the strategy canvas visualizes the market potential for the sustainability change and to which customer groups one should target marketing. We also suggest that this rationale indirectly answers our research question: how, and under which circumstances, can social responsibility be turns into competitive advantage.

Conclusions

This study has investigated two international manufacturers that has implemented sustainability strategies that creates distinct international competitive advantage for them.

Both firms have focused on pressing sustainability issues related to their own industries and introduced innovations that increases buyer value and reduces either cost or risk in their manufacturing or supply processes – we call this sustainable value innovation. The sustainable value innovation has provided the firms with a distinct value curve that reduces direct competition and leads the firm into less competitive and more profitable market space. The new value curve has been created by eliminating, reducing, raising and creating value components that forms the competitive landscape in their industries.

We call this way of thinking Green Planet Strategy, and like Blue Ocean Strategy (Kim and Mauborgne 2005) it is a constructivist way of thinking for international manufacturers that seek to create shared value.

The findings of the study is limited by its case study methodology and we invite others to explore the extent of generalizability of the findings through other cases, cross sectional quantitative studies and longitudinal studies.

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Local Water Stress Impacts on Global Supply Chains: Network Configuration and Natural Capital Perspectives

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Keywords: global supply chains, local resource availability, Supply Chain configuration, natural capital theory,

Summary

In this paper we identify how global supply chains (SCs) that serve geographically dispersed markets can impose stresses on the natural resources of specific locations. However servicing global and/or regional markets is not the only factor leading to local resource shortages at the point of production, as pressures from local environments, such as localised effects of climate change, the aggregate impact of local consumption patterns, and levels of urbanisation in the locality also impact on the level of resource scarcity within a given location. Any evaluation of SC vulnerability and subsequent reconfiguration of SCs should take into account the multidimensional structure of local resource availability and the demand impacts of downstream regional/global supply.

This paper seeks to advance understanding of the causal relationships between two non-static factors; namely local resource availability, or more specifically the shortage of water resources, and the demand side impacts of supplying geographically dispersed markets that form the complex global and/or regional SCs of today. In analysing the vulnerabilities of these dynamic systems from a sustainability perspective, the paper builds on theoretical developments in network configuration and design, natural capital, and industrial ecology to suggest design rules for future resource constrained industrial systems.

A case study has been conducted to test the emerging resource availability framework to analyse vulnerabilities and to suggest more sustainable SC configurations. This approach involves a more informed understanding of both local resource availability and the demand-side implications of supplying global/regional markets as part of a more holistic supply chain design activity incorporating local environmental factors. Research findings suggest that this approach might better identify relationships and vulnerabilities between natural resource availability and the viability of regional/global supply chains. Our research suggests that natural resource availability depends upon three elements – local resource consumption, global resource demand, and external environmental factors.

Introduction

As a result of globalisation, national and indeed local manufacturing operations have become increasingly embedded within the global economy. This has facilitated a greater interdependence of countries, in terms of product supply and the natural resources required in the manufacturing and production process for a wide range of commodities, services, and goods (UN 2008).

Global SC networks, however, are increasingly experiencing resource constraints from commodities such as water in a growing number of locations. This has been brought about by the intensification of local resource consumption in order to supply regional and global markets, and local environmental factors that have eroded natural resource levels and/or increased water stress through greater consumption patterns e.g. through population growth. As a result, water quantity and water quantity induced by both global and local factors can carry potential risks for business operations in particular locations.

Over the last decade, several large multinational companies have become increasingly vulnerable to water related risks in their production operations. These risks include water overuse, droughts, flooding, and water poisoning and have all led to changes within the firm's SC.

Examples of *ground water over pumping* have been found in connection with companies such as Coca-Cola (India) (The Economist Times 2007), Pepsi Co (Morrison and Gleick 2004), Nestle – Perrier (Brazil) (The Council of Canadians 2014; Brady 2014), and British American Tobacco (Mexico, Cambodia, Brazil) (CDP 2012). In some cases the issue has caused plant shut-downs; in others it has facilitated the employment of water reduction technologies across the SC through the establishment of dialogue with both users and suppliers.

Severe drought influenced the availability of barley and aluminium for Anheuser-Busch (US) (Wells 2014), which lead to the utilisation of reclaimed water for cleaning purposes, as well as a replacement of plants with more drought-tolerant ones. Prolonged droughts in Brazil forced Solvay (pharmaceuticals, Brazil) (Baida 2014) to close twenty-two output units in Sao Paulo state. Alta Mogiana (sugar processing company, Brazil) (Leslie 2014) supplemented their income with other products, such as electricity generated from burning spent cane stalk. Fbria (textile company, Brazil) (Baida 2014) developed a contingency lab for water education purposes. Recent droughts in California, US (2014) forced MillerCoors (Beverage sector) (Sacks 2014) to switch from metal conveyor belts to plastic ones in order to allow bottles to slide along the belt without any liquid assistance, hence, saving on the amount of water required in production.

Excessive flooding affected British American Tobacco's operations in Malaysia in 2009 (Abdullah 2009). As a result, the company had to import tobacco leaves from other locations to supplement production. In 2011 floods hit a large number of companies with operations located in Thailand. Toyota, Honda, Mazda, Nissan, Mitsubishi, Sony, Nikon, Sanyo Semiconductor, Canon, Western Digital, Hitachi, Hutchinson, and Microsemi were severely affected by the natural disaster and had to halt all production operations (AON Benfield 2012).

Water quality can have an immense effect on the company's production processes. This is a major concern for the food production industry, where food security is of central importance. Poisoned water used in rice fields in Guangzhou, China in 2009 influenced the entire SC. After rice growing was banned in the area most rice producing and processing companies had to shut down or partially halted production (Jiaoming et al. 2013; Guangwei 2014).

This article aims to develop a theoretical framework linking SC configuration to local water resource availability and global consumption through the lens of natural capital theory (NCT). The central units of analysis of the work are SC configuration characteristics, including SC network structure, governance structure, process and information flow, and product structure that all build on theoretical developments in SC design and water availability levels. The quantification of water availability is undertaken through its concomitant characteristics captured in water tables, level of urbanisation, climate change projections, and water quality data. As a result, a supply chain vulnerability assessment framework for local water stress and global supply chain evaluation will be developed in the following sections.

The first section reviews literature on SC characteristics and water availability and quality parameters. The second part focuses on theoretical development of a SC configuration framework from a natural capital perspective. In the third section the framework is tested through a case study. Finally a number of areas for future research are set out.

Resource availability

Consideration of the natural environment and natural resources used in the production and delivery of goods was first developed through Natural Capital Theory (NCT) originally coined in the 1960-1970s (Hanks 2012; Porritt 2007). The theory, based on premises of economic and ecological economic theory (Hinterberger et al. 1997), emphasises the depletable nature of resources and the effects pollution and ecosystem change have on the environment (Faucheux et al. 1997). These effects brought about as a result of economic activity are framed in terms of intertemporal economic costs (Faucheux et al. 1997). Such environmentally disruptive economic activities create irreversible ruptures between short-run performance and long-run prospects for economic output, the resource renewability cycle, and environmental life-support (Faucheux et al. 1997). The current research adapts the NCT perspective on natural resource availability to be used for subsequent SC reconfiguration analysis.

Water supply

The amount of water available for utilisation varies on the geographical features of a region, facilitating the level of natural water supply and replenishment. Some regions are water affluent whilst others are scarce. Water scarcity emerges when there is “an imbalance of supply and demand under prevailing institutional arrangements and/or prices; an excess of demand over available supply; a high rate of utilisation compared with available supply, especially if the remaining supply potential is difficult or costly to tap” (FAO 2013a, 5; FAO 2013b).

Falkenmark et al. (1989) present a water stress index based on estimated water requirements for the household and agricultural sectors, the population of an area, and annual water availability (Falkenmark et al. 1989). The index presents a simple means of estimating water stress by grading regions across four distinct levels: water secure regions, water stressed regions, regions with water shortages, and water scarce regions (see Table 1) (Falkenmark et al. 1992; Falkenmark et al. 1989; Sarni 2011; Bell et al. 2013; FAO 2012; WRI[1] 2013; Rijsberman 2006).

Annual Renewability of Freshwater (m^3 /person/ year)	Level of Water Stress
< 500	Absolute water scarcity
500-1000	Chronic water shortage
1000-1700	Regular water stress
1700	Occasional or local water stress

Table 1. Levels of water scarcity (Adapted from FAO 2012)

Demand for water varies between different countries depending on both sectorial industrial water usage and consumer use, reflected by levels of (disposable) income (Rajsberman 2006). Additionally, external factors such as climatic conditions, water quality, and levels of urbanisation and industrialisation also have an impact on water availability. The index devised by Falkenmark et al., however, does not taken any of these factors into consideration in the classification of a region's level of water stress (Rajsberman 2006). Each of the parameters will be considered in turn.

Water quality

Water scarcity is closely coupled with water quality (Sarni 2011). Generally, water scarcity is only determined by the quantity of water available; however, not all-available water is equally suitable for agricultural, industrial, or private sector purposes. A region may have a water supply of over 1700 m^3/per person/per year but if 90% of this water is unfit for use it would surely be inappropriate to classify the region as water secure. Water quality, therefore, is a relevant factor to be taken into consideration when examining water scarcity problems.

Water quality is defined by its suitability for use (Ayes and Westcote 1976). However, water "always contains measurable quantities of dissolved substances" (Ayers and Westcote 1976, 4) that can deteriorate productivity levels. The level of such substances can substantially affect the level of salinity, permeability, or toxicity of the water (Ayers and Westcot 1976; Ayers and Westcot 1985). Such contaminating substances include cadmium, chloride, chromium, cyanide, nitrite, sodium, and plasticizers (USGS 2014). In certain regions, the implementation of harmful pesticides, fertilisers in agriculture, or inadequate wastewater treatment will frequently result in water contamination. Additionally, water quality can be deteriorated through the "increasing re-use and recirculation of water" (FAO 2012).

Water demand

Water demand can be characterised as the water footprint of a nation or a particular region showing the total volume of freshwater required to produce goods or services that are consumed by the population of the region (Chapagain et al. 2006). Industrialisation plays a significant role in the availability of water in a particular location due to the intensive concentration of the number of industries in the location as well as the level of water demand required for their production operations.

Various industries have different levels of water demand in their production operations (Table 2). Even though the operation process demands of a single operational unit (e.g. a bottling plant) consumes resources within set limits, an industrial cluster within a region, with each unit operating within required limits, can lead to stresses on resource availability. Moreover, if an industrial cluster aims to serve not only the local population but other regions, exporting goods and services, additional stress is placed on local water availability.

The term "virtual water" is used to characterise the amount of water required in the production process of any particular good or service (Allan, 1997; Hoekstra and Chapagain, 2008). Virtual water, embedded in traded goods and services, can save water globally if water intensive goods are produced in high water productivity areas. International trade, however, is usually more concerned with parameters such as: proximity to market, labour, costs, technologies, etc. (Aldaya et al. 2009). As a result of this, water stressed locations are often further deteriorated by international trade activities.

Industry		Materials	Suppliers	Direct	Product use
Food and beverage	Withdrawal Discharge	High Medium	Medium Low (medium for food)	High Medium (high for food)	Medium Medium
Semiconductor	Withdrawal Discharge	High Medium	High High	Low/medium Low	Low Medium
Power	Withdrawal Discharge	High High	Low Low	High High	N/a N/a
Extractive	Withdrawal Discharge	High High	Low Low	High High	Medium Medium
Manufacturing	Withdrawal Discharge	Low to medium Low to medium	Low to medium Low to medium	Low to high Low to high	Low to high Low to high

Table 2. Generalised water footprint by industry sector (Adapted from Sarni 2011)

Urbanisation combined with the industrialisation of a region can have an immense effect on resource availability. According to Postel (2000) global urban water demand is growing year on year, contributing to increasing levels of water pollution (Figure 3). Toxic discharges from cities und upstream industries contaminating water with heavy metals and toxins mean that the water is no longer of a suitable quality (Feldman 2012; Brown and Halwei1998).

	Water use (litter/capita/day)		
Region	Average	Minimum	Maximum
Developed countries – reported or measured	307	130	578
Newly industrialized countries – reported or measured	199	86	366
Developing countries – reported or measured	44	4	400
African countries – reported or measured	31	5	100
Communities in Central& South America - metered	67	25	133
WHO Standard	50	20	100

Table 3. Water requirements (Adapted from Davis 2014)

External factors

Water supply can be influenced by a number of external climatic factors, including climate change, extreme weather events, and El Niño and La Niña.

Climate change is “expected to account for about 20 per cent of the global increase in water scarcity” (FAO 2007, 15). Changes in climate result in increased droughts, heat waves, glacial melting, early springs, early vegetation, increased evapo-transpiration, changing vegetation cover (due to temperature change) in *mid-latitudes,* high snow falls, increased availability of water at *northern latitudes,* and rising water levels due to an increase in global sea levels and prolonged rain seasons (UCS 2011) in the moist tropics at *higher latitudes* (Feldman 2012).

Evidence suggests that extreme weather events have a direct influence on the increased frequency of droughts, floods, heat waves, heavy rainfall, storms, and tropical cyclones (IPCC, 2012). These extreme weather events have a low probability of occurrence (in a particular place and time) but high impact on resource availability (such as water). At the World Economic Forum (2012) extreme weather events were ranked as the second most significant supply chain disruptor (Bhatia et al. 2013), and according to Feldman (2012), frequent droughts, floods, and uneven precipitation patterns are set to become even more extreme (Feldman 2012) in the future, most adversely affecting countries already experiencing water shortages (FAO 2007; Morrison and Gleick 2007).

Events such as El Niño and La Niña have potentially catastrophic impacts on water availability. The nature of these events, in contrast with climate change and extreme weather events, are a result of extreme changes in air pressure. El Niño is caused by higher than normal air pressure (National Geographic 2015a) and results in "fluctuations in temperature between the ocean and atmosphere in the east-central Equatorial Pacific". (NOAA 2014). Heavy rainfall, costal flooding, erosion, droughts, hurricanes, and typhoons are caused by this event. La Niña, conversely, is induced by low air pressure, which results in increased rainfall, floods, and monsoons (National Geographic 2015b). El Niño and La Niña have an irregular frequency of occurrence and normally only occur every two to seven years. Neither event, however, can be strictly predicted (National Geographic 2015a; National Geographic 2015b), and given the enormous impact of such events, events such like El Niño and La Niña carry huge potential risks to SCs and water availability.

These various external climatic factors increase pressure on global production (Cline 2008), especially in countries of the developing world (Feldman 2012; FAO 2013) where water efficient practices are not commonly used. The current research will therefore consider a number of additional factors, including sector usage, industrialisation, urbanisation, and geo-climatic conditions (Abrams 2009; FAO 2012).

SC configuration and reconfiguration

Globalisation has significantly affected SC research with much emphasis placed on SC footprints and geographical spread. Companies have a number of reasons for locating their supply chains in particular regions (Porter 1994). Conventionally, the driving factors were simply cost and proximity to market. However, this ignores the production processes within the SC as well as geographical features of different locations. Water availability has a direct impact on multinational manufacturers, whose main trend is towards regionalisation under a factory-focused strategy (Christopher 2005). Concurrently, retailers, expanding their operations beyond their home bases into international markets, are also experiencing increased pressure due to local resource scarcity. As a result, the geographical dispersion of firms (producers, processors, and retailers), along with uncertainty relating to local resource availability, can impact on the whole supply chain, placing new requirements on SC configuration.

The concept of supply chain configuration was built upon strategic management theory to help align the company's organisational structure with its operational environment (Meyer et al. 1993; Miller 1986; Chandra et al. 2007). SC reconfiguration, conversely, presents the ability to adjust SC structure with environmental constraints in such a way as to allow SC and the environment to "symbiotically coexist" (Beamon 1999, p.336). Thus, analysis of SC reconfiguration parameters can help in responding to increasing pressure due to resource scarcity.

Combining concepts from both strategic and operations management, Srai and Gregory (2008) identified four main dimensions of SC configuration attributes to be considered in supply network design. First, supply network structure considers the number of network tiers involved in the production process, including: supplier tier(s) (raw materials suppliers, secondary suppliers, and direct suppliers), manufacturing tier (pre-processing, assembly, final assembly, and finishing), distributor tier (warehouses, distribution centers, and cross-docking points), retailer tier(s) (wholesalers, retailers, and brokers), and customer tier(s) (B2B and B2C) (Chandra and Grabis 2007; Lambert 2008; Wisner 2011; Bhadada 2013). In a competitive environment, managing the supply network base is crucial as 50 percent of product value is often created by upstream suppliers (Handfield et al. 1999). The company's production operations and processes can also be dispersed throughout a geographical area resulting in a number of different sites (Srai and Gregory 2008; Lorentz et al. 2013; Caniato et al. 2013; Bolstorff and Rosenbaum 2003; Truong and Azadivar 2005). The optimum configuration in terms of network structure considers the geographical footprint of operations including natural resource constraints.

Second, operating in a resource constrained environment SC process flow design analyses resource intensity in its production/assembly operational processes. In some scenarios where resources are scarce process flow design should ration or minimise such resource use (Bell et al. 2012). Another parameter involved in production flow design is resource quality. Industry sectors vary depending on the level of quality of the resource required for production. For example, the semi-conductor, food, beverage, and pharmaceutical industries all require ultra clean high quality water (Soman 2008; van der Vorst 2000; Sarni 2011; Manivaskam 2011). Traceability of the quantity and quality of the resources used in the production process ensures the future safety of the product (Cooper and Lambert 1997; Roth et al. 2008; Christoopher and Towill 2002***)*** as well as security of the natural environment. Closed-loop industrial systems, concerned with the minimisation of the harmful effects of production processes on the natural environment, consider waste recycling and product reuse (Beamon, 1999; Golinska et al. 2007).

Considering product value structure, similar parameters must be considered in the formulation of the product in terms of raw material resources and components. SC product traceability influences the ability to analyse the amounts of the resource in the product as well as the quality of the resource (Roth et al. 2008). Product waste management provides an opportunity to maximise yields and mitigates potential risks of water shortage and environmental degradation (Beamon 1999).

The final SC configuration dimension involves the governance structure and coordination mechanisms of the SC, which refers to the ways in which SC partner relationships are structured and organised (Kattipanya-ngam 2010). Inter-firm relationships can be considered as a flow of resources (Penrose 1959), and inter-firm collaboration has been demonstrated to be beneficial in terms of reducing cost, time and uncertainty (Frohlich and Westbrook 2001; Handfield and Nichols Jr. 2002; Holweg et al., 2005; Simatupang and Sridharan 2005). One of these uncertainties involves resource scarcity, and therefore consideration of the supplier's relationships should be a priority when designing the SC. The internal position of the site in the company's network structure is also a significant parameter in configuring SC structure, including control over assets, the standardisation of operational processes involved, and the facilities available (Barrat 2002; Cooper et al. 1997; Croom et al. 2000; Gereffi et al. 2005; Harland et al. 2001; Srai and Gregory 2008; Waters 2002; van der Vorst and Beulens 2002; Bhadada 2013; Kittipanya-ngam 2010). Water stress locations are a subject of concern for stakeholders (institutional authorities and customers) (Sodhi and Yatskovskaya 2014). The company's reputation becomes vulnerable to resource availability patterns on certain locations. This in turn places pressure on companies to manufacture sustainable products (Beamon 1999; Cox et al. 2003).

Methodology

The methodological development aims to advance the understanding of how global consumption impacts on local resource availability. Here, we develop a bridge between Industrial Ecology literature and SC configuration theory in combination with the Natural Capital perspective in order to generate a set of dimensions for potential resource availability assessment. The conceptualisation of potential influencing factors on resource availability in SC operations design are used to enable identification of SC vulnerabilities and reconfiguration opportunities that can mitigate against identified risks.

SC, within its production operations consumes various natural resources, such as water, air, minerals, etc. For this article water resource was selected to demonstrate linkages between natural capital and SC configuration. An extensive literature review on resource availability, supply chain design, and resource consumption patterns facilitated the development of the conceptual framing of the problem: that a combination of quantifiable factors (local supply, and global and local demand), influence local resource availability, which in turn needs to be managed through an appropriate and sustainable SC configuration and design. This concept is further developed in the framework allowing evaluation of local resource availability for SC configuration (Figure 1).

The framework incorporates a combination of measurable parameters from resource at the supply location, and the resource demands from industry and population. Natural water supply parameters influence water availability levels for subsequent consumption by industry sectors and a community on a given location. Parameters, which are relatively constant (designated as “+” in Figure 1), include geographical characteristics of the given location, which are characterised by: a) long-term climatic conditions (i.e. precipitation patterns); b) natural water replenishment levels (renewability of water yearly); and c) water quality (natural chemical composition of water, including dissolved solids, salts, antimony, barium, beryllium, arsenic, etc. (Figure 1)). External climatic conditions, on the other hand, can have a positive and a negative effect on water availability at the given location (designated as “+/-” in Figure 1) depending on the nature of the event, including: a) changing weather patterns (higher/lower precipitation, rising sea level, prolonged rain/dry season); b) extreme weather events with a low probability of occurrence but a high impact, resulting in droughts, floods, heat waves, heavy rainfall/snowfall, storms, cyclones; c) El Niño and La Niña, which are climatic conditions caused by atmospheric pressure, resulting in heavy rainfall, flooding, erosion, droughts, hurricanes, typhoons, and monsoons (National Geographic 2015a; National Geographic 2015b; NOAA 2014).

The major parameters influencing local water availability (designated as “+/-” in Figure 1)) are production operations located in the area. This is considered from a cumulative sector perspective, including significant production operations of each industry sector and each company within the sector. The consumption pattern of water (quantity and quality needed) by industry sector varies, depending on the production processes involved. Local water availability and water quality can be increased if the production processes involve wastewater treatment or water replenishment steps (+). Another significant industrial factor influencing local water availability is the purpose of production operations a) for local supply or b) for global supply.

Local supply is determined by satisfaction of the local population needs, whereas global supply presents “virtual water” embedded in commodities and moved away to satisfy global demand without contributing to local communities and potentially causing local water stress.

Local water quantity left after industrial intake is shared between community members. Local water availability is mainly determined by the quantity of water available, the level of urbanisation (number of inhabitants), and population income level (see Figure 1). Based on the considered parameters (water availability, urbanisation, and level of income) Falkenmark’s index will be used. As a result, four possible local water availability conditions will be evaluated.

Further, based on water availability levels, SC re-configuration will take place. The network structure (including local supply base and the number of sites in the given location), process flow (including process water intensity, process waste generation quantities, and process water quality requirements), product value structure (including product water intensity, product water quality requirement, and product waste generation), and SC governance / coordination mechanisms (including supplier relationships, customer relationships, institutional relationships, and internal site role in company network structure) should be reconsidered in order to respond to water availability levels for a given location. Each of these dimensions emerge from equivalent factors used in SC configuration ‘network design’ studies (Srai and Gregory 2008) but with the emphasis now refocused on designing for the sustainability of natural resources, and in this specific case, water resources.

In order to test the proposed framework we employed an exploratory case study, based on secondary data, to examine the arguments for SC reconfiguration driven by local water stress.

Case study

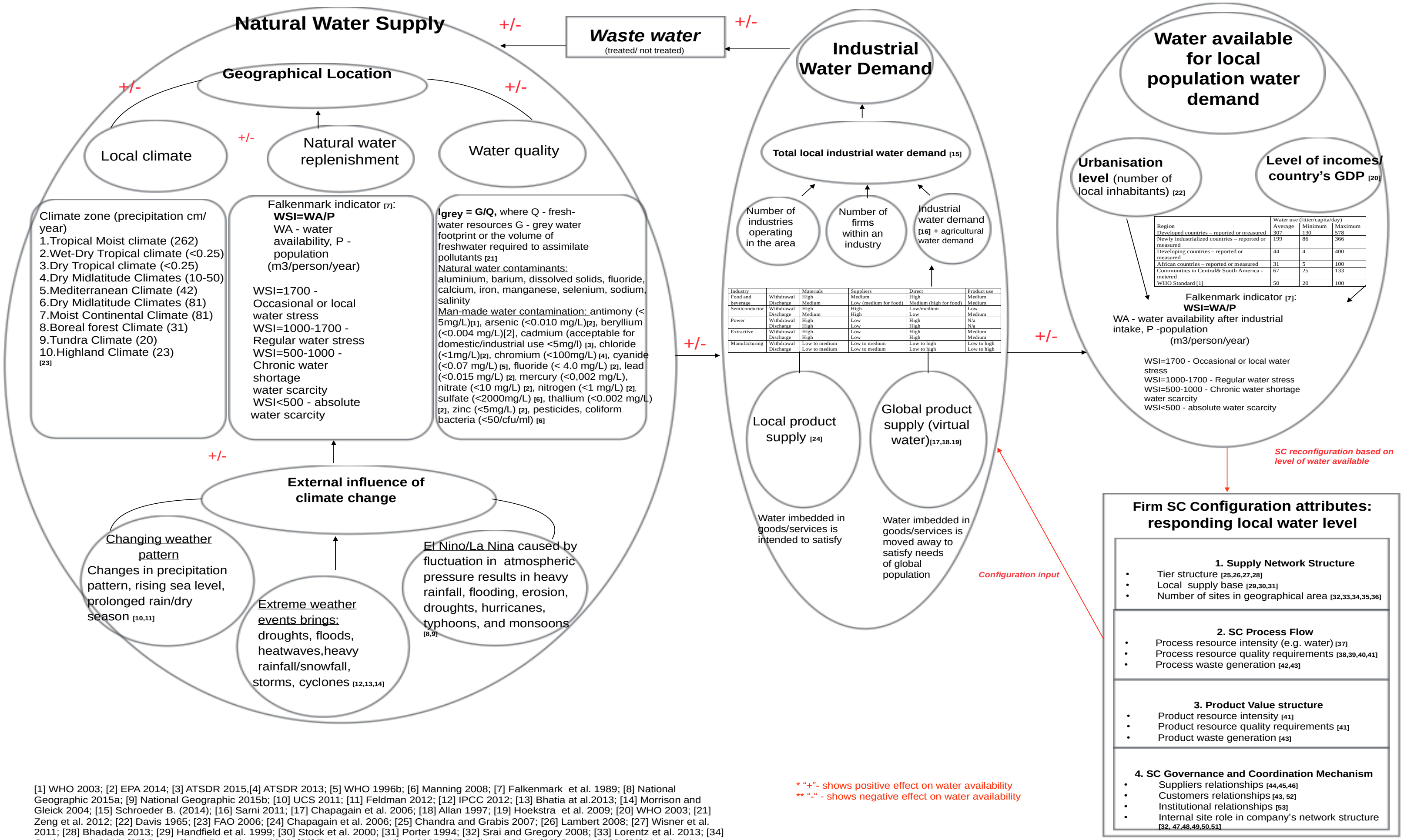
The case selection was determined by its ability to provide a good example of SC reconfiguration strategy as a form of the mitigation of local resource scarcity. Resource shortage at location was primarily caused by a combination of local (changes in climate, population density, water quantity) and global factors (increased SC dispersion and global demand). The study is based on a widely reported historical case of Coca-Cola in Plachimada (India). Data was obtained through secondary sources, including primary data case studies (Hills and Welford 2005; Burnett and Welford 2007, Blacksmith Institute 2014; Sitisarn 2012), reports from the government of India (Jayakumar 2010), Plachimada Supreme court acts (Koonan 2007), and news sources (IRC 2008; RIM 2007; FFFM 2009). These sources of information were chosen to ensure the robustness of the data and to provide potential opportunities to undertake case studies more generally using widely available data sources.

Coca-Cola’s bottling plant in Plachimada, India was operating in this area during the period 1999-2006. During these seven years local water availability significantly deteriorated (HCC BPL 2002). This was caused by three factors. First, Coca-Cola’s bottling operations violated regulations by exceeding abstraction limits (Sitisarn 2010) and releasing sludge, containing high levels of cadmium and lead, onto villages (IRC 2006; Jayakumar 2010). Second, the location of the plant was classified as a severely drought prone area, vulnerable to climate change (Jayakumar

2010). Finally, the district was considered one of the highest, most densely populated areas in the world (Sitisarn 2010). Together these resulted in significant water table depletion and significant water quality deterioration (Rohan 2011). The Kerala State government was forced to close down the plant (IRC 2008; Rohan 2011) and the company chose to reconfigure its supply chain by relocating it's bottling operations from Plachimada to Orissa (The Economist Times 2007) (Table 4).

Parameters	**1999 – before Coca-Cola**	**2003 - during Coca-Cola operating**	**After 2006 - Coca-Cola left**
1) Plachimada natural water supply			
a) Climate zone	Wet-dry tropical climate Average water availability: 3.105 million m^3/year	Wet-dry tropical climate Average water availability: **3.105 million** m^3/year	Wet-dry tropical climate Average water availability: 3.105 million m^3/year
b) Natural water availability	Classified as arable land Water table: 0.65 m	Classified as drought affected area Water table 8 - 13m	Classified as drought affected area Water table start to recover 5-7m
c) Water quality	Acceptable	Contamination with: cadmium (0.02 mg/l), lead (0.065 mg/l)	(2007) Contamination with: cadmium (0.007 mg/l), lead (0.142 mg/l)
d) External influence of climate change	Drought prone area Rainfall 3140 mm/year	Rainfall 1337 mm/year	Rainfall 1835 mm/year
2) Plachimada industrial water demand			
a) Number of industries operating in Plachimada	Agricultural Industry Other industries: N/A	Agricultural Industry Beverage Industry Other industries: N/A	Agricultural Industry - reduced Other industries: N/A
b) Number of operation sites with in an industry		Other industries: N/A Coca-Cola: 1 bottling plant	Other industries: N/A
c) Site's water demand	Agriculture: 2.61 million m^3/year	Agriculture: **2.61 million m^3/year – BDL due to poor water quality** Other industries: N/A Coca-Cola: **0.1825 million m^3/year**	Agriculture: 2.61 million m^3/year- BDL due to poor water quality Other industries: N/A
d) Global water supply vs. Local water supply	Agriculture: N/A	Agriculture: N/A Other industries: N/A Coca-Cola: Regional supply	Agriculture: N/A Other industries: N/A
e) Waste water generation	Agriculture: N/A	Agriculture: N/A Other industries: N/A Coca-Cola: 0.05475 – 0.1095 million m^3/year	Agriculture: N/A Other industries: N/A
3) Water available for population demand in Plachimada			
a) Number of inhabitants	(2001) 54 235 people	N/A	N/A
b) Water requirements	0.9268 million m^3/year	**0.9268 million m^3/year - BDL due to poor water quality**	0.9268 million m^3/year- BDL due to poor water quality
4) Firm SC Configuration attributes of Coca-Cola SC			
a) Supply network structure		Regional plant	Moved the plant to Orissa
b) SC process flow		Water intensive bottling operations	
c) Product value structure		Water and waste intensive product	
d) SC governance and coordination mechanism	On invitation on Kerala government Coca-Cola set up the plant	Consumers: Protest against Coca-Cola plant; Kerala State government: refuse to renew Coca-Cola a license to operate; Coca-Cola case attracts international attention	Imposed to pay compensation

Table 4. Framework verification (Coca-Cola case study)



Industry		Materials	Suppliers	Direct	Product use
Food and beverage	Withdrawal Discharge	High Medium	Medium Low (medium for food)	High Medium (high for food)	Medium Medium
Semiconductor	Withdrawal Discharge	High Medium	High High	Low/medium Low	Low Medium
Power	Withdrawal Discharge	High High	Low Low	High High	N/a N/a
Extractive	Withdrawal Discharge	High High	Low Low	High High	Medium Medium
Manufacturing	Withdrawal Discharge	Low to medium Low to medium	Low to medium Low to medium	Low to high Low to high	Low to high Low to high

	Water use (litter/capita/day)		
Region	Average	Minimum	Maximum
Developed countries – reported or measured	307	130	578
Newly industrialized countries – reported or measured	199	86	366
Developing countries – reported or measured	44	4	400
African countries – reported or measured	31	5	100
Communities in Central& South America - metered	67	25	133
WHO Standard [1]	50	20	100

[1] WHO 2003; [2] EPA 2014; [3] ATSDR 2015,[4] ATSDR 2013; [5] WHO 1996b; [6] Manning 2008; [7] Falkenmark et al. 1989; [8] National Geographic 2015a; [9] National Geographic 2015b; [10] UCS 2011; [11] Feldman 2012; [12] IPCC 2012; [13] Bhatia at al.2013; [14] Morrison and Gleick 2004; [15] Schroeder B. (2014); [16] Sarni 2011; [17] Chapagain et al. 2006; [18] Allan 1997; [19] Hoekstra et al. 2009; [20] WHO 2003; [21] Zeng et al. 2012; [22] Davis 1965; [23] FAO 2006; [24] Chapagain et al. 2006; [25] Chandra and Grabis 2007; [26] Lambert 2008; [27] Wisner et al. 2011; [28] Bhadada 2013; [29] Handfield et al. 1999; [30] Stock et al. 2000; [31] Porter 1994; [32] Srai and Gregory 2008; [33] Lorentz et al. 2013; [34] Caniato et al. 2013; [35] Bolstorff and Rosenbaum 2003; [36] Truong and Azadivar 2005; [37] Bell et al. 2012; [38] Soman 2008; [39] Van der Vorst 2000; [41] Manivaskam 2011; [42] Roth et al. 2008; [43] Golinska et al. 2007; [44] Beamon 1999; [45] Frohlich and Westbrook 2001; [46] Handfield, and Nichols Jr. 2002; [47] Holweg, et al. 2005; [48] Barratt 2002; [49] Cooper et al. 1997; [50] Croom et al. 2000; [51] Gereffi at al. 2005; [52] Waters

Figure 1. Explicit water availability assessment framework for SC configuration

Discussion

Natural capital theory posits that a company's operational processes should be designed from a long-run perspective, enabling the ability to sustain resource renewability cycles and to maintain "environmental life-support functions" (Faucheux 1997, 528). Based on this concept, SC configuration should include assessments of resource availability when establishing the optimal global SC network structure, including natural resource impacts in a particular location. The industrial ecology domain represents a globalised perspective on resource availability assessment within dispersed industrial systems. The integration of these three literature domains has been proposed in order to establish guidance for the design of future industrial systems (Figure 2).

The resource availability assessment framework developed here is based on the propositions that global SCs serving geographically dispersed markets impose stresses on specific local natural resources, and further, that pressures from the local environment, such as climate change, consumption patterns, and levels of urbanisation, also impact the level of resource scarcity within a given location. Therefore, a multidimensional structure of local resource availability and global (downstream SC) demand should be evaluated in a structured manner to inform SC design and subsequent reconfiguration.

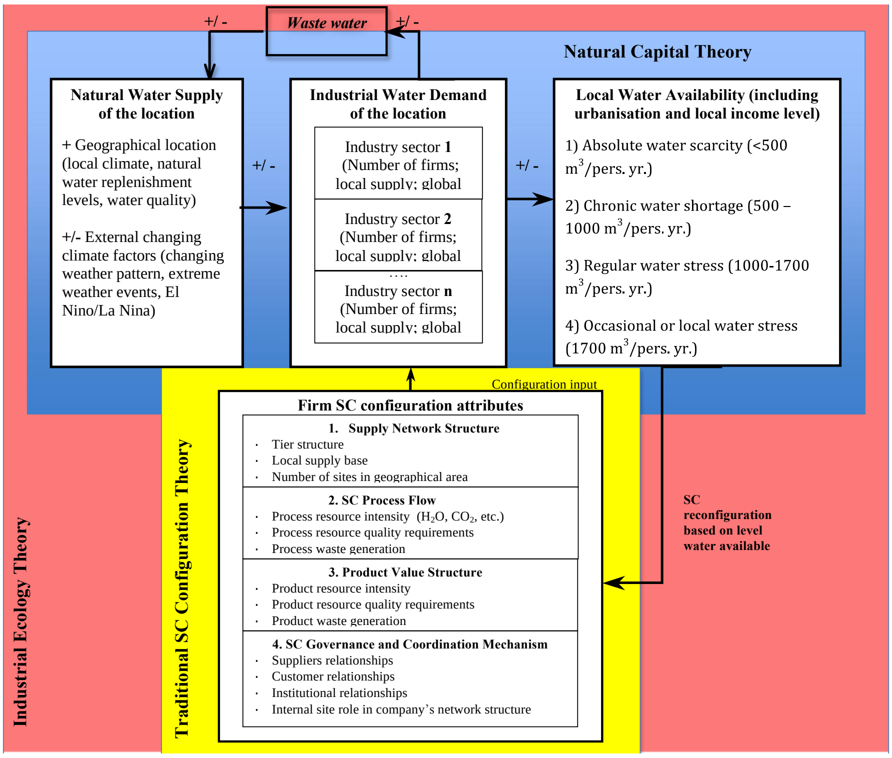


Figure 2. Water availability assessment framework for SC configuration

The case study conducted presents an attempt to test the resource availability assessment framework in order to identify industry vulnerabilities and further propose more sustainable SC configurations. The framework involves explicit representation of both local resource availability and global/regional market demand for comprehensive SC configuration design incorporating environmental factors.

As such, the Coca-Cola case study shows whether industrial problems, faced by Coca-Cola, might be predicted by this framework. The dynamic nature of the framework emphasising three time series considers resource availability before the Coca-Cola plant allocation, during plant operation, and after Coca-Cola left Plachimada.

Evidence shows that the average water availability level in Plachimada equals 3.105 (million m^3/year), which aims to satisfy local community demand (0.9268 million m^3/year) combined with agricultural water needs (2.61 million m^3/year) (Jayakumar 2010). This, however, shows that Plachimada's location had been experiencing water stress (location prone to droughts) lacking on average 0.4315 million m^3/year even before the Coca-Cola site allocation (Jayakumar 2010). Further resource availability assessment shows that the company's water intake (0.1825 million m^3/year) had worsened resource availability within the region. Additionally, during Coca-Cola's operation the quality of water was significantly deteriorated by heavy metals (i.e. cadmium and lead) and sludge from the plant reduced the amounts of water available for domestic and agricultural use.

Evidentially, the case study provides explicit evidence that if Coca-Cola had applied the resource assessment approach the SC structure would have changed towards either less water intensive processes, changing the product structure at the Plachimada site, or changing the supply network structure so as to increase collaboration with suppliers in resource abundant areas, local resource institutes, and governmental authorities.

From an industrial systems perspective, the framework supports the assumption that local resource consumption, global resource demand and external environmental factors are essential attributes determining local resource availability. Furthermore, the assessments made over multiple time periods demonstrates the dynamic nature of the analysis.

Conclusion and future research

The proposed framework was built upon three literature domains. Natural capital theory, which emphasises the importance of sustaining resource renewability for the long-run perspective of business processes, is incorporated with SC configuration theory, evaluating supply and demand aspects of resource availability criteria in SC design considerations, with design attributes informed by the industrial ecology domain. The framework represents an integrated and global view on resource availability, and its assessment within widely dispersed industrial systems.

Building on these theoretical developments and literature domains a resource availability assessment framework has been proposed, suggesting that global and local resource demand, affecting resource availability, in conjunction with external environmental factors, can significantly deteriorate a firm's operational environment. Thus, the framework seeks to deliver mechanisms to evaluate potential vulnerabilities and solutions available to firms through more proactive SC design and reconfiguration processes that account for natural resources, based primarily on network and resource attributes. The Coca-Cola case illustrates how the resource availability assessment framework can be used in order to evaluate resource availability related risks within the upstream SC and production process for a regionally and globally dispersed downstream SC and market.

The framework has two main limitations. First the current work is focused only on a single industry case study. Second, the framework does not consider other possible industries, which might enter or leave the specific location during Coca-Cola's operation. Furthermore, no assessment was made on migration of the population within the area. Therefore, additional study of a broader set of industry sectors and cases would be beneficial for further refinement of the assessment framework.

Future research to investigate relationships between each of the framework attributes, through quantitative and qualitative research study would be desirable. Ultimately, the framework might help to develop a more common approach for resource availability assessment via partnering with climate research scientists, internal resource bodies (WRI, FAO), local governments, and industry sectors.

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Assessing disturbances in food supply chains: Insights from the Indian dairy operations

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Abstract

The objective of this paper is to present a assessment of various sources of disturbances which negatively impact operations of the Indian dairy supply chains. The unit of analysis is the Indian dairy supply chains. The study follows a case approach and investigates dairy producers operating in the state of Madhya Pradesh in India. The data were collected using exploratory interviews as well as through a structured questionnaire with managers. Sources of disturbances in the Indian dairy supply chains emanates from external as well as internal causes and impacts quality of material and its distribution network. They also pose as hindrances in achieving robustness, transparency, traceability and information flow, monitoring and control of day-to-day operations for efficiency, flexibility, responsiveness and product quality. The findings stress the importance of integration across upstream and downstream processes of the Indian dairy supply chains. Moreover, underlying processes of the dairy supply chain needs to adapt with the external environment and eliminates internal causes of disturbances through process redesign. The case highlights the challenge of wastages, fragmentation of various stages and poor support infrastructure in efficient operations of the dairy supply chains. Upstream and downstream stages of the dairy supply chains involve many small and tiny unorganized producers. The overall inefficiency and poor value generation across entire dairy supply chain hamper the livelihood and interest of these unorganized producers. The paper contributes to the literature in sense that it contributes the Indian insights into body of literature which is otherwise build primarily from western countries experiences.

Introduction

India is the world's largest producer of milk, second largest producer of fruits and vegetables and third largest producer of fish. With a large agriculture sector, abundant livestock, and cost competitiveness, India is fast emerging as a sourcing hub of processed food. India produced 250 million tonnes (MT) of food grains in the financial year 2012. India's comparative advantage lies in its favourable climate, geographic location, large agriculture sector and livestock base, long coastline and inland water resources and closeness with key export destinations such as Middle East, South East Asia (India Brand Equity Foundation (IBEF), 2012; Economic Survey, 2013).

Food processing involves value addition to farm produces and includes processes such as grading, sorting and packaging which enhances shelf life of the produce. Due to natural and perishable nature of food, the food processing sector has significant quality, safety and performance implications. The concern is more so in the case of developing countries such as India which is one of the agri-based economies where agriculture accounts for 19 per cent of GDP but employs over 60 per cent of its population (IBEF, 2010). In these countries there are wastages of food grains, vegetables, fruits, dairy products and other food items due to lack of processing capacity, infrastructure facilities, storage facilities and other supply chain constraints (Reardon *et al.*, 2001, Dharni and Sharma, 2008; Ruteri and Qi Xu, 2009). In case of developed countries supply chain of food products has received a great deal of attention due to issues related to public health. In near future the design and operation of food supply chains will be subject to more stringent regulations and closer monitoring. The dairy segment occupies an important position in the agriculture economy of India, as milk is the second largest agriculture commodity contributing to the gross national product (GNP) next only to rice. The strength of the Indian dairy sector lies in the fact that in spite of limited investment, it has shown consistent and sustainable growth (Venugopal, 2008; Patil *et al.*, 2009). The author's purpose is to study the existing dairy supply chain in Madhya Pradesh (MP) state of India and to identify causes of disturbances which impacts robustness of dairy supply chains. Central findings are that dairy supply chains are inherently complex and achievement of robust operations requires identification of disturbances and addressing them through process redesign. It is inferred that process redesign in the Indian dairy context is defined in terms of disturbance prevention and its impact reduction. Disturbance prevention involves design of dairy product as well as design of effective processes. Impact reduction involves building operational excellence in the processes of dairy supply chains.

Review of Literature

Meaning Supply Chain Management

Supply chain management (SCM) is the integrated planning, implementation, coordination and control of all business processes and activities necessary to produce and deliver, as efficiently as possible, products that satisfy market requirements (van der Vorst *et al.,* 2007). The origins of SCM appears to start along the lines of physical distribution and transport (Croom *et al.,* 2000) and is based on the theory derived from the work of Forrester. Another antecedent is total cost approach to distribution and logistics. Both approaches show that focusing on a single element in the chain can not assure the effectiveness of the whole system (Croom *et al*., 2000).

Supply Chain Management and Food Industry

The food industry is categorized by different segments such as fresh food industry, processed food industry and livestock food industry. Each segment has its unique characteristics and associated complexities, therefore, each segment needs different supply chain strategies for its procurement and sourcing, inventory management, warehouse management, packaging and labelling system, and distribution management, thus, the uniqueness characteristics of food supply chain (Georgiadis *et al.*, 2005).

Partnering in Food Supply Chains

A successful supply chain requires coordination and cooperation between its components (Hobbs and Young, 2000). Absence of coordination results in inefficient supply and dissatisfied customers (Chung-Chi and Cheng-Han, 2008). Uncoordinated information from downstream to upstream of the supply chain has created a lot of wastages and losses for most of food processors. The distorted information implies that the processors work on unreliable amplified (bullwhip effect) demand data and this has serious cost implication (Ouyang and Daganzo, 2008). Food products have limited shelf life and it is not easy to recover any materials whenever expiry date is due (Minegish and Thiel, 2000). Losses can be minimized through coordination between partners within the supply chain including customers by forming alliances or sharing information and knowledge to create a collaborative competitive and cost effective supply chain (Wee and Yang, 2004; Ketikidis *et al*., 2008). Collaboration appears as enterprise recognizes cases where working and operating alone is not sufficient to resolve common problems and to achieve the desired goals (Wagner *et al*., 2002; Matopoulos *et al*., 2007). Supply chain collaboration involves design and governance of supply chain activities and the establishment and maintenance of supply chain relationships (Matopoulos *et al*., 2007).

Transparency in Food Supply Chains

Transparency of a supply chain is the extent to which all its stakeholders have a shared understanding of, and access to, the product related information, without loss, noise, delay and distortion (Hofstede *et al*., 2005; Deimel *et al*., 2008). Consumers demand quality, safe and healthy food. Transparency in the food supply chain is essential to guarantee food quality to all users. Integrated information systems involving all chain actors are needed to achieve transparency with respect to multitude of food properties (Trienekens *et al*., 2012). In food and agri-business, transparency can serve various needs. Besides involving market efficiency, enhanced information exchange in the whole supply chain, consistent food quality, support of product differentiation, logistical and process optimization may serve operations management considerations. Organizations in the food supply chain are linked through governance mechanisms that are supported by information systems and aims to achieve pre-defined production standards, specified in quality and safety standards (Trienekens *et al.*, 2012).

Traceability in food supply chains

Traceability is an important issue in FSC management in case of perishable food products subject to rapid deterioration. An effective food traceability system is tool not only to manage food quality and safety risks, but also to promote the development of effective FSC management (Manzini and Accorsi, 2013). Two main types of traceability technologies and devices are identification tags (*i.e.* barcode, label, RFID tag) and data loggers (also called as black boxes) (Abad *et al.*, 2009). Identification tags identify product or an item with a specific code denoting its lot number, shelf life, company *etc*. data loggers aim to trace and record the environmental conditions and profiles experienced by a product throughout SC processes. The main purpose of such traceability devices and systems for FSC is to preserve specificities of food products specifically rapid perishable products for their safety and hygiene requirements as per the food standards (Sarc *et al*., 2010). As food preservation and deterioration depends on intrinsic and extrinsic factors as storage temperature, concentration of oxygen, relative humidity, solar radiation, acidity, microbial growth, endogenous enzyme activities, *etc.* (Howard *et al.*, 1994; Alasalvar *et al.*, 2001; Zhang *et al.*, 2009).

Performance Measurement

An effective performance measurement is essential as it provides the basis to understand the system, influences behaviour throughout the system and provides information about the results of system efforts to supply chain members and outside stakeholders (Fawcett and Clinton, 1996). Furthermore, researchers have found that measuring supply chain performance in itself leads to improvements in overall performance. A common measure of financial performance centres on the use of simple outcome-based financial indicators that are assumed to reflect the fulfilment of the economic goals of the firm (Williamson, 1979). However, operational measures reflect more directly to the efficiency and effectiveness of the operations within the firm. Time-based performance measures at various stages of the value delivery cycle have proposed several measures to evaluate them (Jayaram *et al.,* 1999). The key dimensions of time-based performance include delivery speed and new product development time (Vickery *et al.,* 1995), delivery reliability as well as dependability and manufacturing lead-time (Handfield and Pannesi, 1995). In addition, customer responsiveness has also been recognized in the agility literature as a key aspect of time-based performance. Rapid confirmation of orders and rapid handling of customer complaints are found to be two key indicators of customer responsiveness (Tersine and Hummingbird, 1995). Four principal categories of time, cost, quality, and supporting measures also serve as key performance indicators (KPIs) for examining supply chains performance. Beamon (1998) provide measures of cost, flexibility and delivery reliability, *etc*. Balanced score card (BSC) uses four perspective of finance, customer, internal business processes, and learning and growth (Kaplan and Norton, 1992) and Bigliardi and Bottani (2010) have used it for performance measurement of food supply chain.

In SCM theory, robustness and vulnerability are perceived as opposite though not mature concepts (Wagner and Bode, 2006). Disruption can have direct effect on the organization's ability to get finished goods into a market and provide critical services to customers (Bhamra *et al.*, 2011). Vulnerability refers to the capacity of the system to preserve its structure (Gallopin, 2006) or as the extent to which a system is susceptible to the effects of change (Bhamra *et al.*, 2011). Resilience represents sum total of vulnerability of a system as well as its adaptive capacity (Dalziell and McManus, 2004). Robustness is mainly considered as the ability of the system to continue to function in the event of a disturbance (Dong, 2006). Supply chain robustness is a desired property that is reflected in supply chain performances (Vlajic *et al.*, 2012). In case of food supply chains the vulnerability is high due to inherent factors such as seasonality, perishability and variability. Utilization of resources in terms of cost and profits, social economic welfare and use of resources to cater broad social goals impacts efficiency (Lai *et al.*, 2002).

Methodology

This paper follows a case study approach which is an inquiry of a real life phenomenon having blurred boundaries (Yin, 1994) and involves cycles of description, explanation and testing (Meredith, 1998). This method is also used to serve the purpose of exploring, describing and explaining empirical setting (Yin, 1994). Barratt *et al.* (2011) has defined qualitative case study as an empirical real-world setting to investigate a focussed phenomenon. This approach has appealed the researchers for integration of operation management with other functional areas of the supply chain (Pagell, 2004). This paper primarily used elaboration approach of case research (Ketokivi and Choi, 2014). The underlying reason is that the Indian dairy supply chain context is not known well enough to obtain sufficiently detailed premises that could be used in conjunction with the general theory to deduce precise testable hypotheses. The unit of analysis is the Indian dairy supply chain. Unit of analysis is critical for relating the case to pertinent body of knowledge (Dube and Pare, 2003) and helps in defining boundaries of a theory which in turn sets the limitations in applying the theory. Review of literature has been undertaken to develop a holistic view on the supply chain issues in FPI sector. Data have been collected form different types of dairy supply chains in and around Gwalior region of Madhya Pradesh State of India. Focus group interviews were performed to understand functioning of the dairy supply chain at stages of milk collection, sourcing, processing and distribution. Table 1 shows description of focus group interview and elaborate on data sources and associated issues of discussion. Data have been collected during January to October 2014. The items of measurements as depicted in tables two to six have been taken from literature.

Table 1

Description of exploratory interviews

<table>
<tr><th>SN</th><th>Data sources</th><th>Issues of discussion</th></tr>
<tr><td>1</td><td>District government level officials:
The chief medical and health officer (CMHO), food inspector, Gwalior</td><td>About existing policy framework for administration of dairy products</td></tr>
<tr><td>2</td><td>Officials of organized sector dairy operators:
Gwalior Sahkari Dugdh Sangh, Gwalior, Sterling Agro Industries, VRS Food Limited, S.M. Milkose, Reliance Fresh and Cadbury, India</td><td rowspan="2">Issues involved in production, collection, sourcing, processing and distribution stages of dairy supply chain</td></tr>
<tr><td>3</td><td>Unorganized sector dairy operators:
Reputed small dairy owners and halwaiis from the region.</td></tr>
</table>

Framework of the study

A framework of disturbance has been developed for the Indian dairy supply chains. This framework is based on the disturbance framework developed by Vlajic *et al.* (2012) for FSC logistics functions. Figure 6.1 depicts schematic representation of this adapted framework. The adapted disturbance framework has been applied to the sourcing, processing and distribution stages of the Indian dairy supply chain. Purpose is to understand various sources of disturbances relevant to the Indian dairy supply chains which support the analysis and design of robust dairy supply chain in India. Supply chain configuration represents physical design of the dairy supply chain in terms of stages of sourcing-processing-distribution. Managing supply chain configuration involves strategic, tactical and operational level planning as well as coordination among various dairy processes. Managing supply chain information system involves supporting information flow across inter-organizational as well as intra-organizational linkages and aims to provide real time decision support. Managing supply chain participant actor's organization refers to roles, responsibilities and authority of various employees of each actor organization.

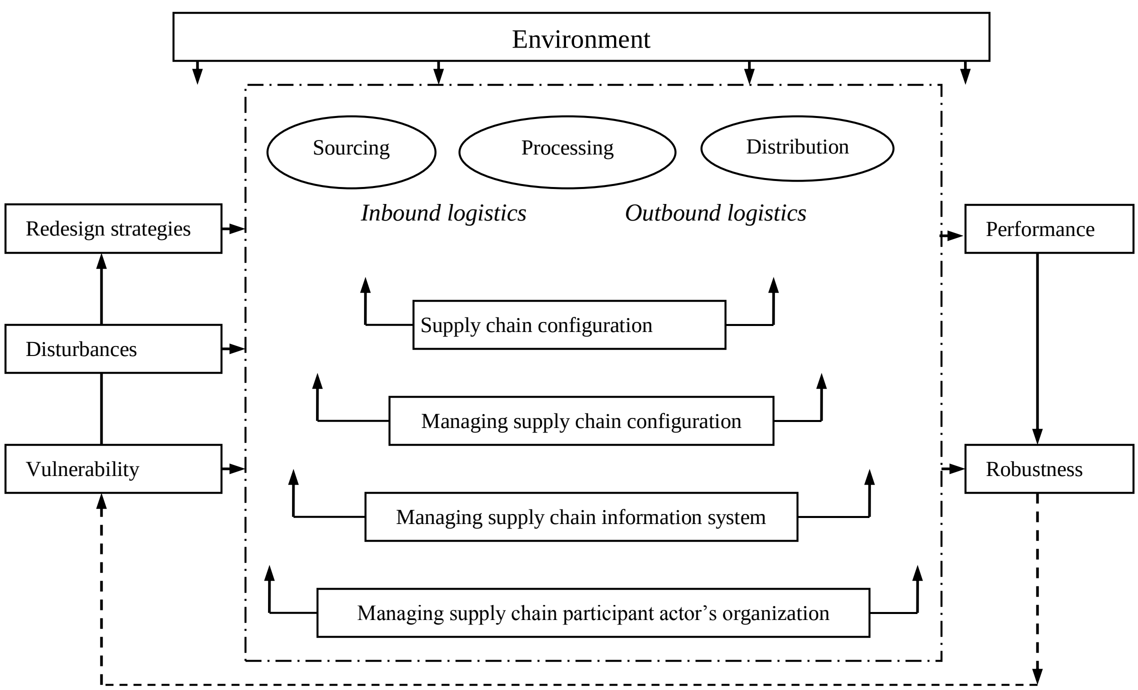

Figure 1. Dairy supply chain robustness framework

This framework helps in determining various dairy supply chain scenarios which helps in achieving desired performance under given set of constraints. Understanding of a given scenarios helps in (re)design of dairy supply chain process for achievement of given level of performance. Key performance indicators (KPIs) are set of indicators, analysis of which reflects presence of various sources of disturbances. The underlying dairy supply chain is robust if it can withstand routine disturbances. The objective is identification of various sources of vulnerability that explain various process disturbances which affect the dairy supply chain robustness and eventually increases the vulnerability of the food supply chain. Disturbances are characterised by elements such as frequency of occurrence, possibility of detection and the impact on the dairy supply chain. Causes of disturbances are related with volume and quality (Svensson, 2000), time (Vlajic *et al.*, 2012), sustainability (Prakash, 2008; Manzini and Accorsi, 2013), cost related. Quality related indicators may be measured in terms of delay in transportation (in days), order fulfilment lead time (in hours), adulteration in milk (as per centage of volume); volume related measures in terms of wastage of milk (in each production cycle), loss in transportation (each trip basis), loss due to poor packaging (each packet basis); service related measured in terms of quality of service (QoS) elements such as tangibility, empathy, assurance, reliability and responsiveness at each supply chain dyads, QoS Index (a composite index consisting of various service related factors); sustainability related measure in terms of shelf life of milk products, time window for availability of milk products (day basis or specified time frame), per centage of target customers served, availability of milk products (on any given day), availability of right volume of milk products (on any given day), benefits delivered to milk farmers and cost related measure in terms of cost of milk products sold, total supply chain management cost to serve the targeted customers, blocked funds (monthly basis),

Findings and Discussion

The Indian dairy supply chains

India has a unique pattern of production, processing and marketing of milk, which is not comparable with any large milk producing country (Ministry of Food Processing Industries (MoFPI), 2009). The dairy supply chains are differentiated based on the processing firm which is the main integrator and differentiator of the supply chain. Main types of the Indian dairy supply chains involves dairy cooperative society (DCS) supply chain, large private dairy processing firms supply chain and small dairy and *halwaiis*[1] supply chain. The processing plants owned by the dairy cooperatives manufacture wide range of western and traditional Indian dairy products. Some of these products are skimmed milk powder (SMP), table butter, cheese, packet milk, ultra high temperature (UHT) milk, flavoured milk, *khoya*[2], *chhena*[3], *gulabjamun*[4], *burfi*[5], *peda*[6], *shrikhand*[7], *rasogolla*[8], *rajbhog*[9], *rasmalai*[10] *etc*.

Vlajic *et al.* (2012), in their study had defined vulnerability sources as characteristics of the supply chain, or its environment that lead to the occurrence of unexpected events and as such, they are direct or indirect causes of disturbances. Accordingly, they have identified two basic groups of vulnerability sources, internal and external sources. Within these two a number of generic and specific sources for the food supply chains (FSC) have been identified. The specific sources arise from specific characteristics of the food supply chain, such as perishability, importance of food safety and quality management, valorisation of by products, the variability in process yield and the rigid time constraints (van der Vorst, 2000). There are six external vulnerability sources which emanates from the supply chain environment, namely, financial, market, legal, infrastructural, societal and environmental, out of these some are controllable to

[1] *halwaiis* are local level small operators who deal with milk and traditional Indian dairy products.
[2] *khoya*: it is solid concentrated remains obtained by continuously steering boiling milk.
[3] *Chhena*: it is obtained by curding milk that separates chhena (an Indian cottage cheese) from whey.
[4] *Gulabjamun*: it is a spherical or cylindrical in shape, dark brown in colour, and soaked in thick sugar syrup.
[5] *Burfi:* it is prepared with kyoya and is cream in colour with firm granular body. Nuts and flavourings may be added to for taste.
[6] *Peda*: a khoya based product flattened circular in shape prepared by mixing *khoya* and sugar and heating on a gentle flame.
[7] *Shrikhand*: made from concentrated yogurt (*dahi)* with a sweet and sour taste, it is a semi-soft whole milk product.
[8] *Rasogolla*: it is prepared using soft *chhena in the* shape of small balls having spongy body dipped in sugar syrup.
[9] *Rajbhog*: a large yellowish and somewhat less soft variety of rasogolla is the *rajbhog*.
[10] *Rasmalai*: it is prepared by kneading *chhena* with wheat flour and rolled into bars and dipped in thickened sweetened milk.

some extent, such as societal and financial sources, others are not such as market and environmental (Simchi-Levi *et al.*, 2008). Vlajic *et al.* (2012) had extracted a list of 21 main sources of external disturbances specific to FSC and classified them according to the controllability level using the criteria of Asbjornslett and Rausand (1999) and Wu *et al.* (2006). In the present study this list has been reviewed and another 22 more external factors belonging to different stages of the Indian dairy supply chains have been added. These are depicted in Table 2.

Table 2

External sources of disturbances for dairy supply chain

Sources and their description
Financial sources
Market price fluctuations, currency fluctuations, regional economic downturns, excise duty on dairy plant machinery, test equipment, packaging material etc.high taxes on dairy products, multiplicity and non uniformity of taxes on dairy products, restrictions on export of dairy products to control domestic prices and meet internal demands, lack of low cost loans to dairy farmers and dairy sector by banks
Market sources
market decline, variability and seasonality in availability of raw materials, variability in quality of raw materials, variability in demands, high demand during festival seasons, increase in domestic demand of dairy products
Legal sources
change in laws and regulations, change in country dependent rules in food safety, delays and deficiencies in implementation of food safety standards (FSS), delays in court cases in adulteration cases, lack of coordination among agencies responsible for implementation of FSS, adulteration in milk and milk products, corruption in implementation of FSS, restriction on FDI in multi-brand retailing
Infrastructural sources
low level of development in transport infrastructure, not sufficient traffic capacity, uneven level of technological development, lack of electricity in rural areas, lack of clean water in rural areas, lack of milk procurement infrastructure, Lack of cold chain and distribution infrastructure, lack of cattle vaccination and extension service
Societal sources
political unrests, criminal acts, negative public reactions, industrial actions, changing customer attitudes towards product/process, preference for traditional dairy products, Law and order issues, Labour problems and strikes
Environmental sources
natural disasters, geological, meteorological, biological factors, manmade hazards, unpredictable factors, change in weather pattern , natural calamity such as floods

Items in italics are primarily identified by Vlajic et al. (2012)

In the case of internal disturbance sources, the causes are within the supply chain *i.e.* within the elements of dairy supply chain (SC) scenario. Vlajic *et al.* (2012) have extracted a list of 39 main internal sources for logistic function according to the controllability level and the elements of the SC scenario.

Table 3

Internal sources of disturbances in dairy supply chains

Sources	**Description**
	Upstream and downstream stages
Supply chain configuration	*Product related hazards, Heterogeneous raw material (quality), Complexity of supply chain One key business partner, Sophisticated equipment/infrastructural restrictions* Inherent rapid perishability of milk and dairy products , Inherent variability in the Indian milk due to mixing of cow and buffalo milk , High level of unorganized processing of traditional dairy products, Lack of branding of traditional dairy products by unorganized sector, lack of milk testing facilities, Lack of scale of milk production, Lack of consolidation Fragmented supply chain , Lack of milk supply in lean season, Dependency on rain for cattle feed, Multipoint handling of milk, Lack of proper hygiene and sanitation conditions of the cattle shelters in rural areas
Managing configuration	*Strict requirement for key customers, Low reliability of chain partners, Lack of control in supply chain, Lack of risk management and recovery planning initiatives along the chain* Dominant unorganized structure of the dairy industry, Lack of integration in supply chain Lack of resources at all levels, Non compliance of quality standards in the chain, Lack of backward integration into milk procurement, production and cattle extension services, Long SC with many intermediaries, Lack of sustainability in SC, Low level of organized processing, Low level of organized retailing
Information system	*lack of infrastructure to support information sharing, Lack of information visibility* *Varying ICT standards used in supply chain,* Lack of traceability and transparency in the supply chain, Lack of investments on information systems
Organizational structure	*Loose contracts, Lack of risk mitigation and recovery plans, Outsourcing , Not clear coordination and cooperation, No sufficient collaboration and lack of trust, Low level of training and experience of employees,* Lack of awareness of SCM, Lack of HRD and entrepreneurship development, Lack of collaboration with dairy farmers, Local optimisation
	Processor stage
Supply chain configuration	*low reliability of equipment, product characteristics, inventory related problems (perishability), low quality of intermediate or final product, lack of capacity increasing product assortment,* Poor distribution network, Low shelf life of traditional dairy products, non standardized processes and procedures, old plant machinery and equipment, Lack of packaging solutions, lack of R&D in product, process, equipment and packaging solutions development, Lack of refrigerated transportation vans, Lack of incentives for clean milk
Managing configuration	*Limited control actions, Subjective decision making, Non accurate forecasting, Lack or no sufficient attention to risks and disturbances management, Rigid planning* Lack of resources, Lack of compliance to quality standards, low quality, safety and hygiene standards of unorganized sector processed traditional dairy products, Lack of professionalism in management of cooperatives, Political interference, Democratic setup of cooperatives hindering competitive decision making , Profit making approach of the corporate, Lack of commitment to CSR, Lack of reverse logistics, Lack of recycling of packaging material
Information system	*Lack of adequate decision support system, Slow data transfer and processing, Late detection of disturbances, Lack of data about disturbances, Inaccuracy of data, Not sufficient data analysis,* Lack of information management and processing procedures
Organizational structure	*Weak internal coordination and cooperation, No standardized working procedures* *Lack of preparedness for disturbances, Low level of training and non experienced workers* Lack of social security of the workers, Low salary to the workers

Items in italics are primarily identified by Vlajic et al. (2012)

In the present study this list has been reviewed and another 48 more internal sources belonging to different elements of SC scenario related to upstream, downstream and to the company (processors and distributors) of the Indian dairy supply chains have been added. These are depicted in Table 3. The company related vulnerability sources have been studied for dairy processors and the distributors. Each of the main sources may have multiple factors (for example low quality of raw material could result in product with a bad organoleptic characteristics, spoiled products, quality defects etc.

Redesign Strategies for the Indian Dairy Supply Chain

As per SCM literature redesign principles (also referred as risk responses, risk protection strategies, mitigation strategies and mitigation tactics) are most appropriate way of dealing with risks and disturbances in the supply chain (Vlajic *et al.*, 2012). These principles are related to the principle of uncertainty (van der Vorst, 2000; Lee, 2002) and more recently to disturbance and risk (Zsidisin *et al.*, 2000; Zsidisin, 2003; Tang, 2006; Tomlin, 2006; Waters, 2007; Hopp, 2008; Zsidisin and Ritchie, 2008; Dani, 2009). Vlajic *et al.*, (2012) defined redesign strategies as set of strategies and tactical plans and operational actions that aim to reduce the vulnerability of supply chains based on one or more redesign principles that make changes in elements of the supply chain scenario. Waters (2007) has carried out classification of risk responses, similarly Vlajic *et al.* (2012) also classified redesign strategies into two groups (1) disturbance prevention and (2) disturbance impact reduction. Disturbance prevention aims for the reduction of disturbance frequencies and its size, by acting in advance in order to eliminate, avoid or control any direct cause of disturbances (source of vulnerability). Disturbance impact reduction implies change of the characteristics of the supply chain scenario elements, such as using buffer stocks or increasing process flexibility. The second group of strategies are employed when the disturbance prevention is impossible, due to non identification of the vulnerability of sources or lack of investments. The classification helps in deciding the kind of response for disturbance, however, the selection of redesign strategy depends on the impact of disturbance to robustness, characteristic of supply chain scenario and vulnerability sources. In the present study, for each group of redesign strategies the tactics used for elimination or control of the vulnerability source and optimum changes in the Indian dairy supply chain scenario has been proposed. Table 4 and Table 5 depict disturbance prevention and impact reduction principles.

Table 4

Redesign principles for disturbance prevention

Supply chain scenario and associated redesign principles for disturbance prevention
Supply chain configuration
Adjust the structure of the supply chain (Waters, 2007) – backward integration into milk procurement infrastructure by the organized sector **Use product management** (Melnyk *et al.*, 2009) – product mix of western and traditional the Indian dairy products – manufacture of traditional dairy products by organized sector processing plants. – co-location of processing plants for traditional Indian dairy products and western dairy products . – manufacture of buffalo milk based speciality products, like Mozzarella cheese, tailored to meet the needs. **Use technical solutions for performance monitoring** – use of latest technology equipment and plant machinery for handling, testing and processing
Managing configuration
Invest to avoid or reduce exposure to vulnerability sources (Tang, 2006) – Investment in milk testing labs for improving quality of raw milk. – Investment in latest technology for milk storage, handling and processing equipments. – Increasing processing capacity to justify investment in milk procurement infrastructure. – Investment in R&D, quality control and new product development. – Investment in cattle extension and veterinary services in the rural areas **Control variability** (Dani, 2009) – Implementing HACCP quality assurance system by organized dairy processing plants. – Implementing FSS (2011) by unorganized sector dairy units. – Implementing codex and other international food standards by the units dealing with export. – Mark-up price for clean and quality milk. **Use revenue management strategies** (Simchi-Levi *et al*, 2008) – Selling packet milk in small sachets of 100 and 250 ml for low income population. – Serving emerging alternate markets for food service institutions, defence, ingredients and parlour market.
Information system
Use of IT to increase data accuracy and speed and support decision making (Hopp, 2008) – Use of integrated information systems (enterprise resource planning- ERP) within the dairy supply chains. – Use of decision support system (DSS) by the organized sector dairy processing units for "what if" analysis **Create support for information transparency in the supply chain** (Waters, 2007) – Implementation of national/codex food standards by unorganized/ organized dairy supply chains. – Packaging and labelling of exporting dairy products as per codex standards. **Collect relevant data about disturbances** (Hopp, 2008) – Analysis of risk management by the Indian dairy supply chains
Organization
Increase collaboration in supply chain (Ritchie and Brindley, 2009) – Private sector participation in cattle extension and veterinary services in rural areas. – Public private partnerships (PPP) in infrastructure development in rural areas **Increase cooperation and coordination between departments** (Waters, 2007) – Coordination among planning, production and marketing departments **Create an adaptive supply chain community** (Simchi-Levi *et al.*, 2008) – Improving partnering and trust in dairy supply chain – Increasing awareness about SCM concepts in the dairy supply chain **Improve human resource management** – Improvement in social security of the workers in dairy industry. – Training of workers in dairy industry.

Table 5
Redesign principles for reducing impact of disturbance

Elements of SC scenario and redesign principles for disturbance impact reduction
Supply chain configuration
Adjust the structure of the supply chain (Melnyk *et al.*, 2009) − Reduce the length of the dairy supply chain by elimination of intermediaries **Buffering in capacity and inventory** (Melnyk *et al.*, 2009) − Improvise existing western dairy processing plants for manufacturing traditional Indian dairy products. − Increasing capacity of existing dairy plants in the organized sector. **Increase flexibility of the supply chain** (Simangunsong *et al.*, 2008) − Use own retail outlets by organized sector units for marketing of short life dairy products. **Product management** (Simangunsong *et al.*, 2008) − Use good quality milk for manufacture of high value export oriented dairy products. − Use milk procured from intermediaries for manufacture of dairy products for domestic market.
Managing configuration
Hedging (Hopp, 2008) − Outsourcing transportation − Stock skimmed milk powder (SMP) during flush milk season and use SMP during lean seasons. − Diversifying operations across multiple markets **Make back up options** (Simchi-Levi *et al.*, 2008) − Use multiple sources for milk procurement. − Use different distribution channels. − Use alternative transport routes. − Global marketing of traditional Indian dairy products. **Increase flexibility of planning and control** (Melnyk *et al.*, 2009) − Using flexible manufacturing systems in processing plants. − Use automation in employing technological interventions. − Attaining ability to respond to seasonal and peak demand. **Use lead time management** (Simangunsong *et al.*, 2008) − Optimum utilization of distribution network to reduce lead time of supplies. − Enhance the distribution network to reduce lead time − Open plants for reprocessing of pasteurized milk before distribution at distant locations
Information system
Use of IT to increase data accuracy and speed and support decision making (Hopp, 2008) − Use of statistical process control and data mining for knowledge discovery **Create support for information transparency in the supply chain** (Simchi-Levi *et al.*, 2008) − Use of software packages for milk testing, recording and traceability. **Use feedback loops** (Disney *et al.*, 1997)
Organization
Increase preparedness to disturbances (Hopp, 2008) − Make alternate plans for breakdowns and disturbances **Increase collaboration in chain** (Simchi-Levi *et al.*, 2008) − Partnerships and joint ventures (JVs) in dairy supply chain. **Create an adaptive supply chain community** (Simchi-Levi *et al.*, 2008) − Make alternate plans for the entire s dairy supply chain **Use risk sharing contracts for strategic components** (Hopp, 2008) − Vendor managed inventor (VMI), quantity flexibility contracts, buy back contracts, cost sharing contracts, revenue sharing contracts

Assessing consequences of disturbances

Sourcing and Processing Stage

The low quality of final product in case for the Indian dairy supply chains results from low quality of raw material and lack of collaboration and trust in supply chain. The list of disturbance sources for low quality of final dairy products in India is depicted in Table 6.

Table 6

Consequences of select external disturbances on quality

Sources	Description
Market	high demand during festival seasons, increase in domestic demand of dairy products
Legal	delays and deficiencies in implementation of food safety standards (FSS) lack of coordination among agencies responsible for implementation of FSS, adulteration in milk and milk products, adulteration in milk and dairy products
Infrastructural	low level of development in transport infrastructure, not sufficient traffic capacity due to lack of unit scale of production, lack of electricity in rural areas, lack of clean water in rural areas, lack of milk procurement infrastructure, Lack of cold chain and distribution infrastructure
Environmental	biological factors, unpredictable factors, failed monsoon, floods

The low quality of dairy products is mainly a consequence of external and internal vulnerability sources. In the present study a total of 49 specific causes have been found which may lead to quality related issues. In this there are 16 external disturbance sources belonging to infrastructural (6), legal (4), market (2) and environmental (4) sources. There are 33 internal sources of disturbances which results into low quality of final product. Out of which 14 are configuration related internal disturbance sources, seven each at upstream, downstream and processor level, ten are managing supply chain configuration related internal disturbance sources, four at supply chain level and six at company (collector/processor) level. Four are information system internal disturbance sources, two each at supply chain and at company level. Five are organization structure disturbance sources, three at supply chain level and two at company level. Low quality of final product is also due to lack of collaboration and trust in the Indian dairy supply chain. Sources of vulnerability for this problem are mainly internal disturbance sources at upstream, downstream and processor level and are partially controllable. There are 27 causes for this problem specific to the Indian dairy supply chain. Table 7 details consequences of internal disturbances. Eight are organizational structure disturbances sources, five at upstream, downstream level and three at processor level.

Table 7

Consequences of select internal disturbances

Sources	Description
A. Poor Quality of Raw Material	
Upstream and downstream stages	
Supply chain configuration	Inherent rapid perishability of milk and dairy products, Inherent variability in the Indian milk due to mixing of cow and buffalo milk , lack of milk testing facilities, Lack of scale of milk production, Lack of milk supply in lean season, Multipoint handling of milk Lack of proper hygiene and sanitation conditions of the cattle shelters in rural areas
Managing configuration	Inherent rapid perishability of milk and dairy products, Inherent variability in the Indian milk due to mixing of cow and buffalo milk , lack of milk testing facilities, Lack of scale of milk production, Lack of milk supply in lean season, Multipoint handling of milk Lack of proper hygiene and sanitation conditions of the cattle shelters in rural areas
Information system	Lack of traceability and transparency in the supply chain, Lack of investments on information systems
Organizational structure	Loose contracts, Outsourcing, Local optimisation
Processor stage	
Supply chain configuration	lack of capacity, non standardized processes and procedures, old plant machinery and equipment, Lack of packaging solutions, lack of R&D in product, process, equipment and packaging solutions development, Lack of refrigerated transportation vans
Managing configuration	Lack of compliance to quality standards, Lack of professionalism in management of cooperatives, Political interference, Profit making approach of the corporate, Lack of commitment to CSR, Lack of reverse logistics
Information system	Not sufficient data analysis, Lack of information management and processing procedures
Organizational structure	No standardized working procedures, low level of training and non experienced workers
B. Lack of Collaboration and Trust	
Upstream and downstream stages	
Supply chain configuration	High level of unorganized processing of traditional dairy products
Managing configuration	Lack of integration in supply chain, Lack of resources at all levels, Non compliance of quality standards in the chain, Lack of backward integration into milk procurement, production and cattle extension services, Long SC with many intermediaries, Lack of sustainability in SC, Low level of organized processing, Low level of organized retailing
Information system	lack of infrastructure to support information sharing, Lack of information visibility, Varying ICT standards used in supply chain, Lack of investments on information systems
Organizational structure	Loose contracts, Outsourcing, Lack of awareness of SCM, Lack of HRD and entrepreneurship development, Lack of collaboration with dairy farmers
Processor stage	
Supply chain configuration	Lack of incentives for clean milk
Managing configuration	Lack of professionalism in management of cooperatives, Political interference, Profit making approach of the corporate, Lack of commitment to CSR
Information system	Lack of information management and processing procedures
Organizational structure	Low level of training and non experienced workers, Lack of social security of the workers, Low salary to the workers

Twelve are managing configuration disturbances sources, eight at upstream, downstream level and four at processor level. Five are information system disturbance sources, four at upstream, downstream and one at processor level. There are two supply chain configuration disturbances sources, one each at upstream, downstream and collector/processor level.

Distribution Stage

The other important performance indictor of the Indian dairy industry on which the disturbance framework has been tested is poor delivery performance. The results reveal that, poor delivery performance results from poor distribution network and lack of penetration of organized retailing. The list of external disturbance sources for poor delivery performance is depicted in Table 8.

Table 8

Consequences of select external disturbances on distribution network

Sources	Description
Financial sources	excise duty on dairy plant machinery, test equipment, packaging material etc., high taxes on dairy products, multiplicity and non uniformity of taxes on dairy products, lack of low cost loans to dairy farmers and dairy sector by banks, uneven taxes on organized and unorganized sector dairy products
Market	variability in demands, high demand during festival seasons, increase in domestic demand of dairy products
Legal	restriction on FDI in multi-brand retailing
Infrastructural	low level of development in transport infrastructure, lack of electricity in rural areas, lack of clean water in rural areas, Lack of cold chain and distribution infrastructure
Societal	changing customer attitudes towards product/process, preference for traditional dairy products, Law and order issues, Labour problems and strike
Environmental	unpredictable factors, floods

Poor distribution network of Indian dairy supply chain is mainly a consequence of external and internal (upstream, downstream and distributor/retail level) vulnerability sources for which there are about 45 specific causes. There are 19 external disturbance sources (four infrastructural, five financial, three market, four societal, one legal and two environmental disturbance sources) to this problem. There are 26 internal sources of disturbance resulting into poor distribution network of the Indian dairy supply chain. Out of this nine are configuration related internal disturbance sources, four at upstream, downstream level and five at distributor/retailer level. Six are managing configuration related internal disturbance sources, three each at upstream, downstream and distributor/retailer level.

Table 9

Impact of Internal Disturbances on Delivery Performance

Sources	Description
A. Poor Distribution Network	
Upstream and downstream stages	
Supply chain configuration	Inherent rapid perishability of milk and dairy products, High level of unorganized processing of traditional dairy products, Lack of branding of traditional dairy products by unorganized sector, Lack of milk supply in lean season
Managing configuration	Non compliance of quality standards in the chain, Low level of organized processing, Low level of organized retailing
Information system	Lack of traceability and transparency in the supply chain, Lack of investments on information systems
Organizational structure	Not clear coordination and cooperation, Lack of collaboration with dairy farmers, Local optimisation
Distributor stage	
Supply chain configuration	lack of capacity, Low shelf life of traditional dairy products, Lack of packaging solutions, lack of R&D in product, process, equipment and packaging solutions development, Lack of refrigerated transportation vans
Managing configuration	Lack of resources, Lack of reverse logistics, Lack of recycling of packaging material
Information system	Not sufficient data analysis, Lack of information management and processing procedures
Organizational	Lack of preparedness for disturbances, Low level of training and non experienced workers, Lack of social security of the workers, Low salary to the workers
B. Lack of Organized Retailing	
Upstream and downstream stages	
Supply chain configuration	Dominant unorganized structure of the dairy industry, Lack of integration in supply chain, Non compliance of quality standards in the chain, Lack of backward integration into milk procurement, production and cattle extension services, Long SC with many intermediaries, Low level of organized processing
Processor stage	
Organizational	Lack of resources, Lack of compliance to quality standards

Four are information system related internal disturbance sources, two each at upstream, downstream and distributor/retailer level. Seven are organization structure related internal disturbance sources, three at upstream, downstream level and four at distributor/retailer level. Poor delivery performance of dairy products in the Indian dairy supply chain is also due to lack of penetration of organized retailing. There are eight specific managing configuration related disturbance sources for this problem, six at upstream, downstream level and two at distributor/retailer level. Table 9 details consequences of internal disturbances on distribution performance. Figure 2 depicts the causal diagram for low quality of final dairy products in India. Figure 3 depicts the causal diagram for poor delivery performance of dairy products in India.

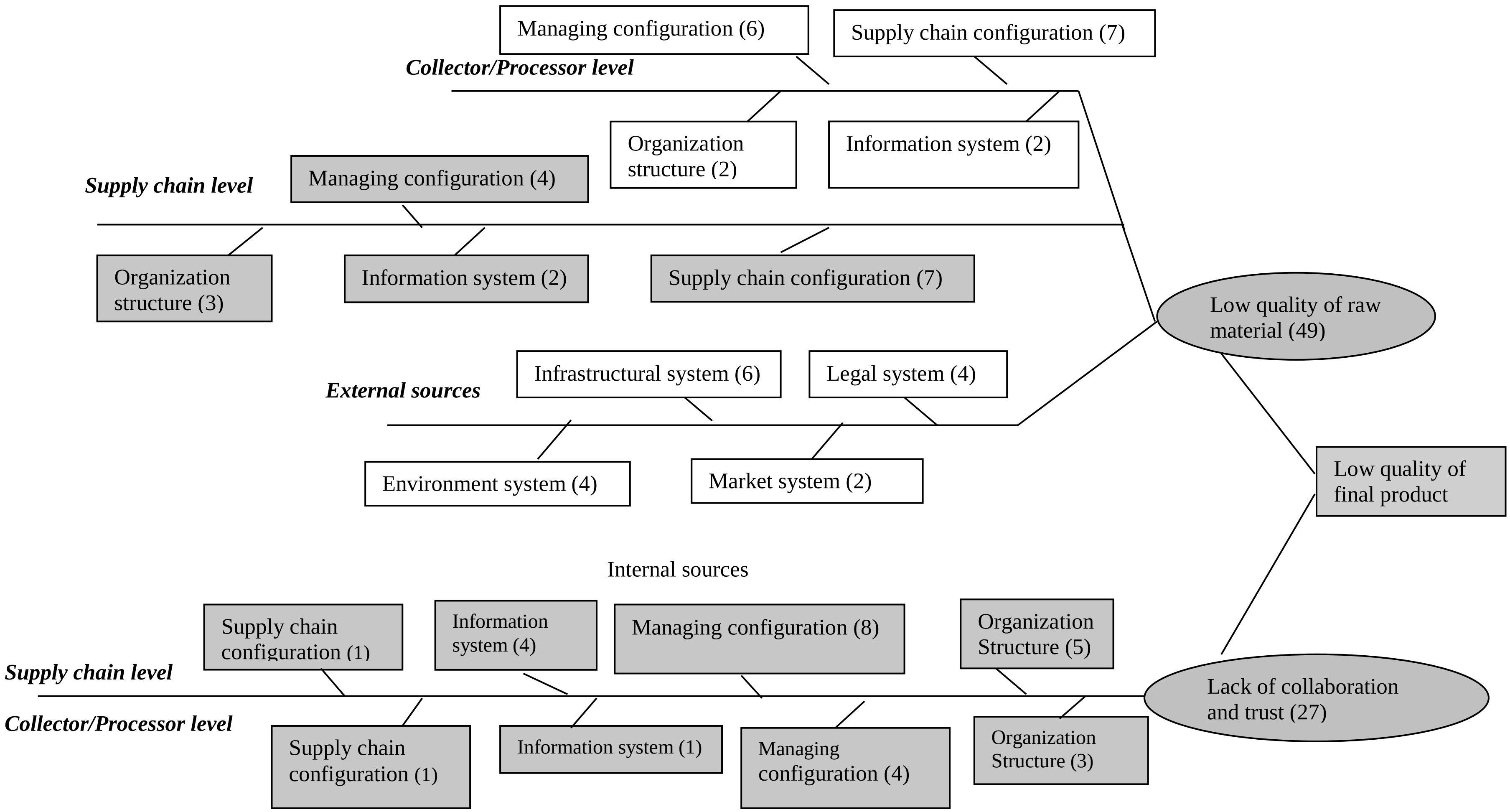

Figure 2. Causal diagram at sourcing and processing stages for low quality of dairy products in India (number within brackets show number of sources of disturbance of particular category)

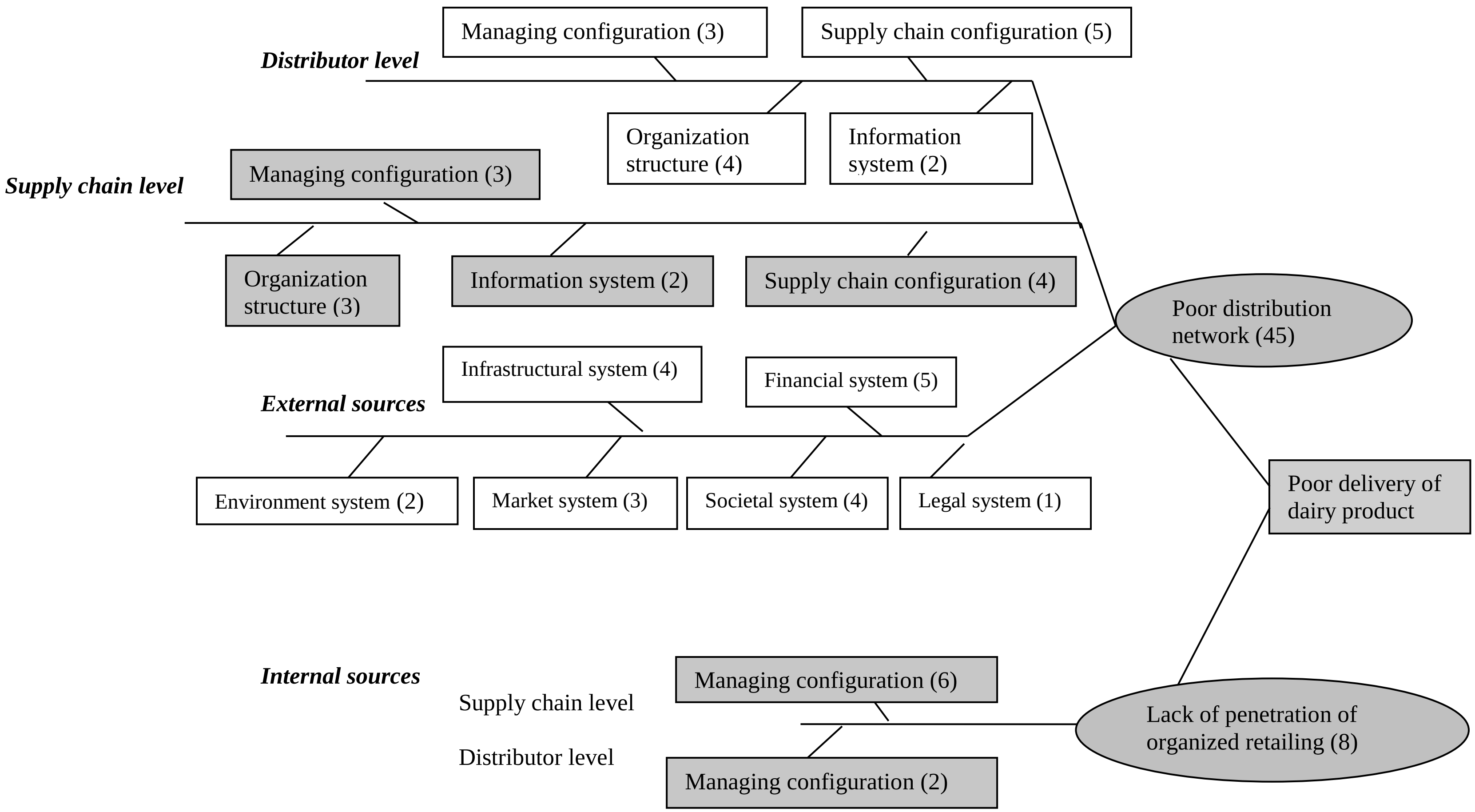

Figure 3. Causal diagram for poor delivery performance of dairy products in India (number within brackets show number of sources of disturbance of particular category)

Selection of Redesign Strategies

There are two types of redesign strategies that prevent the disturbance to happen. These are based on changes in the supply chain (SC) scenario elements *i.e.* configuration, managing configuration, information system and organization structure. The first redesign strategy is disturbance prevention – requiring analysis of the vulnerability sources with an aim to eliminate them or reduce the exposure of the supply chain to them. The second redesign strategy is disturbance impact reduction. Table 10 depicts various redesign strategies for the disturbance sources faced by the Indian dairy supply chain which affect the quality of the final product. The main disturbance sources for low quality are due to lack of milk procurement infrastructure, and testing labs; lack of compliance to quality standards; low level of organized processing and retailing; lack of awareness of SCM traceability and transparency in the supply chain etc. The various disturbance prevention and impact reduction redesign strategies to control these disturbance sources are:

Managing configuration: Purpose of this is to as far as possible eliminate disturbances sources thereby reducing the effect of exposure to vulnerability sources. For this purpose enhance investment through PPP mode for building infrastructure to support activities of milk procurement, R&D, testing, cattle extension services, development of quality systems, technology and new product development and increase capacity. Implement FSS, 2011 and codex standards and comply with HACCP. Develop milk supplier rating system and develop food quality certifications. Further, build flexibility across all stages to manage dynamic demand with supply.

Supply chain configuration: Eliminate dairy supply chain fragmentation through backward integration of activities of milk procurement and production; formation of cooperatives of unorganized dairy processors. This will not only ensure reliable supply base but also enhance quality of incoming milk. Procurement and processing systems need to develop buffer capacities so as to deal with variable volume of milk supply. Balanced product mix consisting of western milk products as well as traditional Indian dairy products needs to be developed.

Organization structure: Dairy supply chain actors need to develop systems to increase cooperation and coordination not only between them but also between their functional departments also. Human resource development through training and capacity enhancement sessions needs to be undertaken.

Information system: Smooth dairy supply chain operations require real time surveillance of product and process flows. Integrated information systems such as enterprise resource planning systems are needed to provide information transparency. Analytical tools such as decision support systems and data mining tools would be of help in generating various scenarios for managing demand with supply.

Conclusions

Implication for theory

Supply chains are usually not designed in agreement with a risk evaluation and assessment, although one of the most critical issues is the management of risks. In food supply chains, where risk factors may threaten food product quality and safety thus, customers' health, risks are much less tolerable (Marucheck *et al.,* 2011). This paper identifies sources of various disturbances in the Indian dairy supply chains and presents process redesign driven solutions. The purpose is to understand various sources of disturbances relevant to the Indian dairy supply chains to support the analysis and design of robust dairy supply chains in India. The disturbance framework developed during the study has been validated by applying it on the Indian dairy supply chains for testing of important disturbances which affect the quality of the final dairy product and delivery performance at stages of upstream, processor and downstream.

Table 10

Addressing vulnerability through process redesign

Vulnerability sources	**Addressing vulnerability**
A. Disturbance prevention	
lack of electricity in rural areas; lack of clean water in rural areas; lack of milk procurement infrastructure; lack of refrigerated transportation vans; old plant machinery and equipment; lack of packaging solutions; lack of R&D in product, process and equipment development; lack of milk testing facilities; lack of proper hygiene and sanitation conditions of the cattle shelters in rural areas.	**Managing configuration:** invest to avoid or reduce exposure to vulnerability sources- investment through PPP in milk procurement, R&D, testing, cattle extension services and infrastructure development; investment in quality, technology and new product development; increase capacity
delays and deficiencies in implementation of food safety standards (FSS); delays in court cases in adulteration cases; adulteration in milk and milk products ; variability due to mixing of cow and buffalo milk by the farmers; lack of compliance to quality standards.	**Managing supply chain configuration:** control variability – implementation of FSS and codex standards; implementation of HACCP; supplier selection; food quality certification
low level of organized processing; low level of organized retailing; political interference; profit making approach of the corporate; lack of commitment to CSR and lack of reverse logistics	**Managing supply chain configuration**: Adjust the structure of the supply chain- backward integration by private sector in milk procurement and production; formation of cooperatives of unorganized dairy processors
lack of coordination among agencies responsible for implementation of FSS ; non standardized processes and procedures; non standardized working procedures	**Organization structure**: increase cooperation and coordination between departments- increase cooperation
lack of professionalism in management of cooperatives; low level of training ; non experienced workers; lack of awareness of SCM; lack of HRD and entrepreneurship development	**Organization structure**: improve human resource management – training and courses on dairy farming, milk processing and marketing
lack of traceability and transparency in the supply chain; lack of investments on information systems; lack of information management and processing procedures	**Information system:** create support for information transparency in the supply chain- advanced DSS, collect data, information sharing
B. Disturbance impact reduction	
Outsourcing; local optimization; loose contracts.	**Managing configuration**: make back up options- alternate suppliers, flexible contracts **Organization structure**: use of risk sharing supply contracts for strategic components
Lack of scale of milk production; lack of capacity.	**Supply chain configuration:** Buffering in capacity and inventory- factory production of traditional the Indian dairy products; collocation of plants for manufacture of western and traditional dairy products
Low level of development in transport infrastructure; not sufficient traffic capacity; multipoint handling of milk.	**Supply chain configuration**: increase flexibility of the supply chain- use multiple modes of transportation; use multiple purpose resources
Lack of collaboration and trust ; lack of collaboration with dairy farmers; lack of social security of the workers; low salary to the workers.	**Organization structure**: increase collaboration in chain- SC integration
Insufficient data analysis, varying ICT standards used in supply chain and lack of information management and processing procedures, lack of information visibility	**Information system**: use of IT to increase speed of disturbance detection and support decision making – statistical process control, data mining
Lack of incentives for clean milk production, lack of milk supply in lean season.	**Managing configuration**: increase flexibility of planning, control and manufacturing

The results reveal that, low quality of final product in case for the Indian dairy supply chains results from low quality of raw material and lack of collaboration and trust in supply chain. Similarly, poor delivery performance in case for the Indian dairy supply chains is due to poor distribution network and lack of penetration of organized retailing.

Implication for practice

Operations of the Indian dairy supply chains are highly complex. They involve different types of supply chains. On one hand local level dairy supply chains operate with very small volume of milk and on the other hand large cooperative and big private players operate on big scale and volume. The objective of small operators is to supplement their income through dairy activities. For some dairy is the only means of livelihood. Practitioners from developing countries would benefit from the findings of the study in a sense that they can identify various possible disturbances sources and take appropriate actions.

Scope for future study

The study may be taken as a foundation for future studies on modelling and simulation of various issues pertaining in the dairy supply chain. Design of a facility layout for collection and movement of milk products at the processor may be an interesting area of work. Network planning for procurement of milk could be another theme of study. Development of a distributed information system for linking of various actors of dairy supply chain may also be investigated.

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Solution approach and effect measurement method in design and engineering (1st proposal)
-based on new schematic interview in 14 major Japanese manufacturing companies-

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Abstract
There exist great potential and possibilities on design and engineering in frond-end, so-called early stage design or upstream design, for business. “Design pushes business” might be an attractive phrase for designers, but it’s difficult to persuade it works in realty, since design is intangible and hard to evaluate cost-effectiveness in general. For this reason, design’s ROI (return-on-investment) is discussed intensively recently, which gives us just overall number and no idea to improve it. Design’s effectiveness is described in a lot of reports in the past, by introducing previous best examples or practices in several companies, which provides almost no idea to solve design non-activated companies’ problems, since they have their own barrier against ideal situation with different outer circumstances. Here we provide some idea on design’s effect measurement with factorization and some new idea of multi scanning interview scheme for deeper consideration by catching current barrier against their ideal situation.

Keywords: Design, Cost-effectiveness, Effect measurement, Schematic interview

1. Introduction

This work is an initiative is part of “Digitization of Design/Engineering Effect” of the Research & Design (R&D) project “R&D of Ultra-Upstream Engineering Management/Environment Construction that can accelerate the Communication Between Teams” (research presented by The National Institute of Advanced industrial Science and Technology) under the R&D of the cabinet office “R&D of Strategic Innovation Program(SIP)/ Ultra-Upstream Delight Engineering Method” (2014-2018), and the cross-ministry R&D project based on a Japan revitalization strategy/comprehensive strategy of scientific innovation regarded as one of the three arrows of the Abe Government. The purpose of the study is to map how to digitize and factorize the Effect on Design / Engineering by analyzing the patterns of the relationships between design, engineering and business teams in Japanese companies, which might be applicable to other cases.

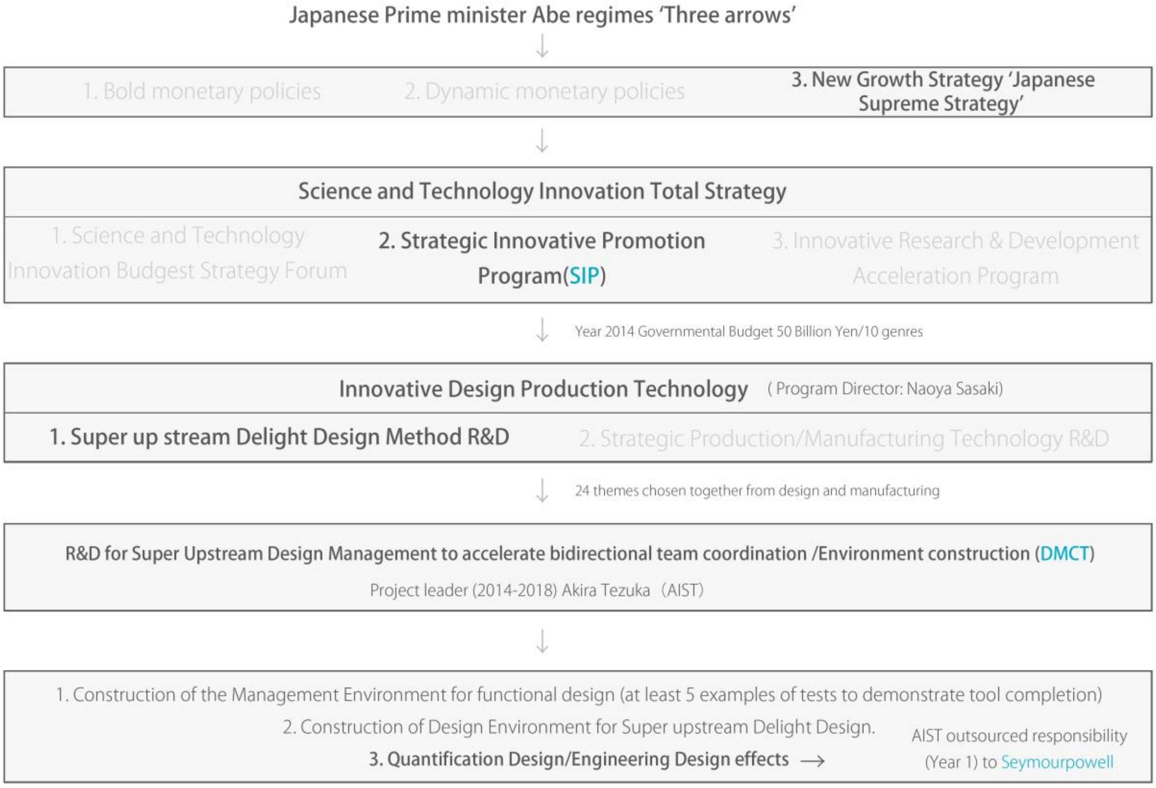

Figure 1 R&D of Strategic Innovation Program(SIP)/ Ultra-Upstream Delight Engineering Method

2. Previous Research

The cost-effectiveness survey (*1) conducted by the British Design Council resulted in increased company awareness of the importance of good design practice and encouraged them to implement it. For example, they state that "we can expect £20 return from every £1 invested in design". This data shows the result of a cost-effectiveness measurement which observed change before and after a company's engagement with good design practice. In order to maximize the success of cost-effectiveness analysis in Japan it is essential to provide a method to assess the impact of good design practice on a project by project basis in comparison to more holistic measures which only quantify the success of a whole company or industry.

Many Japanese companies have engaged in design activities over a long period of time. Accordingly there is a clear need for a method that would allow measurement of continuous activity inside a company, instead of just measuring from a zero base.

Furthermore, the related survey (*2), conducted by €Design, was extremely useful. Using a quantitative method it systematically recorded the contribution of design towards company activity. For this study it was decided to conduct interviews to collate qualitative data within the limited time available. This enabled us to measure the detailed contribution of both Design and Conceptual Engineering (*3) from a real world perspective. In Japan there are few initiatives towards quantifying design cost-effectiveness. With that in mind, the intention was to create a document that would help companies to implement a better NPD process.

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*1 Designing Demand National Evaluation 2007-2012, Eden Partners (2012)
*2 Measuring Design Value, €Design | Measuring Design Value (2014)
*3 Conceptual Engineering means "activities prior to the decisions of specification" conducted by the Engineering Department.

3. Targeted Area in Design

There are many divisions involved in the new product development (NPD) process, including product planning teams, sales team, marketing teams and so on. This research study focusses on design and technical design teams.

Design goes beyond color or form factors, it also covers insight gathering and problem solving. Technical design is the front end activity of the engineering team (activities before fixing the specification for mass production).

Based on output from current research data and the findings from the interviews carried out within this study, we have outlined our view on design and technical design roles. Design has expanded its role from just color or form to insight gathering and problem solving. Technical design has expanded from 'Pure Engineering' to system engineering and delight engineering. The fact the two teams now have wider roles means that they are more free from the closed specialized roles, enabling more and more effective cross disciplinary activity is enabled. Although this research study targets front end activity, we have been taking manufacturing feasibility, yield rate, information gathering and the expression of good design activity into account.

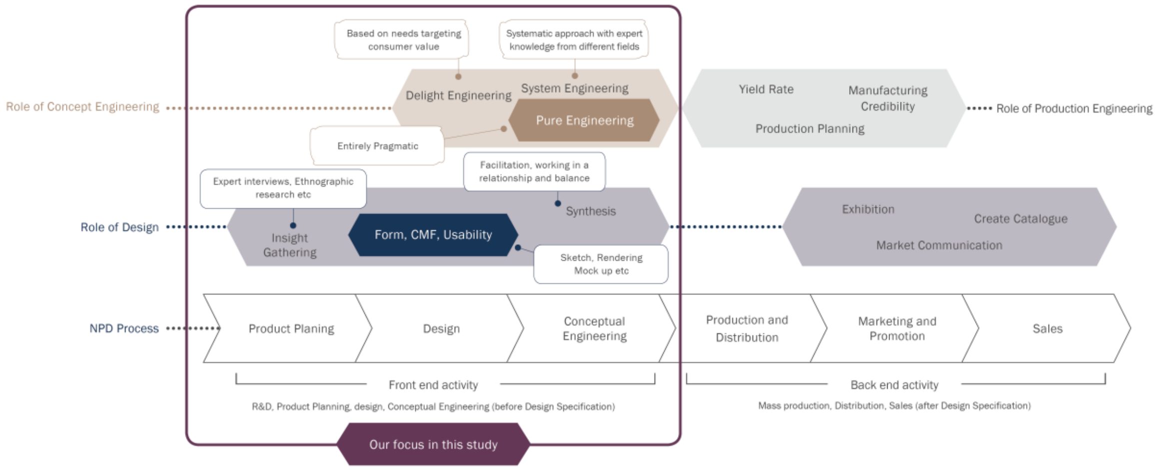

Figure 2 Targeted area in design and engineering

4. Design and Concept Engineering - Their Relationship

This conceptual diagram forms the hypothesis in preparation for the interviews with companies and experts. In the West, the word "Design" often includes both Japanese meanings of "design" and "engineering". In Japan the two disciplines exist separately. This can cause a good effect such as "challenging the threshold value of technology", created when the designer directly questions the engineer. However, some negative aspects are also recognized, such as creating a gap between the understanding of a market and the understanding of production.

There is an old analogy in which the design department would draw "a beautiful rice cake" and the engineering department would create "a horrible tasting rice cake". However, in recent years, many Japanese companies have facilitated the cooperation between these two departments. Company specific resource allocation and the contributions of both the Design and Engineering departments was a primary point of discussion for the interviews carried out for this study.

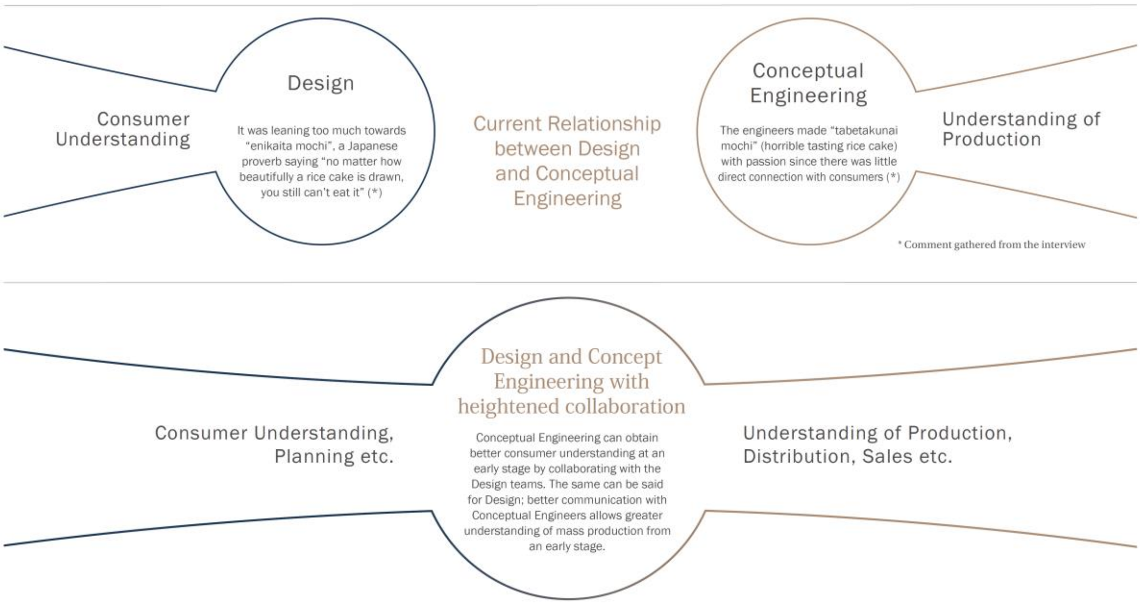

Figure 3 Design and concept engineering

5. Effect Measurement Method

The formula itself is quite straightforward, there are three key elements that the company must understand, as shown in the below diagrams.

Firstly there are front end and back end activities in most Japanese manufacturing companies. Secondly, they must also understand the underlying issues that drive consumer purchasing habits (consumer interests). A carefully considered questionnaire or interview should be used to gain a clear understanding of what consumers are most interested in. The necessary solutions required to deliver against these factors can then be categorized into front and back end activities. These consumer interviews could potentially be integrated within the existing marketing and consumer research activities of a large manufacturer. It is worth noting that front and back end activities are equally as important to successful NPD. The third element pertains to how much each team contributes to the front end activities of a particular project.

The relative contributions can be ascertained by internal interviews between representatives of those divisions involved in front end activities. The figures can then be averaged to reflect an overall consensus of opinion. There are so many factors that contribute to NPD. This makes it almost impossible to measure a contribution just by aggregating the cost or time invested by each team. For this reason the recommendation from this study is to value and trust the opinions and experiences of those working in real situations.

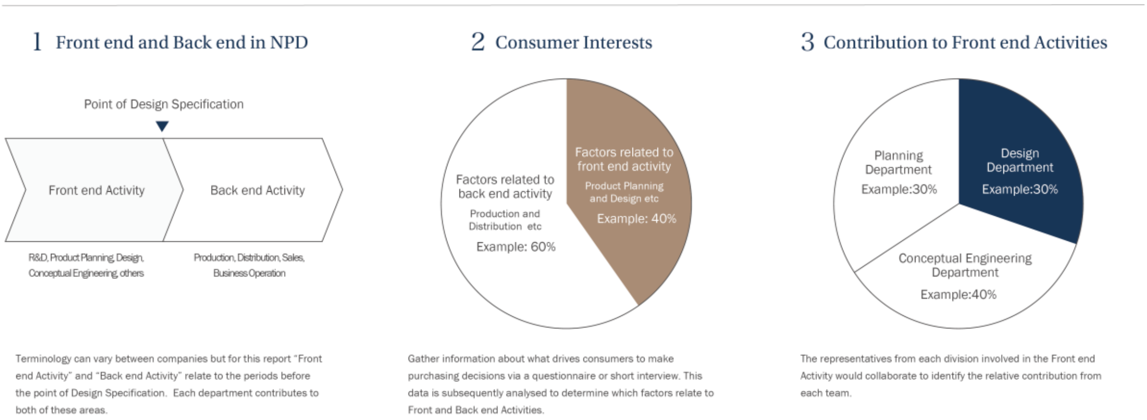

Figure 4 Three key elements in model formula

By using the three key elements the cost-effectiveness of Design and Conceptual Engineering activity can be measured. Here is an example of how this might work:

- Company A creates a new camera with an overall turnover of £2m
- The Consumer interest towards the front end activities was estimated at 40% (estimated from relevant consumer research)
- The contribution from the design team towards Front end Activity was agreed to be 30%
- The financial investment from the Design team was £100k

By applying the formula, as shown in the diagram above, the Return On Investment (ROI) for Design team involvement would be 2.4 times.

There are two unique features to this formula; one is that mutually exclusive data sets gathered from both manufacturer and consumer are amalgamated. The second is that informed, yet subjective, opinions are used to quantify the contribution of each team towards a particular project.

This formula is intended for use on individual projects but when used frequently overtime the collective results can be used to assess an entire company or industry.

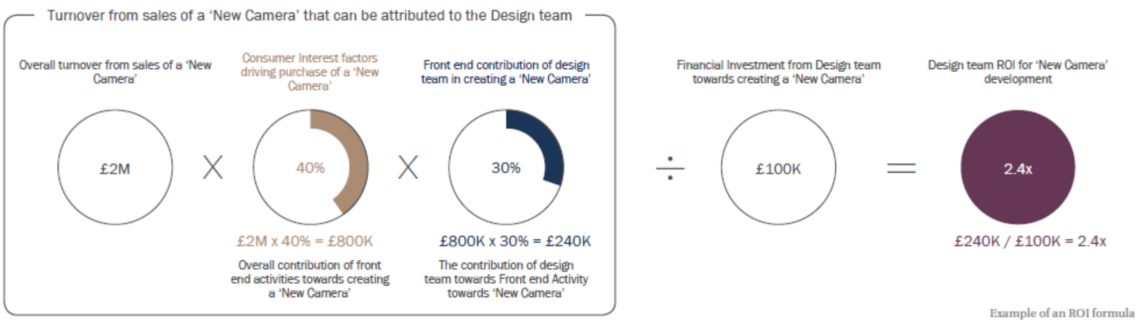

Figure 5 Example of an ROI formula

6. Field Based Distribution Survey

The output from an ROI Formula is effective to measure the relative success of a process, however such figures will not alone improve performance. To try to assist with this, an interview methodology was designed to gain better understanding on how to best allocate resource and which objectives to focus on.

Members from twelve Japanese manufacturing companies were interviewed. Representatives from three divisions (Design, Conceptual Engineering and Business) were invited to participate. Due to busy schedules, in some cases respondents replied on behalf of their absent colleagues.

The objective of these interviews was to highlight the variance between what the current situation and the ideal situation. It was also to raise awareness of any differences of opinion that may occur between different teams.

During the interview respondents were asked to focus their responses around one project which involves NPD with some new innovative solutions (either product concepts or how they sold the product). These projects were to have relatively more involvement from the design team and/or Conceptual Engineering teams. An interactive approach was adopted to engage the respondents and to gain as much information as possible. Playing cards were prepared with inputs and outputs printed on them. Thirty coins were used to physically represent a limited amount of resource. They were then asked to allocate coins to the cards in a way that reflected their current NPD situation and then their ideal NPD situation.

The purpose of the interviews was not to highlight the differences between participating companies, rather to raise awareness of any differences between their current and ideal situations. This interview technique was well accepted by some of those taking part who expressed willing to use this method to plan their next project resource.

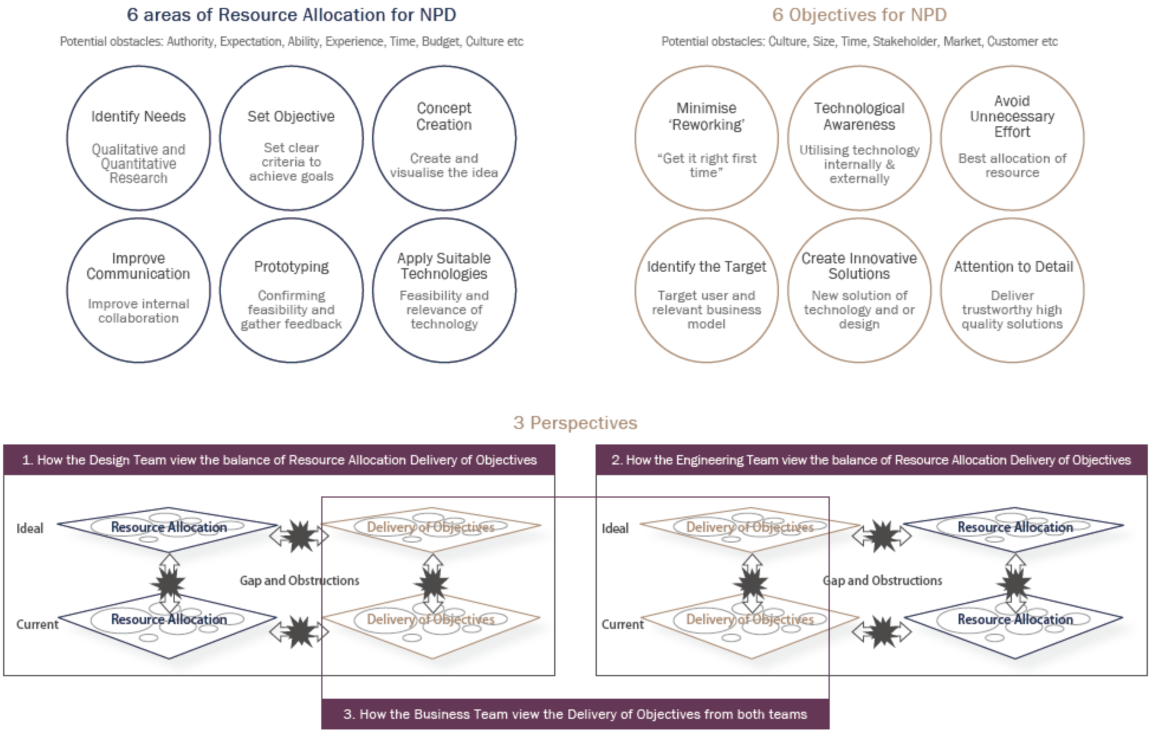

Figure 6 Interview method with three perspectives

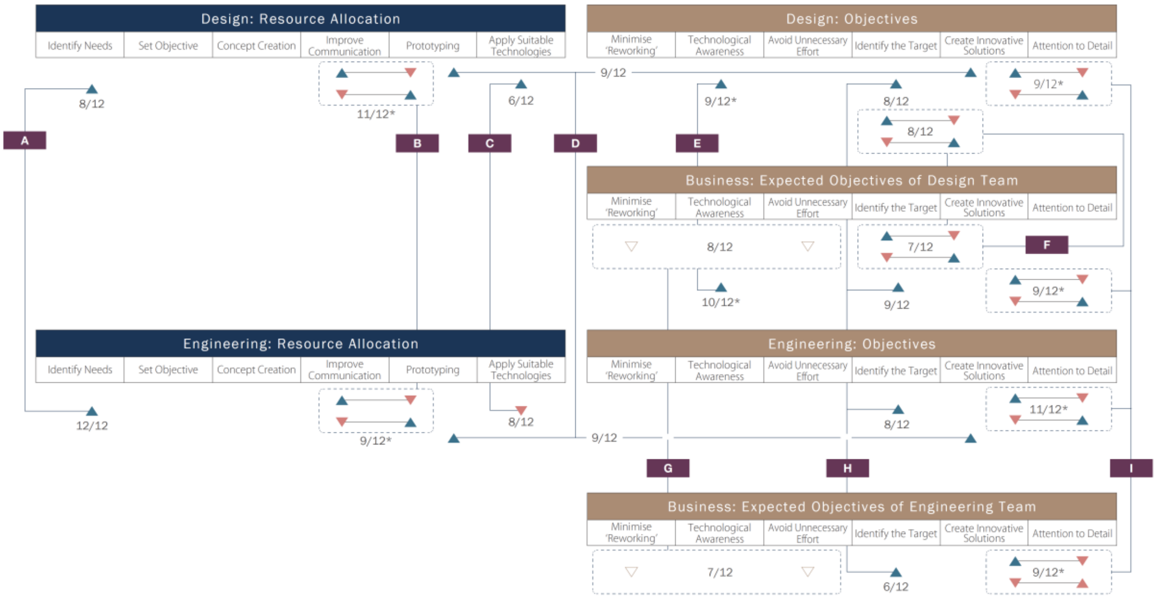

Figure 7 Illustration of the level of current and ideal resource allocation

A

Identification of Customer Needs

Many cases from the design side and all twelve cases from the engineering side would like more resource allocated to the identification of customer needs in the innovation process.

Design Commentary

- Time and resources must be allocated to allow enough time to identify hidden needs
- This needs to be done internally to get first hand information about users.
- Drawing insights from qualitative customer research often takes more time and needs more skills to be developed internally

B

Collaboration vs. Prototyping

Many cases from the design side and from the engineering side believe that increased collaboration between teams results in less resource for prototyping and vice versa.

Design Commentary

- An increase in collaboration between teams results in less time for product development
- There is a lack of understanding between the teams
- The design teams often feel "supplementary" to the process

Engineering Commentary

- A strong IT infrastructure may make collaboration efforts much more effective and efficient

C

Technical Assessments

Many cases from the design side believe that designers should allocate more resource to technical assessments. Many cases from the engineering side believe that engineers should allocate less resource to technical assessment.

Design Commentary

- Designers with expertise in numbers succeeded in establishing today's design team
- Designers could be more proactive in applying smart design solutions but time constraints are often an issue
- Design teams need to be more proactive about contributing to engineering and therefore being more at the heart of Japanese manufacturing

D

The Role of Prototyping in Innovation

Many cases from both the design and engineering teams believe that if you invest more resources into prototyping you arrive at more innovative solutions.

Design Commentary

- Prototyping new concepts allow the design team to better communicate with other teams within the business
- Certain types of usability assessment can be done via computer technologies. However prototyping is necessary for testing tangible product features such as touch and feel

Engineering Commentary

- Engineers could be more proactive in prototyping

E

Internal & External Technology Capabilities

Many cases believe that more design team resource should be allocated to work on internal and external technology capabilities.

Design Commentary

- More collaboration with engineers during the technical assessment phases is key
- Increased sharing of ideas and information between engineering and design teams results in novel ways of applying new technologies

Engineering Commentary

- Engineers could be more proactive in prototyping
- Developing technologies internally requires more time and cost investment and would therefore need partnering with another company

F

Identify the Target vs. Innovation

Many design cases believe that the more resources dedicated to identifying the target, the less innovative the solutions and vice versa.

Design Commentary

- Old technology stymies innovative solutions
- Company silos between business and design teams cause difficulties in identifying target markets for NPD

G

Work Efficiency

Many cases from the business side believe that the design and engineering contribution is less than what the engineering side believe they are contributing in regards to wasted work efforts.

Design Commentary

- Business teams within organisations often do not have clear sight of design teams efforts
- There is a lack of understanding between the business and design teams regarding skills and the appreciation of design

H

Identifying the Target

Many cases from the business side believe that there should be more contribution to identifying the Target.

Design Commentary

- There is a desire for more design involvement in this area but hesitancy due to lack of expertise in business & marketing

Engineering Commentary

- There is often a clear briefing on the target market from the client so therefore less focus is needed here

Business Commentary

- There is a desire for more involvement from the engineers in contributing to identifying the market rather than just the tasks at hand

I

Trade-off between innovative and 'perfect' solutions

In many cases there is a trade-off between allocating resource to achieving more 'realised' solutions versus more innovative solutions.

Design Commentary

- Innovation is important, but there is a need to produce a perfectly finished product to appeal to customers

Engineering Commentary

- Achieving a perfectly realised product takes precedence over ensuring the most innovative solution. There needs to be a balance
- There are many issues involved in the NPD process so securing enough time and resource to perfect the product is key

Figure 8 Field based distribution survey - contents of distribution analysis

7. Conclusions

Formula to quantify Return On Investment has been a big discussion point for decades. This intensive three month study has resulted in a new ROI formula and Field Based Distribution Survey method. This is a first step towards developing what would ultimately be optimized solutions for collating, analyzing and putting data to good use.

The final version of this discussion paper with updated measurement method is available at http://monozukuri.org/dmct/index_en.html.

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Title: Innovation ecosystems: the role of Business Model Evolution as an 'adaptive exploration'

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Abstract:
New developments such as Precision Medicine, Regenerative Medicine and Digital Health are emerging as important areas for future healthcare. However they are underpinned by the concept of 'convergence' or cross-industry innovation, which has had limited research to date, with only a few empirical studies.

Convergence creates the potential to drive innovation, new business models and new value chains. But innovators face greater uncertainty and influence from knowledge and actors not traditionally part of their ecosystem. Understanding the landscape, the emerging ecosystem and the new capabilities required is therefore critical for innovators.

Based upon diverse literature, this paper proposes a conceptual model for early stage innovation in convergent ecosystems. The model identifies activities to integrate the evolution of the business model, the new product or service and the value network and importantly provide an explicit link to the ecosystem. Drawing analogies from evolutionary biology, the concept could be considered as analogous to Kauffman's '*adaptive walks on rugged landscapes*', with recursive value exchanges of evolving boundary objects providing the underpinning mechanism.

Keywords: innovation, business modelling, ecosystems, convergence, value exchange
Paper type: conceptual

Introduction:

There is increasing interest in cross-industry or 'convergent' innovation (Brunswicker & Hutschek, 2010; Enkel & Gassmann, 2010; Gassmann, Zeschky, Wolff, & Stahl, 2010). Many major healthcare developments such as Precision Medicine, Regenerative Medicine and Digital Health rely on convergence, and the technologies and capabilities from diverse industries (Sharp, 2014). However, convergent innovation can result in very high levels of uncertainty and risk as the diverse science and technology, diverse partners and diverse innovation ecosystems merge (Hacklin, Marxt, & Fahrni, 2007; Hacklin & Wallin, 2013; Rikkiev & Mäkinen, 2013). In healthcare this is further exacerbated by the complex customer value systems (Institute of Medicine, 2011) and that many innovations have a systemic effect (Midgley, 2000). Whilst the phenomena are important in practice, limited research has been conducted on the challenge of convergent innovation, where conducted, it has mainly focussed on ICT (Bernabo et al., 2009a; Hacklin, Marxt, & Fahrni, 2009; Stieglitz, 2003), with very few papers on convergence in healthcare ecosystems (Bernabo et al., 2009b; Eselius, Nimmagadda, Kambil, Hisey, & Rhodes, 2008; Shmulewitz, Langer, & Patton, 2006).

Similarly, business model innovation and evolution is often focussed on mature firms (Demil & Lecocq, 2010; Fritscher & Pigneur, 2014; Tongur & Engwall, 2014), there is more limited research in start-ups (Fiet & Patel, 2008; Trimi & Berbegal-Mirabent, 2012), and again there is very limited study of business model innovation in healthcare.

This research is conceptual, but aims to address some of these gaps by drawing on diverse literature from economics, innovation, business models and value analysis, and evolutionary biology. The objective of this concept paper is to make a contribution to the understanding of activities and mechanisms that operate to link ecosystems and innovation, and as such, innovators and their value networks, and required capabilities. The contextual focus is on convergence, and in nascent or emerging innovations with high levels of uncertainty in the technology, products, business models and ecosystems, by addressing the question: *How do organisations innovate in complex, highly dynamic convergent and emergent ecosystems?*

Literature Review:

Economic progress and innovation, derived from Schumpeter (1939; 1942) and the evolutionary economics of Nelson and Winter (R R Nelson & Winter, 1982; Richard R Nelson & Winter, 1974, 2002; Richard R. Nelson, 1994), point to evolutionary processes. More recent concepts such as business ecosystems (Moore, 1993, 1996, 2006) and stakeholder theory (Freeman, Harrison, Wicks, Parmar, & De Colle, 2010; Freeman, 1984; Mitchell, Agle, & Wood, 1997) provide different perspectives and the need to engage in activities that span industries and the boundaries of the firm. The complexity of value systems in healthcare (Institute of Medicine, 2011) with patients, practitioners (physicians, nurses, pharmacists), providers (clinics, hospitals and health management organisations) and payers (government, insurers and patients) are such that they can be considered as complex systems and that interactions with stakeholders (as actors in business ecosystem) influence the outcomes in innovation ecosystem, thereby resulting in systemic effects (Midgley, 2000, 2006)

Innovation has been the focus of extensive research (Fagerberg, Fosaas, & Sapprasert, 2012) with much of that focus being on the innovation system or on organizing innovation. Montoya-Weiss (1994) in a meta-analysis, identified factors that influence development processes, and similarly Holahan (2014) identified best practices; the main focus being in organizing innovation. Adner (2008; 2012), extending the concept of the business ecosystem (Moore, 1993, 2006), introduced the concept of innovation ecosystems, spanning the innovation systems and organization fields. His model addresses two important concepts, seeing or understanding the ecosystem and choosing a position, by mapping the adoption chain (i.e. those stakeholders necessary to launch a new product or service). This approach offers potential to investigate convergent innovation as it addresses industry-spanning phenomena. But these approaches only partially address the value creation and business model challenges, largely because much innovation literature is rooted in a resource based view, which is not considered to adequately explain value creation and capture (Bowman & Ambrosini, 2000).

The fundamental issue then, is the lack of a clear link between the ecosystem, value creation and the required network (and thus, capabilities). Innovation is ultimately about creating value (Makadok & Coff, 2002; Priem, 2007). The concept of a business model has a variety of interpretations (DaSilva & Trkman, 2013), but essentially a business model describes the logic and the link between the customer value proposition (VP), and how an organization creates and captures that value (Teece, 2010); it would and therefore appear to be a more fruitful field for enquiry. As a result, the business model concept is of increasing interest and importance (C. Baden-Fuller & Mangematin, 2013; Charles Baden-Fuller & Haefliger, 2013;

Teece, 2010), in both industry and academia. Much of the extant literature takes an essentialist view of the business model as either a description (Osterwalder, Pigneur, & Smith, 2010) or, a representation or model (Charles Baden-Fuller & Morgan, 2010; Massa, Zott, & Amit, 2010). But a business model can also be considered as a ‘market device’ (Liliana Doganova & Eyquem-Renault, 2009). It has been suggested that a business model is a boundary object (Velu, n.d.), but here it is proposed that the model itself is not the boundary object but that its components, namely: the value proposition, the use value and exchange value act as ‘boundary objects’ (Carlile, 2002, 2004; Leigh Star & Griesemer, 1989) that enable an organization to connect with its stakeholders.

How innovator’s innovate and entrepreneur’s develop businesses is fundamentally about identifying the value proposition (Anderson, Narus, & Rossum, 2006; Zott & Amit, 2007), seeking feedback on the value perceived by customers and stakeholders, and defining the product/service, underpinning technology and value network required to support it. The literature typically emphasises the role of trial and error (L Doganova, 2013; McGrath, 2010; Sosna, Trevinyo-Rodríguez, & Velamuri, 2010). However that predisposes the innovator’s understanding of ‘what trials to do’ and ‘where to undertake them’, and also in recognising their boundaries of power and competence (Santos & Eisenhardt, 2005). This is not trivial, and is especially challenging in multi-stakeholder markets (Frow & Payne, 2011) which characterise the healthcare value system, and even more so under conditions of convergence.

Two key components of a business model are value creation and value capture (Bowman & Ambrosini, 2000; Lepak, Smith, & Taylor, 2007). In identifying how value is created, captured and destroyed (2010), Bowman and Ambrosini introduced definitions for Use Value (UV) and Exchange Value (EV), as part of a value exchange, which provides a construct to more precisely define the ‘boundary objects’. The exchanges take place not just with customers, but with a range of stakeholders in the ecosystem, where stakeholder orientation focuses on understanding which values are the most important to satisfy certain stakeholders (Carvalho & Jonker, 2015). The concept of using integrated models that address the value build up, dynamics and exchange were proposed by Khalifa (2004). But, as noted, a real challenge is to identify the relevant stakeholders, which is made more complex in convergence, where the ecosystem is still evolving. Classical stakeholder management (Freeman, 1984) would stress identifying all the stakeholders as a first step. However stakeholder salience is highly dependent on the innovators position within the ecosystem (Frow & Payne, 2011). In emergent ecosystems, key stakeholders may not be immediate (Maignan, Ferrell, & Ferrell, 2005), and so identification needs to be a continual exploration, with iteration and refinement as part of the innovation of the product, service and business model.

Allee (2000, 2008) used a value analysis to address both tangible and intangible assets, identifying that they may be converted to monetary value or a negotiable form of value. Traditionally, this value exchange has been seen as a dyadic relationship (Jacobides, Knudsen, & Augier, 2006). In healthcare a triadic relationship, or more, may be necessary to explain the complex nature of the value exchange between a producer, and the patient, practitioner, provider and payer. In business model terms this is described as a ‘multi-sided model’ (C. Baden-Fuller & Mangematin, 2013), requiring different cognitive capacity from traditional customer relationship models.

It is proposed that, conceptually, the ‘value exchanges’ form the interaction mechanisms as the business model value propositions (VP) and the product, technology and service offerings, as boundary objects, co-evolve to address stakeholders perceptions (see Figure 1), thereby creating an explicit link between the ecosystem, the innovation activities and the value network. The exchanges provide the opportunity to transfer, translate or transform the value proposition (Carlile, 2002, 2004) and implicitly result in an exchange and the evolution of the offering and business model. Some examples of these exchanges are summarised in Table 1.

Table 1 Healthcare examples of value exchanges in business modelling and innovation

Stakeholder	Nature of Value exchange	Boundary Object(s)
Investor(s)	Investment in innovator in return for equity. For venture capital this is typically syndicated amongst several investors	Potential Value Proposition Potential Exchange Value of innovator (as invested entity)
Grant Funder(s)	Grant funding for R&D for projects that meet grant criteria	Potential Value Proposition
Regulator(s)	Assessment of potential use value and risk	Potential Use Value (efficacy, safety and risk)
Health Technology Assessment	Assessment of overall health value versus alternative medical pathways	Potential Value Proposition Potential Use Value Wider economic health value
Alliance Partner(s)	Agreement to collaborate in innovation	Potential Value Proposition Potential Expected Value of alliance agreement
Payer(s)	Expected utility of innovation (versus alternatives) in return for payment	Potential Value Proposition Use Value Exchange Value (cost versus alternatives)
Practitioner / Provider(s)	Expected utility of innovation versus alternatives	Potential Value Proposition Use Value (efficacy versus risk and total use cost versus alternatives)
Patient(s)	Use of innovation, to improve health, versus use risk	Use Value (efficacy versus risk and convenience)

A 'value exchange' is, however, considered as part of a broader process for the innovator, the ultimate aim being to *optimise* the business model. As this activity takes place in a complex evolving ecosystem, it suggests analogies to biological evolution in a rugged landscape, as described by Kauffman's NK (Kauffman & Johnsen, 1991; Kauffman & Levin, 1987; Kauffman & Weinberger, 1989) and an 'adaptive walk'. An adaptive walk is '*one that starts at a solution and moves by some algorithm or procedure, including mutation and selection, toward better solutions*" (Kauffman & Levin, 1987, p. 16). The ecosystem is analogous to an '*uncorrelated landscape'* (i.e. actual fitness values are unknown, but can be 'ranked'); here, a 'greedy walk' which picks the best of the alternatives, provides the fastest route to the optimum (Kauffman, 1993). In later developments McKelvey (Boisot & McKelvey, 2011; McKelvey, 1999) suggest implications for NK(C) landscapes, implications for innovators, as complexity increases, with a need to keep internal connectedness (C) low relative to the external connectedness (K). This would suggest aiming for a high level of external engagement (and value exchanges), with diverse actors. It also points to keeping internal complexity low (as typically exists in start-ups), to avoid early 'lock-in', which in major organisations would indicate the use of a 'skunk works' or a smaller 'looser' autonomous innovation team (Levinthal, 1997).

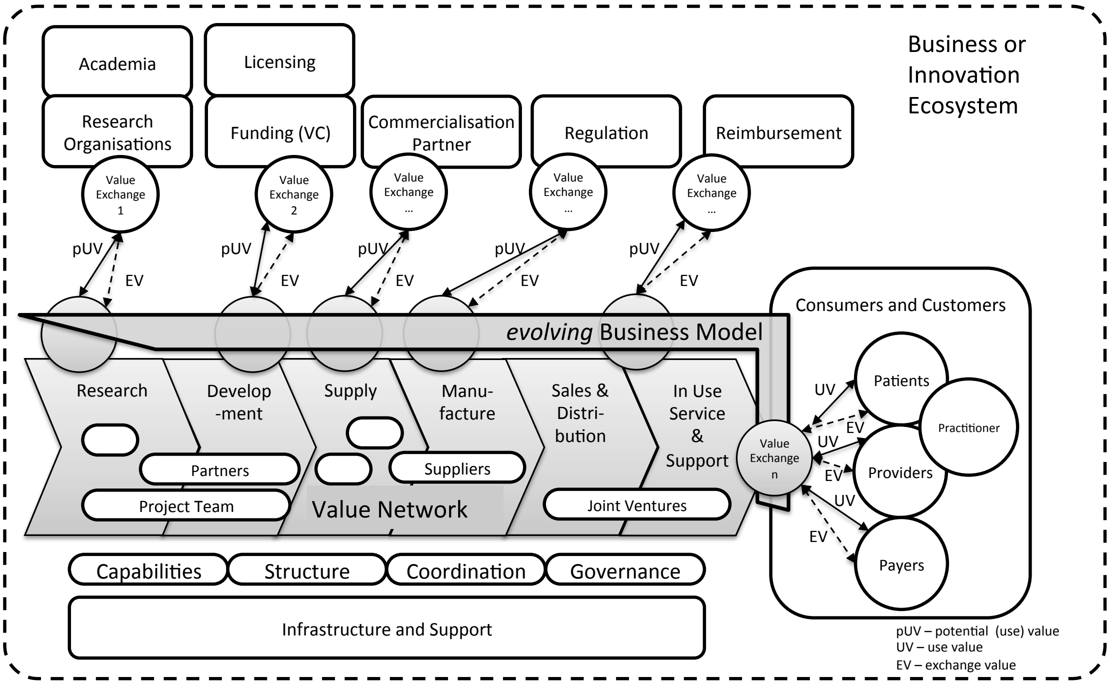

Figure 1 – the evolving business model as an explicit linking mechanism

There may also be more than one potential value proposition from the innovation. Each value exchange is an opportunity to adapt (or mutate) the offerings, or in Carlile's (2004) boundary object terminology: to transfer, translate or transform them. These processes draw on cognitive capabilities to search creatively (Garud & Gehman, 2012; Pandza & Thorpe, 2009) and sense-make (Gioia & Mehra, 1996; Sutcliffe, Weick, & Obstfeld, 2005; Weick, 1993) via inter-subjectivity, and on absorptive capacity (Cohen & Levinthal, 1990; Enkel & Heil, 2014) to assimilate and act upon new knowledge. The search for insightful stakeholders and then sense-making is critical, but challenging, as different stakeholders have different (and sometimes conflicting) perspectives about value (Garriga, 2014), particularly in a healthcare setting (Institute of Medicine, 2011). Sense-making involves "*the reciprocal interaction of information seeking, meaning ascription, and action*" (Thomas, Clark, & Gioia, 1993, p. 240), it is grounded in individual and social activity (Weick, 1995, p. 6), and is "*about authoring as well as interpretation, creation as well as discovery*" (Weick, 1995, p. 8). So, these steps are more than just reactionary; they are creative and anticipatory processes (Rosen, 1985) suggesting a combination of path creation and path dependency (Garud, Kumaraswamy, & Karnøe, 2010; Sydow, Windeler, Müller-Seitz, & Lange, 2012) or of causation and effectuation (Chandler, DeTienne, McKelvie, & Mumford, 2011; Dew, Read, Sarasvathy, & Wiltbank, 2008; Sarasvathy & Dew, 2005), or both (Sitoh, Pan, & Yu, 2014), as innovators engage the ecosystem to shape their offerings and the required capabilities.

In the proposed model, the concept of a potential value proposition (pVP), potential use value (pUV) and potential exchange value (pEV) are used to clarify the evolving nature of the innovation and business model. But sustainable value creation also requires the management and reduction of risk (to the innovation, the value network and business model) by investing in innovation processes, value network capabilities and the ecosystem itself (Smith, Day, & Shoemaker, 2013). In systemic and convergent innovation there is increased risk complexity and interconnectedness (Hellström, 2003) with potential risks in the technology, its integration (Smith et al., 2013) and in the commercial model, and also with different stakeholders having different perceptions of risk (Hall, Bachor, & Matos, 2014), so focussing on value creation alone is insufficient.

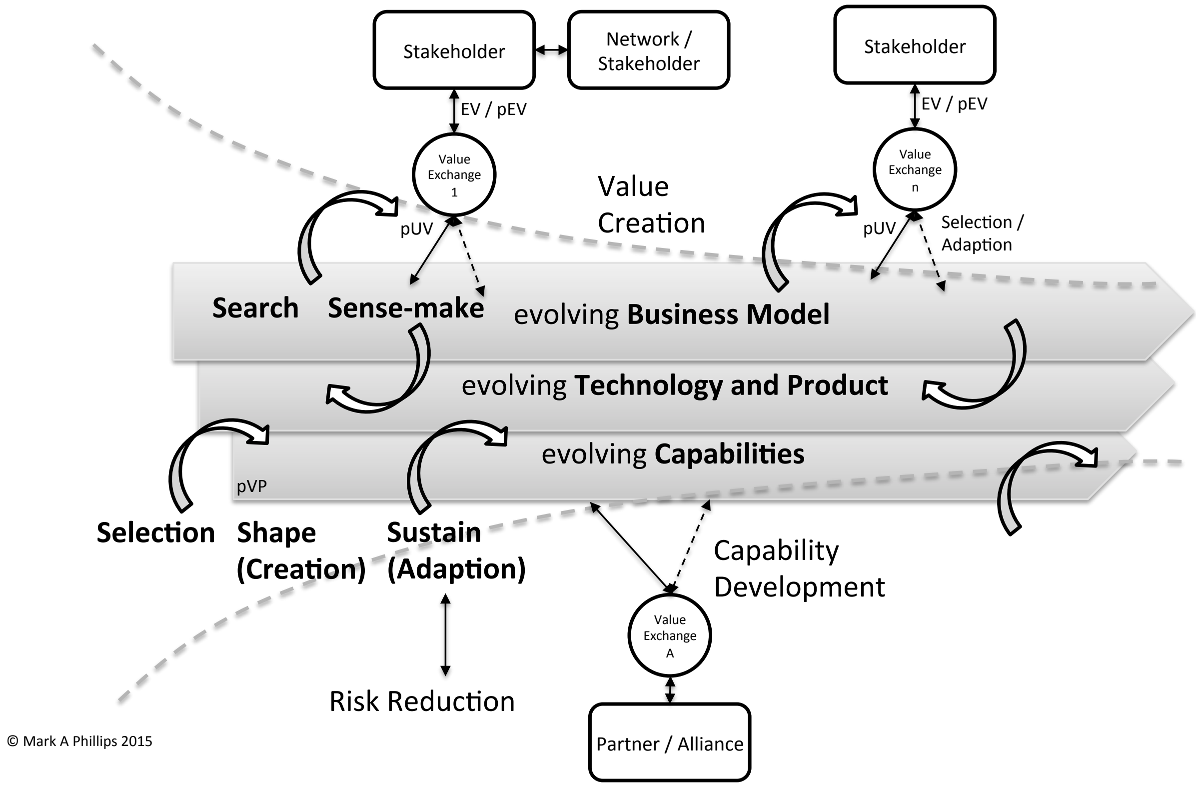

Figure 2 – Causal mechanisms and configurations in business model evolution

The proposed model integrates the concepts of value exchanges and of supporting activities to transfer, translate or transform the offerings via searches, sense-making, selection and sustaining activities, that ultimately enable the innovator to shape their offering. The proposed '5S model' is summarised as:

- Search – identifying potential value propositions (pVP) and insightful and appropriate stakeholders to engage
- Sense-Making – through value exchanges to assess or test the viability of the pVP (obtaining feedback in terms of pUV and pEV) –both tangible and intangible value
- Selection – of the preferred (or best) proposition(s) to date
- Shaping – directionally shaping the selected offering, before the value exchange processes
- Sustaining - investing in the innovation, value network and ecosystem, to both create value and reduce risk

The model is depicted in Figure 2. In executing these processes, the innovator and ecosystem co-evolve, creating value, building capability (by similar exchanges with alliance partners and suppliers) and reducing risk. It is suggested that this model provides a more systemic view of innovation (Midgley, 2000, 2015) which recognises the complexity of interactions between stakeholders, and the iterative, recursive processes (rather than linear ones often suggested by innovation literature). In convergence and especially health care, many innovations have a wider impact, with potentially multiple value propositions, and affect customers' value processes, and so are likely to be systemic in nature.

Discussion:
The proposed model suggests the concept of the business model as an explicit linking mechanism, and specifically refines a potential Value Proposition (pVP) via Value Exchanges as the mechanism by which the boundary objects, namely the potential Use Value (pUV) and potential Exchange Value (pEV) are transferred, translated or transformed, through a series of activities that cycle through search, sense-make, select, shape and sustain processes to co-evolve the innovation, the business model and the value network.

Extending the biological analogy, the aim of the innovator, as noted previously, is to optimise their offering, or to search for the optimum in a 'fitness or rugged landscape'. Drawing again from evolutionary biology, computer science and artificial intelligence, genetic algorithms (Grupe & Jooste, 2004; Holland, 1992) are a search heuristic that provide a useful analogy. The aim of a genetic algorithm (GA) is to mimic the biological evolutionary processes to find the ecosystem optimum. The GA process involves the steps of selection, recombination or crossover, mutation, and then an evaluation i.e. a fitness assessment, before acceptance. The performance of GA to find a true optimum is improved by taking multiple or bigger crossover steps versus smaller incremental steps which may result in finding a local sub-optimum (Mocanu & Kalisz, 2012), in the case of innovation this would be achieved by increasing the diversity of stakeholders engaged in cross-over (i.e. value exchanges). This suggests wide interaction with 'unusual suspects' and boundary crossing (Akkerman & Bakker, 2011), rather than with close-knit confidants. Increased interaction reduces (later) surprises (Weick, 1995, p. 24), but only up to a limit, there is a need for balance to avoid equivocality and confusion (Weick, 1995, p. 27) by focussing on values, priorities and providing clarity. In networking terms, organizations should engage the 'network of their network' (i.e. via snowballing (Doreian & Woodard, 1994)), using weak ties (Grannovetter, 1973) so that value exchanges initially explore diverse options, then by combining exchange parts (analogous to biological genetic cross-over). As a near optimum is identified 'home in' by reducing diversity (i.e. focus on stakeholders in the selected domain) and reducing the acceptance of 'worse solutions' in a process analogous to 'annealing' (Kirkpatrick, Gelatt, & Vecchi, 1983).

In the world of innovation, this is a cognitive process and therefore not just about chance; it is not just causal. The implication of path creation and effectuation suggest that the process is not simply reactionary, but is anticipatory (Louie, 2010; Rosen, 1985), with the innovator's agency (Eisenhardt, 1989) and cognitive processes defining the direction and shaping choices. Returning to the evolutionary biology analogies this is more suggestive of an anticipatory genetic algorithm (Mocanu & Kalisz, 2012), which employs the principle of rejecting (filtering) adaptions that are worse than the worst in previous generations. These additional steps enable an improvement in the performance of the algorithm, by internally evaluating each 'potential' boundary object and filtering based upon acceptability criteria, then either rejecting or inserting the update as the new 'boundary object' (i.e. potential value proposition). Table 2 summarises the analogies between anticipatory genetic algorithms and the proposed 5S Framework.

Iterating through these steps, each value exchange is an opportunity to transfer, translate and transform the offering, and to optimise the business model via an '*adaptive walk on a rugged landscape*' (Kauffman & Levin, 1987), as depicted in Figure 3.

Table 2 – Analogies between Genetic Algorithms and Proposed 5S Framework

AGA Steps (from Mocanu)	5S Model Activities	Activity Description
Evaluate	Search and Sense-Make	Assess potential Use Values (Value Propositions) for identified Stakeholders
Select, Recombination (crossover) and Mutation	Select and Shape	Based on Value Exchange feedback, select and shape most promising offerings
Filter and Acceptability	Sense-Making and Select	Internally assess options versus risks
Insert and Update	Sustain	Invest in value creation and risk reduction activities

Conclusions

This conceptual paper attempts to move forward the thinking and theory on ecosystems, innovation and business models and, importantly how they interact. A model is suggested by which innovators can evolve their offering and make explicit connections with their ecosystem.

The paper makes a contribution to known gaps in business model evolution thinking (C. Baden-Fuller & Mangematin, 2013; Velu, n.d.) by addressing how the concept of business modelling provides an explicit mechanism to link the value network to the ecosystem. It makes a further contribution to the understanding of business modelling (innovation and evolution) by proposing mechanisms and activities by which potential value propositions (as boundary objects) can be used in value exchanges, with diverse stakeholders to co-evolve the business model, the product or technology and the value network. Furthermore it makes a contribution to business model evolution literature by identifying activities or routines needed to effect the evolution.

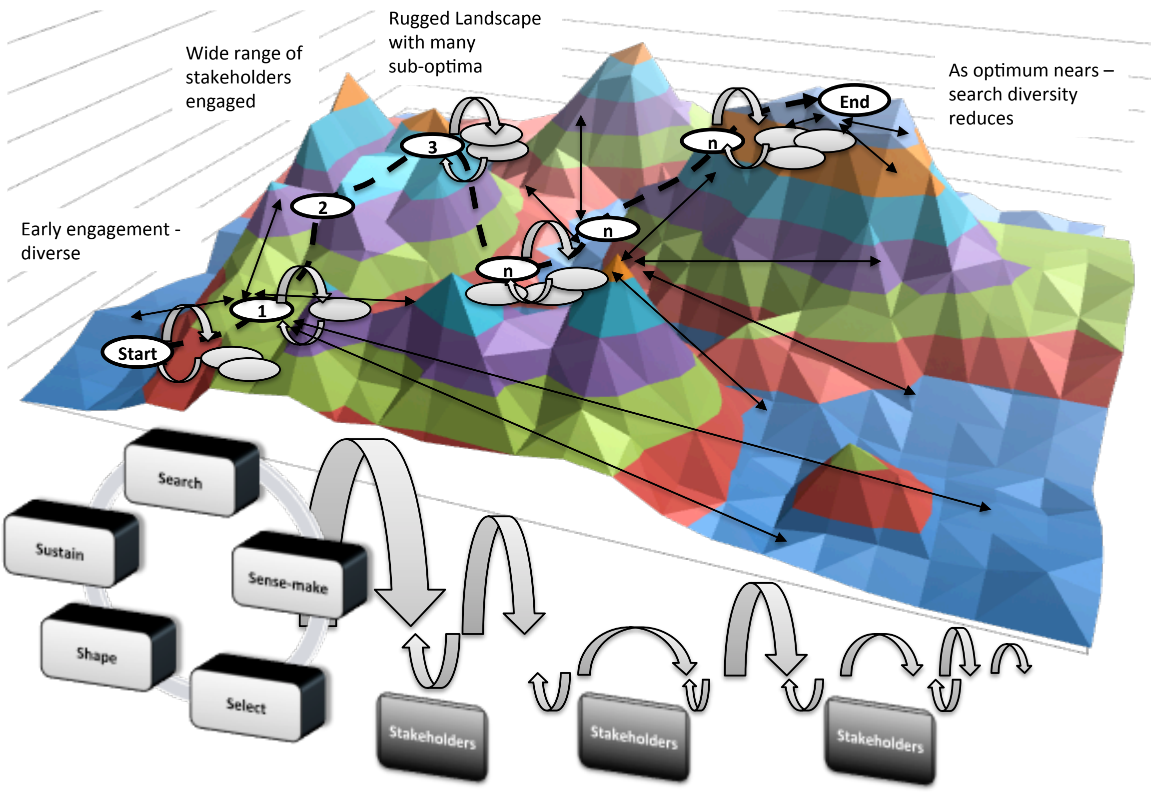

Figure 3 – Business Model evolution as an 'adaptive walk'

A further contribution is made to understanding evolutionary approaches to innovation in complex convergent or nascent ecosystems, by drawing analogies to anticipatory genetic algorithms, as innovators seek to optimise their position.

Some authors contend that such business model innovation activities constitute dynamic capabilities (Eisenhardt & Martin, 2000; Helfat et al., 2007; Teece & Pisano, 1998), defined as "*the capacity of an organization to purposefully create, extend, or modify its resource base*" (Helfat et al., 2007, p. 4) through sensing, seizing and transforming clusters (Teece, 2007, 2014). Dynamic capabilities are classically rooted in the resource-based view, and are focussed on the processes, paths and positions of firms (Teece, 2014), but as exemplified by Lepak, "*the dynamic capabilities literature on creating new advantages currently neglects the importance of the target users, their perceptions, desires, and alternatives, as well as the context in which users are embedded*" (Lepak et al., 2007, p. 184). However Teece (2014) later indicates inclusion of value creation or capture activities to address this. The activities in the proposed 5S model could therefore be construed as elements of dynamic capabilities that are focussed on value creation and capture, making a contribution to that literature.

For the practitioner, or innovator, the challenges of cross-industry or convergent innovation are great; innovators face new challenges from the inherent increasing risk and uncertainty. An approach is proposed to improve innovation performance by identifying and engaging with diverse stakeholders, as part of a sense-making and selection process, to help drive business model evolution, to provide a framework for innovators to optimise business models by exploring and adapting, via potential value exchanges.

This paper forms part of an on-going research project, a number of case studies are currently being undertaken to investigate the activities and processes used by organizations in convergent innovation in health care. These cases will be used to further explore mechanisms and refine this conceptual model.

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Industry network embeddedness of emerging multinationals

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Abstract

The central argument of network theory is that economic processes are embedded in the structure of social relationships. Our aim in this paper is to explore the consequences of the embeddedness on the economic process of internationalization, with particular focus on emerging multinationals in an established industry. We integrate embeddedness and International Business literature and illustrate the network embeddedness of emerging multinationals in explorative study of the white goods industry.

Performance assessment of International Manufacturing Networks: an exploratory study

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Abstract

The global spread of production opens challenging research streams concerning the management of ever-increasing global manufacturing systems, with particular interest on the network-based manufacturing systems known as International Manufacturing Networks (IMNs). This article discusses how to assess the performance of an IMN whose priorities change over time. Performance is a multidimensional and contextual concept related to effectiveness and efficiency. Different types of IMNs are designed to achieve different strategic goals but the performance appraisal will always deal with a more complex set of dimensions, comprising some that are not directly related to those goals. This article seeks to contribute to the IMN theory by proposing a method for multinationals to assess IMNs' performance when goals bear more than one relevant dimension, or when they change over time. The performance assessment must combine dimensions that reflect the IMN's mission (the required performance), must be at strategic level, meaning few synthetic dimensions measured from aggregated data, have to be more quantitative than qualitative (based on operational data rather than on managers' perceptions) and finally have to grasp the interdependent and synergistic nature of a network-based structure like an IMN. The illustrative case presented shows that performance assessment indeed has to be adjusted when the IMN is redesigned for whatever reason. Future research may provide more insights on the contingencies that affect performance and how performance assessment can deal with them, as well as research with quantitative data.

Keywords: International Operations Management, International Manufacturing Networks, Performance measurement.

1 – Introduction

In the field of Operations Management (OM), International Manufacturing Networks (IMN) has been increasingly recognized as relevant stream of research due to internationalization and globalization trends. IMN is defined as a network of factories around the world, within multinational companies, that operate as integrated and interdependent units (Shi and Gregory, 1998; Cheng et al., 2015). Many authors have contributed to address a number of related issues, such as IMN's capabilities (Colotla et al., 2003), typologies (Kulkarni et al., 2004; Ferdows, 2009), optimization (Chan et al., 2005), design (Friedli et al., 2014), strategy (Miltenburg, 2009), and strategic context and evolution (Fleury et al, 2015a; 2015b). However, issues concerning performance assessment have been underinvestigated (Cheng et al., 2015).

The literature on International Operations Management (IOM) has already considered performance assessment when dealing with particular types of IMNs, like those designed for maximum performance primarily on cost, or flexibility, or innovativeness (Kulkarni et al., 2004; Mauri, 2009). They however fail to investigate problems faced by multinationals that have to set the IMNs' goals that are composed of more than one relevant dimension, or have to change these goals over time.

Supply Chain Management (SCM) studies show considerable concern with performance through goal setting (performance required) and KPIs – Key Performance Indicators (performance delivered), though for extra-firm networks (Meixel and Gargeya, 2005; Srai and Gregory, 2008). Then, such source literature might add to the present research though it must be properly scrutinized, due to the sometimes conflicting perspectives between the fields of OM/Manufacturing and SCM/Logistics (Rudberg and Olhager, 2003).

The literature on International Business (IB) pays little attention to manufacturing networks as such, for its studies either focus on the networks of specific functions, especially R&D/Innovation (Dunning and Lundan, 2009), or consider the network of subsidiaries as a whole (Bartlett and Ghoshal, 1998; Verbeke, 2009). Also, IB usually adopts a strategic and aggregated perspective in what regards performance, based on general indicators like foreign sales and foreign assets, mainly.

The aim of this paper is to develop a method for multinationals to assess the performance of their IMNs when they have goals that are composed of more than one relevant dimension, or when these goals change over time. The fact that multinationals have to deal with such issues is associated to environmental demands. In this case, the issue has to be tackled through contingency approaches considering that the organization is always seeking for the appropriate alignment between the business environment and the organization's strategy and structure (Venkatraman, 1989; Galbraith, 2000; Boyer et al., 2005). Therefore, this dynamic view of IMN performance assessment leads to the following research question:

"How to assess the performance of an IMN whose priorities and characteristics change over time?"

2 - Literature review

There is a growing consensus among OM researchers on the benefits of getting insights from broader theoretical fields, such as economics, management and organization theory (Amundson, 1998; Sousa and Voss, 2008). This tendency is linked to the perception that OM issues have interdisciplinary nature, and the IMN topic is no different. As put by Cheng et al. (2015): "…the area of IMN has received considerable attention in the research literature… Nevertheless, the existing IMN research appears multifaceted and interdisciplinary." Therefore, the literature review will consider three constructs, each one from a distinct field: international manufacturing networks, organizational performance and contingency theory.

2.1. International manufacturing networks

Research developed at the Institute for Manufacturing, University of Cambridge, has been setting the agenda for IMN studies, a concept introduced by Shi and Gregory (1998). The authors expanded Hayes and Wheelwright's (1984) Factory Manufacturing System (FMS) towards an International Manufacturing Network system, by extrapolating FMS's organizational elements into a broader set of key "levers" of the IMN. The combination of these levers, which can assume different values, creates different types of IMN. In this study although the adopted typology is the one proposed by Shi and Gregory (1998), the term "configuration of IMN" coined by them is replaced by the more generic term "type of IMN".

According to strategic fit principles, changes in strategy convey changes to the structure (Chandler, 1962; Galbraith, 2000). In a company's strategic process, once the corporate international strategy is formulated, the IMN's mission is defined. Zhang and Gregory (2011) propose the following missions: Efficiency; Flexibility; and Innovation. The mission – or combination of missions - for a given company then guides the design of the IMN, which has the following organizational elements:

Configuration - Structural elements

Configuration is the static part of an IMN; for Meijboom and Vos (1997), it refers to the location of the factories around the world and what each one does, with the consequent allocation of resources. It is composed of two elements:

- Geographic dispersion: Dispersion is usually drawn by forces external to the company, especially new market opportunities. There is a full range of options for dispersion. Shi and Gregory (1998) classify as Domestic those in which all production is carried out in a single country serving both home and export markets. Regional approaches refers to factories and networks located in a particular geographical region, usually sharing similar cultural value systems. Multinational approaches, with trans-regional dispersion, involve factories located in several countries or free-trade zones.

- Subsidiary role: Each subsidiary has a strategic role to play in the IMN. Ferdows' (1997) types of subsidiary roles (offshore, source, server, outpost, contributor, and lead) remain predominant in literature; each type demands distinct sets of resources and competences. Rugman, Verbecke and Yuan's (2010) classify them as Production, Innovation, Marketing and Administrative competences.

Coordination - Infrastructural elements

Coordination refers to the dynamic integration of the production and distribution facilities (Meijboom and Vos, 1997:790); in other words, it means to manage the IMN and make its factories operate interdependently (Cheng et al., 2015). It is composed of two elements:

- Governance: it refers to the mechanisms that direct and control the network, including authority structures, performance measurement and coordination mechanisms. There can be two generic orientations: multidomestic (weak coordination and more independent factories) and global (strong coordination and more interdependent factories, from either designed system structures or operations processes).

- Operations Processes: it refers to the flow of material, information and knowledge between factories in the network. For Shi and Gregory (1998) and Zhang and Gregory (2011), the processes control the operational mechanisms.

Each type of IMN is the combination of the four elements aforementioned. Shi and Gregory (1998) propose the following IMN typology: Home Exporting (GMC1), Regional Uncoordinated (MMC1), Regional Exporting (GMC2), Multidomestic (MMC2), Glocalised (MMC3), Global-Integrated (GMC3) and Global-Coordinated (GMC4). Each of the seven types has a particular potential effect on performance.

2.2. Organizational performance

There are many streams of research on strategic management helping research on organizational performance. Neely et al. (1995) define performance as the effectiveness and efficiency of the actions of an organization. Moreover, for Tangen (2005) performance is a multidimensional and contextual concept, which means it can be disaggregated into its constituent dimensions and observed according to various organizational sets.

2.2.1 Performance as an element of operations strategy

For Slack and Lewis (2002), every generic performance objective should be disaggregated into the performance dimensions that are equivalent to the market requirements the company strives to meet. On the other hand, Turkulainen and Ketoviki (2012) argue that performance should be disaggregated into the dimensions that better capture the organizational processes that one is trying to examine.

Supply chain strategy authors assess performance usually based on the SCOR model (Meixel and Gargeya, 2005), whereas Slack and Lewis (2002) and Cheng et al. (2015) affirm that each operations strategy author has usually defined its own set of performance dimensions. Actually, the basic options usually go down to those based on Hayes and Wheelwright's list (1984) and additional dimensions related to learning (for example, see Shi, 2003). They are:

- Cost: good use of resources, leading to smaller costs and shorter production lead-times;
- Flexibility: quick adaption to changing circumstances quickly and without disrupting the rest of the operation;
- Speed: reduction of the level of in-process inventory between micro operations, as well as reducing administrative overhead
- Dependability: reliance on the delivery exactly as planned. This eliminates wasteful disruption and allows the other micro operations to operate efficiently
- Quality: no waste of time or effort having to re-do things, nor are their internal customers inconvenienced by flawed service;

- Innovativeness: technological and managerial innovations in production process that are quickly and flawlessly learned and incorporated into the routines of one or more factories.

It is noteworthy that the dimensions are not isolated elements. On the contrary, they have to be bundled together and prioritized in order to make sense in an analysis (Neely et al. 1995, 1997; Tangen, 2005). Table 1 presents a summary of dimensions, according to IMN researchers.

Table 1 – Performance dimensions in IMN literature.

Characterístics	Shi and Gregory (1998)	Rudberg and West (2008)	Miltenburg (2009)	Zhang and Gregory (2011)	Fleury et al. (2015a)
Term	Strategic requirements	Performance objectives	Strategic goals	Mission	Mission
Dimension: Cost/Efficiency	X	X	X	X	X
Dimension: Flexibility	X	X	X	X	X
Dimension: Speed	-	-	-	-	-
Dimension: Dependability	-	-	X	-	-
Dimension: Quality	-	-	X	-	-
Dimension: Innovativeness	X	X	-	X	X

2.3. Contingency theory

The contingency theory (CT) contributes to organizational performance studies as it provides a backdrop. Based on the seminal works of Lawrence and Lorsch (1967) and Drazin and Van de Ven (1985), the CT states that there is not a single best way to design an organization in order to optimize its performance, which is, however, contingent upon the fit (alignment) between the business environment and organization's strategy and structure.

Souza and Voss (2008) argue that OM research is strongly based on contingencies, and Slack and Lewis (2002) and Hill and Hill (2009) affirm that, the bigger and more complex the manufacturing system, as is the case of IMNs, the bigger the need for the organization to understand its contingencies and pursue fit, if the organization is to perform well.

2.3.1 OM research based on contingencies

CT also assumes that performance is mainly determined by the level of fit. Since Voss (1995) and Boyer et al. (2005) it has been proposed that the main sources of performance in operations are the fit, the best practices and the development of capabilities, in what became known as the three operations strategy paradigms. Sousa and Voss (2008) confirm, in their comprehensive literature review on the application of CT to OM best practices research, that "…these approaches have later resulted in what may be called the manufacturing strategy contingency (or fit) paradigm, according to which internal and external consistency between manufacturing strategy choices increases performance".

For Donaldson (2001) and Sousa and Voss (2008), organizational design has the following pattern: (i) introduction; (ii) experimentation; (iii) maturity; and (iv) understanding of contingencies, for improvement of the fit (therefore, performance). Then, a fully fledged contingency model should comprise three sets of variables: the organizational set or response, contingencies and performance.

- Organizational response – there can be a number of types of organizational elements that will be linked to performance, as shown by Papke et al. (2001), Ketoviki and Schroeder (2004), Turkulainen and Ketoviki (2012);
- Performance –grouped in three broad categories: (i) level (strategic or operational); (ii) nature of data (quantitative or qualitative); and (iii) type (financial or non-financial);
- Contingencies – grouped in four broad categories: (i) national context and culture; (ii) size of company; (iii) strategic context; and (iv) organizational context (Ketoviki and Schroeder, 2004).

2.4. Definition of research scope and key research variables

Since the unit of analysis is the IMN as a whole, this study is subject to scope delimitation, as follows:

- the research will focus the manufacturing (or production) function, irrespective of other organizational functions such as supply, R&D, transportation and distribution;

- the mission set for the IMN is the only contingency to be herein considered; the remaining external and internal contingencies are outside the scope and will be left for a posterior stage of the research, an acceptable procedure for OM research (Sousa and Vos, 2008);

- the aim is not intended to develop a fully fledged performance measurement system especially designed for IMNs, due to the fact that this step is more complex and will be left for a posterior stage of the research.

In order to devise an "IMN-performance" model that is sufficiently encompassing and detailed, with acceptable power of explanation and generalization, it is necessary that the aspects required in Sousa and Voss (2008) are covered, especially the three sets of variables, as follows:

- *Organizational response*

O.1) Geographic dispersion - Measure: it has to reflect the degree of dispersion of the entire network of factories. From 1 – Domestic to 3 – Multinational (Shi and Gregory, 1998; Fleury et al., 2015a).

O.2) Role of factories – Measure: it has to reflect the relative importance (in % of the total) of each type of role in the entire network of factories. From 1 – Offshore to 6 – Lead (Ferdows, 1997; Fleury et al., 2015a).

O.3) Governance – Measure: it has to reflect the degree of control exerted by the headquarters over the entire network. From 1 – Multidomestic orientation or 2 – Global orientation (Shi and Gregory, 1998; Fleury et al., 2015a).

O.4) Operations processes – Measure: it has to reflect the relative importance (in % of the total) of each type of the flows of materials and information within the entire network of factories. From 1 – standardized process; 2 – tailored processes, and 3 – ad hoc processes (Fleury et al., 2015a).

- *Performance variables*

An organizational set like an IMN is a large and higher-level manufacturing system (Miltenburg, 2009), thus its performance has a strategic-level nature. The definition of variables requires performance dimensions that are more aggregated than those for a single factory. Therefore, the variables for the performance delivered will be split into as few dimensions as possible, such as those employed by Rudberg and West (2008) and Fleury et al. (2015a):

D.1) Cost;

D.2) Flexibility; and

D.3) Innovativeness.

Measure: as proposed by Fleury et al. (2015a), the best option is to measure the "intensity" of each dimension, that is, the relative importance in the total performance delivered (in % of total).

Contingencies

The IMN's mission is herein considered a contingency because it is part of the strategic context and, in opposition to the organizational elements, it has a moderating effect on the delivered performance. While the mission defines the goals (the performance required) the other end measures the actual outcome (the performance delivered); nevertheless, both ends should be as similar as possible to the dimensions as the performance delivered. They are:

M.1) Cost;

M.2) Flexibility; and

M.3) Innovativeness.

Measure: as proposed by Fleury et al. (2015a), the best option is to measure the "intensity" of each dimension, that is, the relative importance in the total performance delivered (in % of total).

3 – The IMN-Performance analytical model

The analytical model combines the constructs formerly presented. The model has a normative approach (Venkatraman, 1989), that is, the IMN is an organizational set in which its (internal) alignment has a causal relationship with the performance it delivers. The causal diagram in Figure 1 exposes the relationships between the organizational variables and the performance variables.

The delivered performance dimensions "cost" (D1), "flexibility" (D2) and "innovativeness" (D3) are the dependent variables. The organizational elements "geographic dispersion" (O1), "roles of factories" (O2), "governance" (O3) and "operations processes" (O4) are the independent variables, with indirect effect upon delivered performance. The required performance dimensions "cost" (M1), "flexibility" (M2) and "innovativeness" (M3) are part of the IMN's mission, and have moderating effect. The other (internal and external) contingencies, as previously stated, are outside the scope of this study.

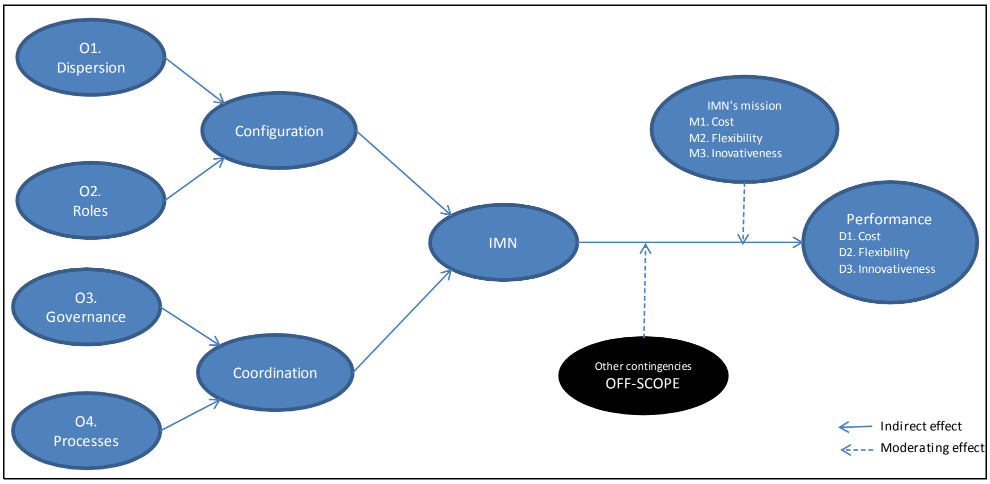

Figure 1 – Analytical model "IMN-performance".

Table 2 is a summary that presents, in the analytical cells, the trade-offs that emerge from the causal relationships between the four organizational elements and the three delivered performance dimensions.

It is possible to see that in some cells the organizational elements lead to performances that are conflicting, which shows that, given the existing type of IMN, it is not possible to maximize all of the dimensions simultaneously (Hayes et al., 2005). This is why each company has to balance or prioritize the relative importance of each dimension for its IMN, especially when one particular dimension does not overwhelm the others or when there are changes in the environment that require re-alignments in strategy and structure.

Table 2 – Relationship between IMN's organizational elements and performance dimensions.

Organizational response IMN		Performance dimensions		
Organizational variables		D1. Efficiency/cost	D2. Flexibility	D3. Innovativeness
Configuration (Structure)	O1. Dispersion	More dispersion, more cost (Meijboom and Vos, 1997)	More dispersion, more flexibility (Shi and Gregory, 1998)	More dispersion, more innovativeness (Rugman et al., 2010)
	O2. Role of factories	More complex roles, more cost (Feldmann et al., 2013)	More complex roles, more flexibility (Feldmann et al., 2013)	More complex roles, more innovativeness (Feldmann et al., 2013)
Coordination (Infrastructure)	O3. Governance	More globally oriented, less cost (Vereecke and Van Dierdonk, 2006)	More globally oriented, more flexibility (Vereecke and Van Dierdonk, 2006)	More globally oriented, more innovativeness (Vereecke and Van Dierdonk, 2006)
	O4. Processes	More standardized processes, less cost (Shi and Gregory, 1998)	More standardized processes, less flexibility (Fleet and Shi, 2005)	More standardized processes, more innovativeness (Zheng and Gregory, 2011)

3.1. Research proposition

The literature review showed a gap in research on IMNs and performance. It is not clear how to properly assess the performance of an IMN in an ever-changing complex and competitive environment. Should performance assessment be regarded as a dynamic managerial tool and coordination mechanism for the IMN? Therefore, the proposition to be investigated is:

P1. If an IMN is redesigned due to changes in strategic goals, the performance assessment of the referred IMN has to change accordingly.

4 –The illustrative case: Embraer

As this is an exploratory study, one case of a Brazilian multinational will be employed to illustrate the analytical model herein proposed, because the topic is in its initial stages, as well it will allow for an in-depth analysis.

Embraer was founded almost 50 years ago, and in the last 20 years has expanded its presence abroad, especially as for production. It is the world's third largest commercial aircraft manufacturer, with more than 5,000 airplanes produced up to 2013 and 19,000 employees in nine countries besides Brazil: USA (full-fledged subsidiary), Portugal (one site for aircraft maintenance and one for production of wings), France Ireland, Holland, UK (sales and client support), China (sales, client support and manufacturing), Singapore (logistics hub), United Arab Emirates (sales office). Embraer's five business units include commercial aviation, agricultural aviation, executive aviation, defense&security, and systems integration.

The reason why a company from an emerging market (EMNE) was chosen is that the rise of EMNEs, in the last 20 years, has created a privileged field for empirical research on IOM in general and manufacturing networks in particular. They are newcomers in global markets and, consequently, are still experimenting new forms of organization, in contrast with the more mature – and "rigid" – worldviews and organizational models adopted by developed country multinationals (DMNE). Furthermore, EMNE's internationalization patterns are usually different, especially because they rely on production and operations as key competences, while DMNEs concentrate on marketing and new products (Fleury and Fleury, 2011) and therefore have had to develop new configurations for their internal value networks (Srai and Gregory, 2008) better suited for their fast-paced expansion (Mathews, 2006). Embraer was chosen due to the following reasons:

- It is a successful manufacturing emerging multinational, with subsidiaries located in developed regions (Europe and North America) as well as in other developing countries, such as China, which means it operates in diverse economic and institutional environments;
- It has an IMN that is complex although recent;
- The evolution of its international strategies and operations is largely documented.

In order to capture potentially different types of changes in the IMNs, the unit of analysis is the IMN as a whole, avoiding particularization for one product or business unit. Historical data was gathered and analyzed for further discussion with company executives at both the headquarters and subsidiaries where they are embedded. Such an approach led to the identification of factors that define performance assessment and if they change over time. Due to the nature of the topic, very little documentation was available in the company, thus making historical data and interviews transcription as the main source of information. Triangulation was possible through the access to some related public presentation material.

Semi-structured questions were used during the sessions, with opportunities for clarification as well as collecting supplementary information between sessions. Most of the meetings had two researchers, one leading the discussion and the other taking notes and asking clarifying questions. Notes were compared after the meetings, and then shared with the executives for validation. Then, a compilation of data and synthesis of conclusions was carried out.

4.1. Creation and evolution of Embraer's IMN

1969-1994 – The local producer of a global product

Embraer was born a State-Owned Enterprise, to create and produce airplanes with internally developed technology. As Embraer's creation was part of a large national public project, the federal government was its client for both civilian and military planes. Embraer's strategy was then focused on domestic demands but, as airplanes are global products, exports started in the late 1970s. To make that strategy feasible, a network of foreign subsidiaries for sales and after-sales was created. Moreover, the Brazilian factory, since the very beginning, had a "lead" role in manufacturing.

Therefore, in the first stage of its history, Embraer was an isolated, vertically integrated aircraft manufacturer, assembling key modules imported from DMNEs, as well as selling small regional airplanes around the world. Embraer's IMN would then be categorized as Home Exporting Manufacturing (GMC1), because it had centralized manufacturing in home country, with only modest international logistics operations for the acquisition of supplies.

1995-2001 – From local producer to leader of a global production network

After privatization, in the end of 1994, the government gradually withdrew direct support, though keeping indirect influence through a "golden share" stake. Nevertheless, it remains Embraer's major client in the defense area, as it happens with other major global companies in the industry. A new product, the ERJ-145 regional jet, was designed and manufactured under a radically innovative approach, where Embraer created and led a network of four risk-sharing foreign partners. They were, previously, common suppliers for Embraer.

The ERJ-145 was very successful, and the flexibility of Embraer's global network allowed it to manage its international operations in order to emerge as a new challenger in the aerospace industry. In other words, the company reshaped its international network to be able to maintain its position in international markets. The new mission for its IMN was resource searching (from the partners) with tailored processes for the flow of information and knowledge among the risk-sharing partners, and standardized processes for the flow of parts and components that feed assembly lines in the Brazilian factory. During most of the second stage of its history, Embraer's IMN remained a Home Exporting Manufacturing (GMC1), because it had no transnational manufacturing operations, that is, manufacturing and assembling was kept in the home country although a growing part of the components was outsourced to risk-sharing partners.

2002- – A global player in the aerospace industry

In the 2000s' Embraer gradually consolidated its experience with decentralized global sourcing, thus allowing it to organize a much more complex supply network for its new ERJ-190 jet, now involving 11 risk-sharing partners like GE and Mitsubishi. Embraer's IMN was gradually expanded. When it began to lead such network of risk-sharing partners, Embraer became more flexible, by "deverticalizing" and dispersing manufacturing, as well as strengthening ties with suppliers, close partners and customers. Additionally, factories as the one in the USA started operations, already aiming to play a "lead" role in the near future, just like the Brazilian factories. Other factories, such as the one in Portugal, are likely to follow same path.

Its IMN became now a global-integrated manufacturing (GMC3) type; at the same time, there is a regional orientation in what concerns sales and maintenance. The GMC3 type is meant to lead to better performance in flexibility, but keeping a balanced performance in innovation and cost, to satisfy the overall mission of market presence. Table 3 summarizes the evolution of Embraer's IMN.

Table 3 – Embraer and the evolution of its IMN.

Period	Type	Overall mission	Performance dimension priority	Governance
1969-1994	GMC1	Innovativeness	Innovation – Cost – Flexibility	Non existent
1995-2001	GMC1	Innovativeness	Innovation– Flexibility– Cost	Non existent
2002-	GMC3	Flexibility	Flexibility - Innovation – Cost	Globally oriented

4.2. Performance assessment of Embraer's IMN

The current IMN can be examined in regards to performance as follows. The data regarding the configuration elements of geographic dispersion (O1) and factory role (O2) was available. But, due to confidentiality reasons, executives did not grant full access to quantitative data on coordination elements of governance (O3) and processes (O4). The answers were of more qualitative and abstract level, nevertheless they were good enough for this stage of the research and allowed to grasp the changes in performance assessment of its IMN.

Configuration

O1. The dispersion of factories outside Brazil, occurred in the last 15 years, jeopardizes cost performance (D1). On the other hand, it is likely to bring more flexibility (D2) and innovativeness (D3), which has great importance to the performance of Embraer's IMN; moreover, it is unlikely that Embraer inaugurates more foreign factories in the future, thus leading to the conclusion that this organizational element has low impact on the performance delivered; that is, after internationalization, Embraer added only three factories (US, China, Portugal);

O2. The roles of factories always lean towards greater complexity, like most of the Brazilian factories and the recently inaugurated manufacturing facilities in the USA. They all play "lead" roles and are the majority of factories in the IMN. The factory in Portugal, although a contributor, seems to follow the same path. That is, it is not plausible for an aircraft manufacturer to have a factory classified as "offshore" or "outpost", for example. The prevalence of more complex and sophisticated roles indicates tendency to higher costs (D1), flexibility (D2) and innovativeness (D3).

Coordination

O3. The governance adopted in the last 15 years seems to be the organizational element that has evolved the most during Embraer's globalization push, from virtually non-existent to globally oriented. The global orientation of a GMC3 type of IMN indicates the use of integrated planning techniques and integrated performance assessment, all of them leading to improved performance on cost (D1), flexibility (D2) and innovation (D3).

O4. Although the processes between Embraer and its close partners are mostly tailored, the operations processes within Embraer's IMN are mostly standardized, for operational efficiency, therefore towards improved cost performance (D1). The inter-factory physical processes, which up to a few years ago did not even exist, stand out: for example, the transfer of parts and airframes between factories is rigorously scheduled and executed according to the plans made in the headquarters. The wings for executive jets, produced in Portugal and used in the Brazilian and American factories, are transferred according to the final assembly schedules. Embraer has also developed processes for information and knowledge exchange, which in turn leads to growing innovation performance in production (D3). On the other hand, such standardization jeopardizes IMN's flexibility (D2).

Table 4 summarizes the analyses. The compilation of the data gathered seems to display quite well the dilemmas Embraer has had to face as the IMN originally designed as GMC1, had to evolve to GMC3 in order to deliver the performance required by market demands. As to causal relationship, the governance adopted seems to have the most relative impact on performance, when compared to the remaining three organizational elements. The choice for a global orientation gives Embraer exactly what it wants: more flexibility, more innovativeness, less cost.

Table 4 – Embraer and the evolution of its IMN. Adapted from Fleury et al. (2015a).

Organizational response IMN – From GMC1 to GMC3		Performance dimensions From innovation to flexibility		
Organizational variables		D1. Efficiency/cost	D2. Flexibility	D3. Innovativeness
Configuration (Structure)	O1. Dispersion - Global	-	-	-
	O2. Role of factories - Mostly "Lead"	-	-	-
Coordination (Infrastructure)	O3. Governance - Global orientation	More globally oriented, less cost	More globally oriented, more flexibility	More globally oriented, more innovativeness
	O4. Processes - Mostly standardized	-	-	-

6 - Discussion and conclusion

The narrative shows that Embraer kept a GMC1 - Home Exporting Manufacturing after the development of the ERJ-145 airplane. However, the international network put in place allowed the company to change towards GMC3 – Global Integrated Manufacturing. In other words, the main assembly process was kept in-house (in Brazil), while the assembly of subsystems were transferred to the risk-sharing partners, for subsequent shipment to Embraer's main assembly plant. This restructuring is consistent with the new corporate strategy devised by the headquarters: becoming a Complex Product Systems integrator and a Global First-Mover (Ramamurti and Singh, 2009).

In its current stage, new strategic options consolidated Embraer's GMC3 type of IMN: the opening of new international markets, as well as new strategic business units (executive jets). Important evidence is the decentralization of the final assembly executive jets in the American factory. Consequently, the competitive priorities changed over time, with consequent changes in the way the performance was assessed. The global orientation of a GMC3 type is in accordance to Bartlett and Ghoshal's transnational solution (1998), which seeks to simultaneously improve performance on efficiency/cost, flexibility and innovativeness.

From the illustrative case, evidences that support the proposition were observed: restructuring of the type of IMN designed to achieve the changing mission, is positively associated to changes in the performance assessment, also with rebalancing of the performance dimensions. The more dispersed network of factories inevitably increases total costs, but there are gains in flexibility and innovativeness. Therefore, the way Embraer deals with the dilemma is to improve coordination mechanisms, including the way it assesses performance has changed, while striving to keep production costs at bay.

From the standpoint of theoretical development, this study deepens the analysis of IMNs by further integrating Operations Management issues with the backdrop of Contingency Theory. This study has implications for researchers in that we show that strategic and network decisions are strongly interrelated, with consequent effect on performance assessment.

For managers, this research provides insights on the need to rethink performance assessment when the IMN is redesigned for whatever reason. Otherwise, they may end up measuring something that is no longer an acceptable measure for performance, or the balance among the performance dimensions are now different.

Future research can propose new and updated typology of IMNs, as well as the study of contingencies such as the product-process matrix; for example, a global product requires more globally oriented types of IMN, with consequent effect on the performance assessment. Additionally, researchers should seek more quantitative evidence of aggregated performance, especially the performance delivered due to interdependence and synergy among factories, with indicators like those provided by Vahlne and Ivarsson (2014).

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