Distributed Information and Automation Lab

Professor Duncan McFarlane

Institute for Manufacturing
University of Cambridge
Department of Engineering

2015

IfM Distributed Information
And Automation Lab

UNIVERSITY OF CAMBRIDGE

Distributed Information & Automation Lab

Resilient Manufacturing
Automation & Control

Automated System
Repair

MISSION

- smarter, distributed ways of **automating** systems
- Getting better value from **industrial information** and quantifying it
- Managing systems subject to **disruption and change**

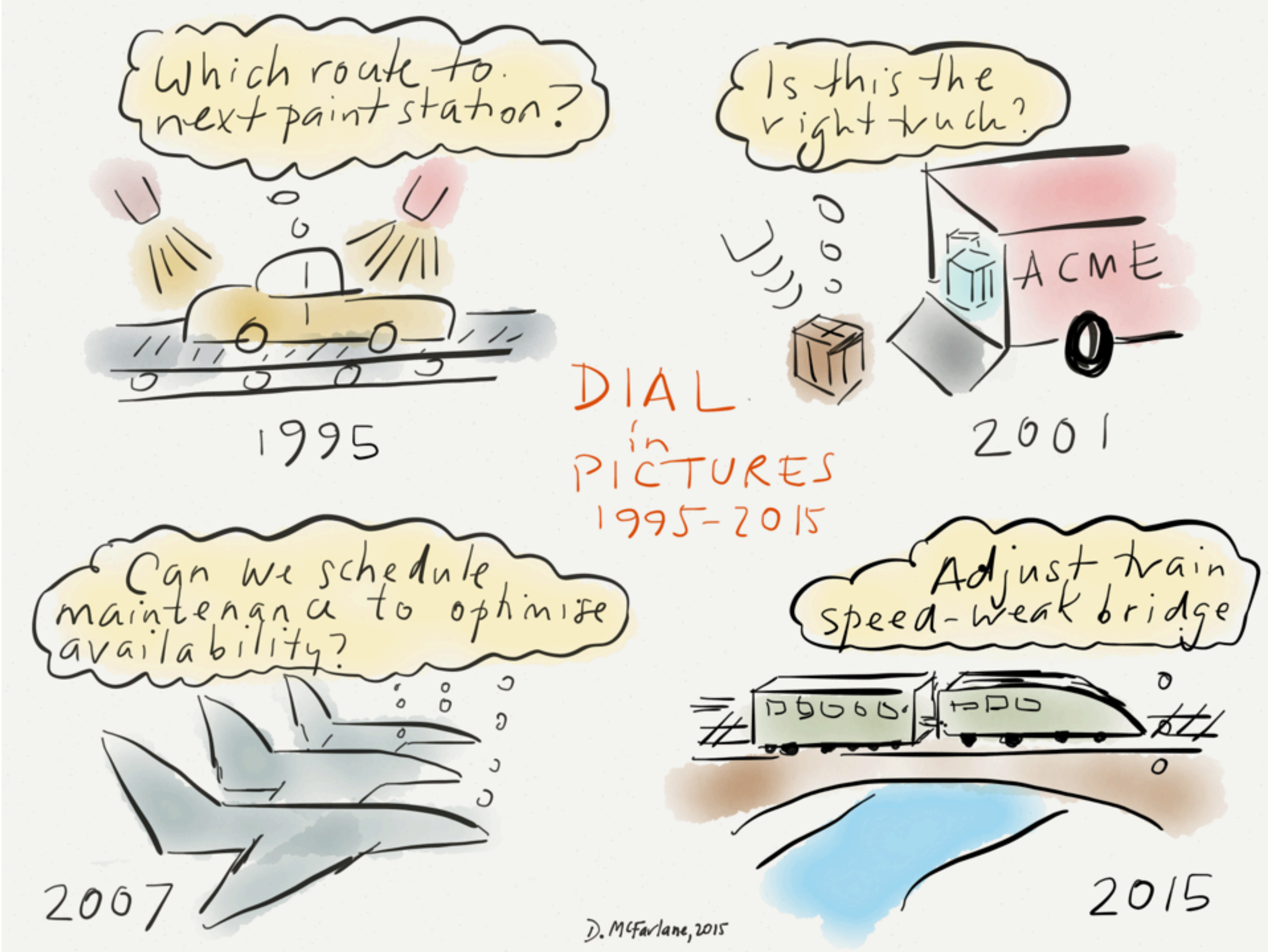
Asset &
Infrastructure
Information
Management

Intelligent Logistics

Efficient Airport
Operations

IfM Distributed Information
And Automation Lab

UNIVERSITY OF CAMBRIDGE


Which route to next paint station?
1995
Is this the right truck?
ACME
2001
DIAL in PICTURES 1995-2015
Can we schedule maintenance to optimise availability?
2007
Adjust train speed-weak bridge
2015
D. McFarlane, 2015

Some Key & Current Projects

KEY PROJECTS

1997-1999 Responsiveness of Manufacturing Production [EPSRC]

1997-99 MASCADA [EU, Mercedes]

2000-2003 Auto ID Centre [103 industrial sponsors]

2004-2008 BRIDGE, PROMISE, SMART [EU, SAP, Nestle, ….]

2005-2007 Aero ID Programme [16 industrial sponsors]

2007-2010 Self Serving Assets [SAHNE -Boeing]

CURRENT PROJECTS

2004 - Auto ID Labs [GS1]

2011- Infra Asset Management & Futureproofing [EPSRC]

2011- Intelligent Data in Procurement [Boeing]

2012 - Resilient Manufacturing [DisTAL - Boeing]

2014 - Intelligent Logistics [ITALI - Y H Global, China]

2015 – Virtual Procurement Data Prediction [VIPR – Boeing]

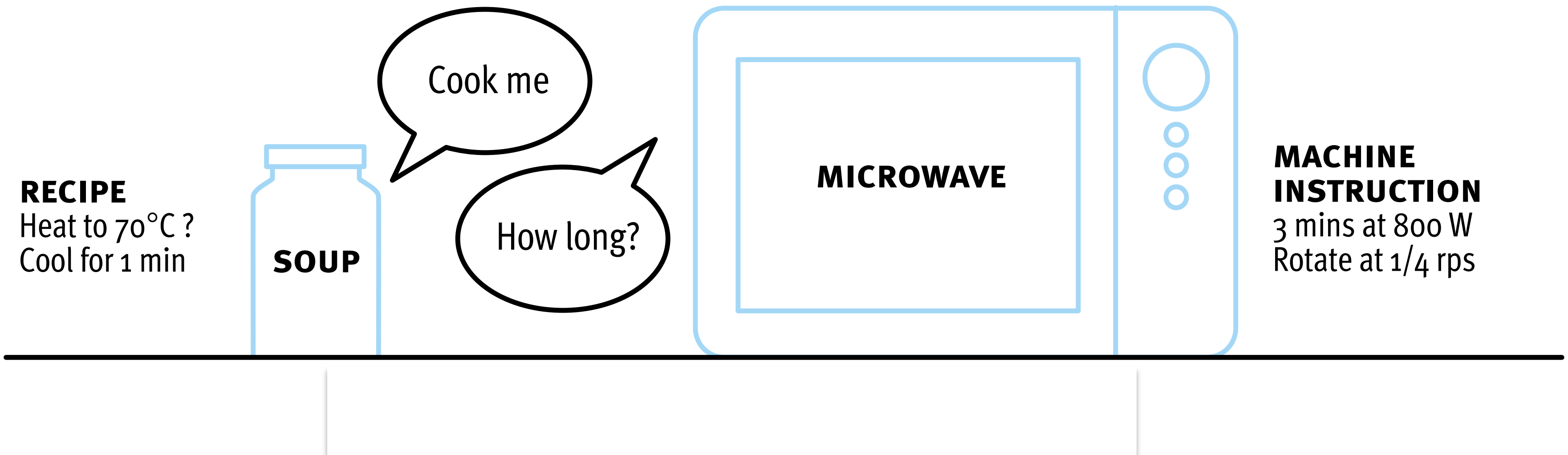
2015 - Advanced Manufacturing Supply Chain [LOR, IUK, BCC]

2015 - 3D Printing in Distributed Production Networks [EPSRC]

Industrial Product Intelligence

Professor Duncan McFarlane

Distributed Information & Automation Lab
Institute for Manufacturing
University of Cambridge
Department of Engineering

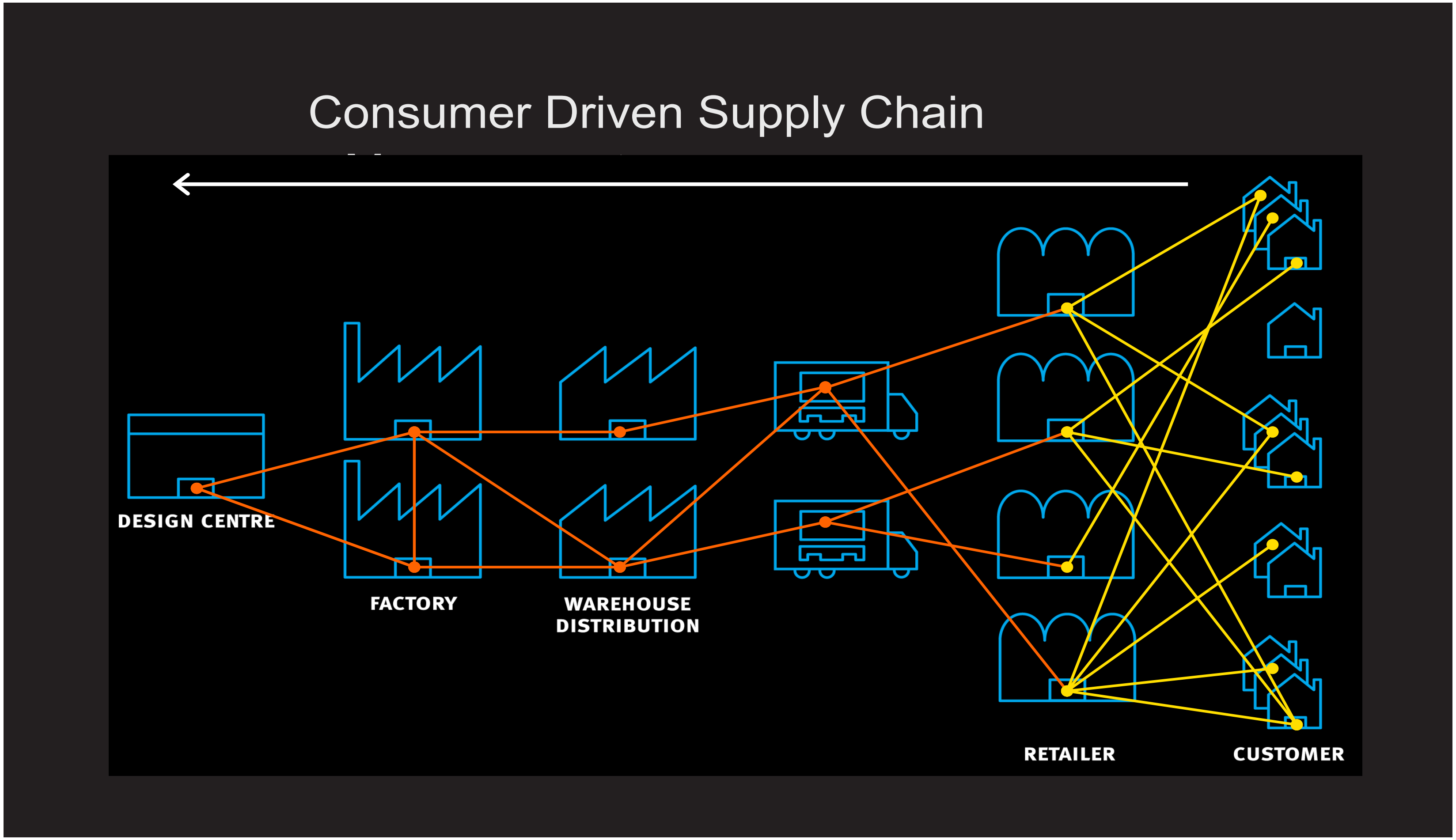


[Auto ID Center 2000]

Intelligent Supply Chain Vision 2002

AUTO-ID CENTER

benefits of product driven supply chain



Overview

- Introduction: “Product Intelligence” in use
- Industrial Rationale
- Product Intelligence?
- Research Issues
- Examples of Developments
- Deployment Challenges

Linked Concepts

Product intelligence

Customer orientation

"Pull" systems

Order Driven systems

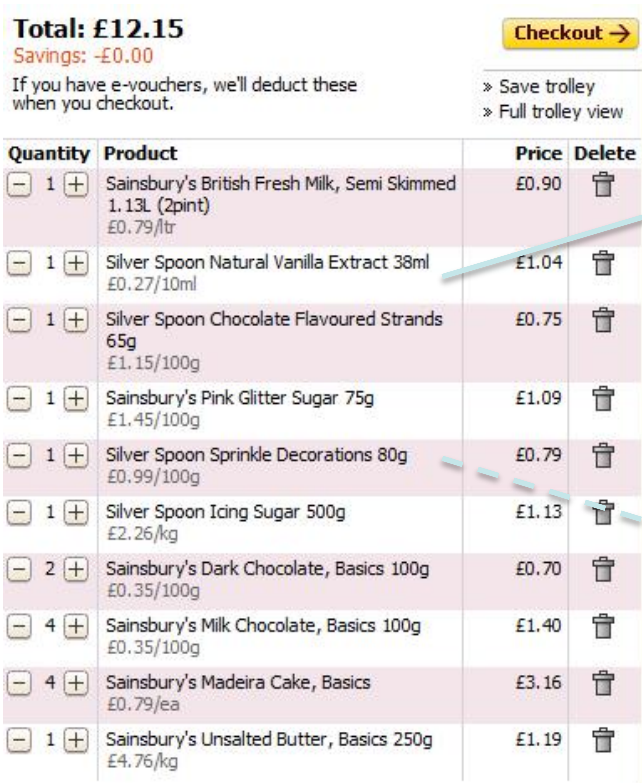
Kanban production control system

Part Description				Part Number	
Smoke-shifter, left handed.				14613	
Qty	20	Lead Time	1 week	Order Date	9/3
Supplier	Acme Smoke-Shifter, LLC			Due Date	9/10
Planner	John R.	Card 1 of 2			
		Location		Rack 1B3	

Distributed Information
And Automation Lab

UNIVERSITY OF
CAMBRIDGE

Web Based Shopping

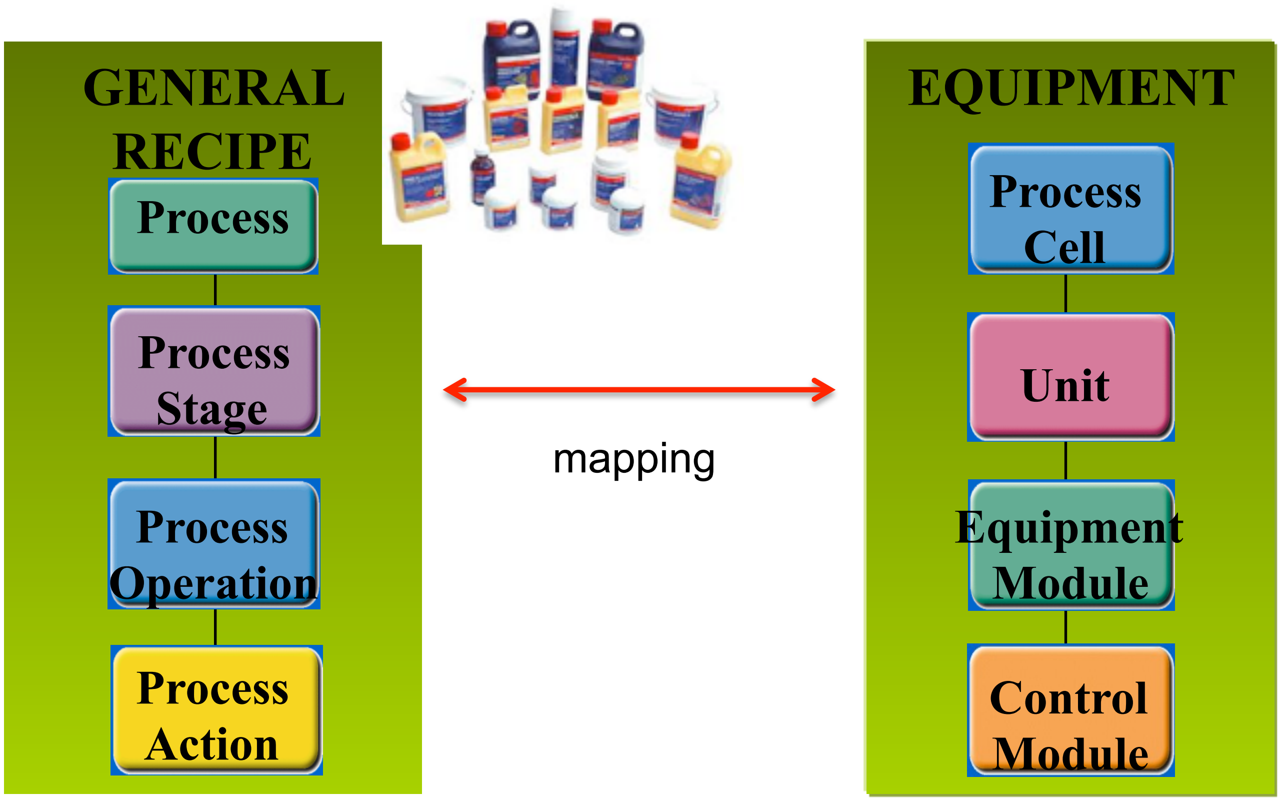


Total: £12.15
Savings: -£0.00
If you have e-vouchers, we'll deduct these when you checkout.

Checkout →
» Save trolley
» Full trolley view

Quantity	Product	Price	Delete
1	Sainsbury's British Fresh Milk, Semi Skimmed 1.13L (2pint) £0.79/ltr	£0.90	
1	Silver Spoon Natural Vanilla Extract 38ml £0.27/10ml	£1.04	
1	Silver Spoon Chocolate Flavoured Strands 65g £1.15/100g	£0.75	
1	Sainsbury's Pink Glitter Sugar 75g £1.45/100g	£1.09	
1	Silver Spoon Sprinkle Decorations 80g £0.99/100g	£0.79	
1	Silver Spoon Icing Sugar 500g £2.26/kg	£1.13	
2	Sainsbury's Dark Chocolate, Basics 100g £0.35/100g	£0.70	
4	Sainsbury's Milk Chocolate, Basics 100g £0.35/100g	£1.40	
4	Sainsbury's Madeira Cake, Basics £0.79/ea	£3.16	
1	Sainsbury's Unsalted Butter, Basics 250g £4.76/kg	£1.19	

Batch Control: S88 / ISA-95



customer

Provider(s)

Autonomous [Pizza] Logistics!

Common Threads?

- Customer directly shapes order
- Customer directly shapes execution of order
- Customer can influence who executes the order

STATIC

- Customer can change aspects of the order execution
- Customer can change aspects of the order during execution

DYNAMIC

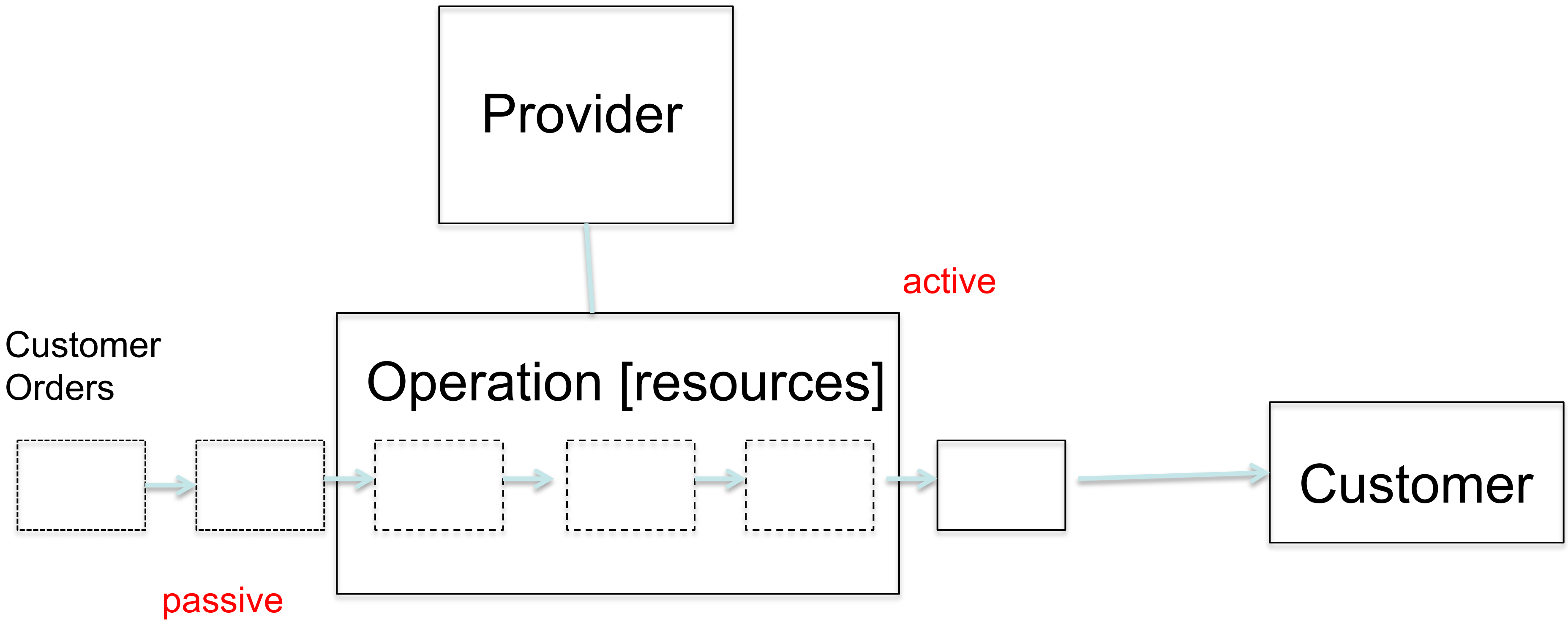
- Customers influence is automated

AUTONOMOUS

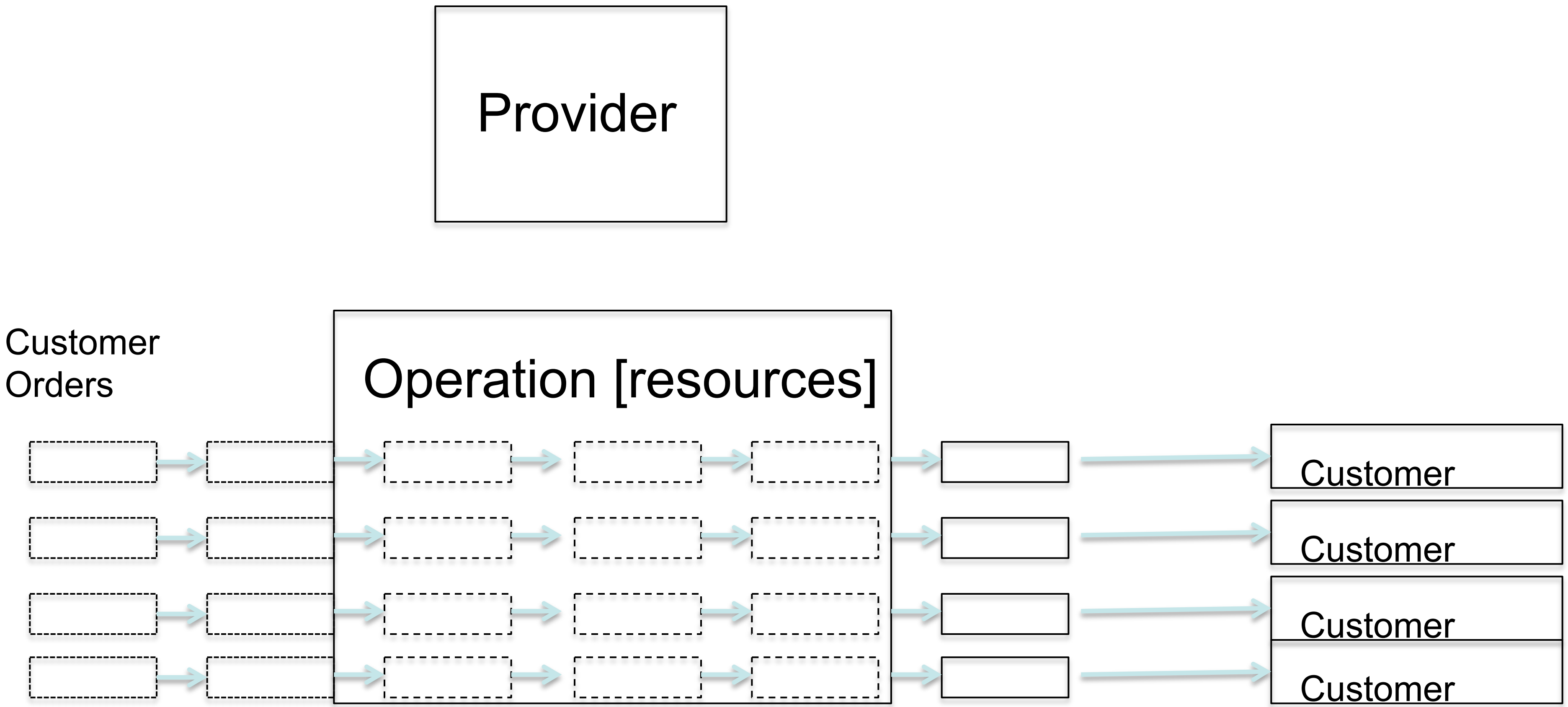
Overview

- Introduction: Examples of “Product Intelligence”
- Industrial Rationale
- Product Intelligence?
- Researchl Issues
- Examples of Developments
- Deployment Challenges

Provider vs Customer Oriented



Provider vs Customer Oriented



When Customer Orientation can help?

Static Scenarios	Dynamic Scenarios
Multi Organisation: When a product or order moves between organizations in its delivery	Changing Environment: When options arise frequently and unpredictably for alternative routings to be considered.
Multi Ordering: When a specific item can be part of multiple orders/ consignments for certain stages of its production/ delivery.	Frequent Disruption: When disruptions are frequent and performance guarantees are difficult to achieve.
Customer Specific: When a customer's specific requirements for his order is at odds with the aggregate intentions of the logistics organisation.	Dynamic Decisions: When decision making about order management requires human resources that are not available.
Distributed Orders: When an order exists in multiple segments scattered across multiple organizations..	Customer Preference Changes: When customer's preferences change between ordering and delivering.
Unique Order: When an order is irreplaceable	

Overview

- Introduction: Examples of “Product Intelligence”
- Industrial Rationale
- Product Intelligence?
- Theoretical Issues
- Examples of Developments
- Deployment Challenges

Intelligent Product [Descriptive]

"A physical order or product that is <u>linked</u> to information and rules <u>governing</u> the way it is intended to be made, stored or transported that enables the product to <u>support or influence</u> these operations"

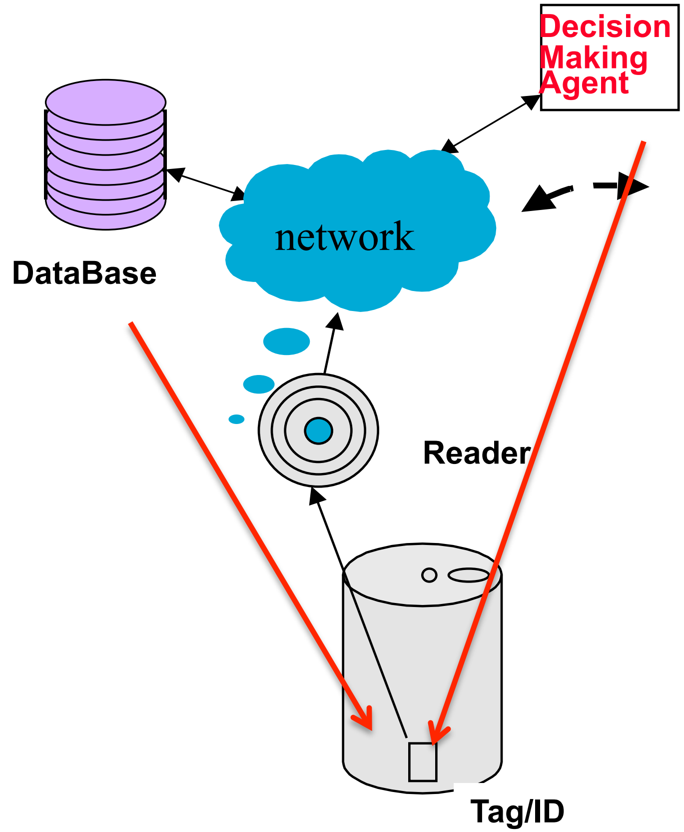
Tomatoes [supplied]	150.0g
Tomato puree type A [supplied]	10.0g
Onions [supplied]	10.0g
Garlic [supplied]	0.9g
Basil [supplied]	0.5g
Sugar [supplied]	10.0g
Preservatives [supplied]	0.5g


```
Separate raw materials:
        Wash tomatoes
                Chop tomatoes
                        Wash to deseed
        Peel onions
                Chop onions
        Peel garlic to separate cloves
                Peel cloves
                        Crush cloves
        Wash basil
                Separate leaves from main stalk
                        Chop leaves
Prepared raw materials:
        Weigh QUANTITY A of tomatoes
        Weigh QUANTITY B of tomato puree
        Weigh QUANTITY C of onions
        Weigh QUANTITY D of garlic
        Weigh QUANTITY E of basil
        Weigh QUANTITY F of sugar
        Measure QUANTITY G of Preservatives
```

Characteristics of Intelligent Product

- *Possesses a unique identity*
- *Is capable of communicating effectively with its environment*
- *Can retain or store data about itself*
- *Deploys a language to display its features, production requirements etc.*
- *Is capable of participating in or making decisions relevant to its own destiny*

(Wong et al., 2002, McFarlane et al, 2003)



Characteristics of Intelligent Product

- *Possesses a unique identity*
- *Is capable of communicating effectively with its environment*
- *Can retain or store data about itself*
- *Deploys a language to display its features, production requirements etc.*
- *Is capable of participating in or making decisions relevant to its own destiny*

(Wong et al., 2002, McFarlane et al, 2003)

- Able to match physical goods to order information
- Access to a network connection [directly or indirectly]
- Linked to static and dynamic data about item – across multiple organisations
- Able to respond to queries
- Priority, routing, production, usage decisions can be made [on behalf of] the item

Levels of Product Intelligence

- *Level 1 Product Intelligence:* *which allows a product to communicate its status (form, composition, location, key features), i.e. it is information-oriented.*

- *Level 2 Product Intelligence:* *which allows a product to assess and influence its function in addition to communicating its status, i.e. it is decision-oriented.*

(Wong et al., 2002)

Levels of Product Intelligence

Level 1

- Represent the (customer) needs linked to the order: e.g. goods required, quality, timing, cost agreed
- Communicate with the local organisation (as well as with the customer for the order)
- Monitor/track the progress of the order through the industrial supply chain

Level 2

- [Using the preferences of the customer] influence the choice between different options affecting the order when such a choice needs to be made
- Adapt order management depending on conditions.

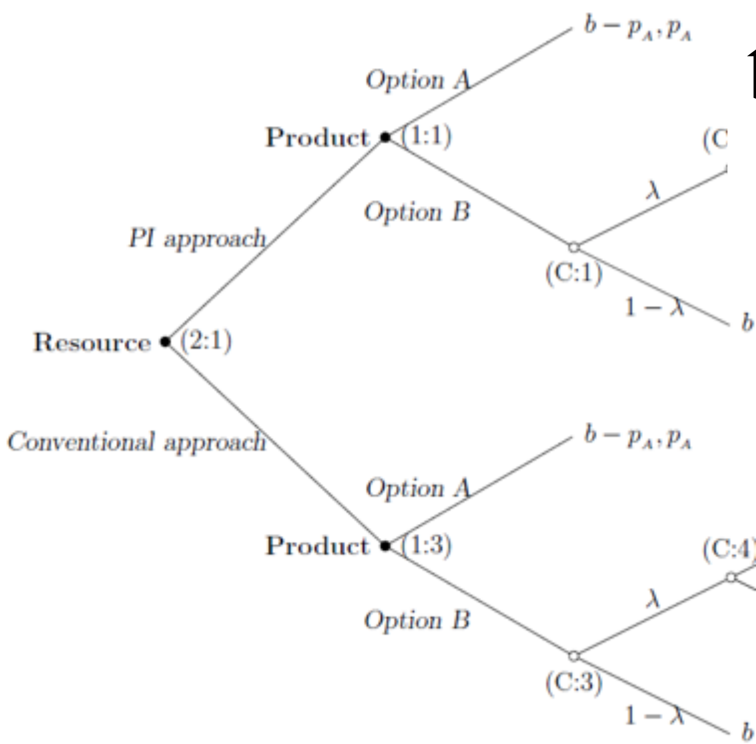
Who is doing Research in [Industrial] Product Intelligence?

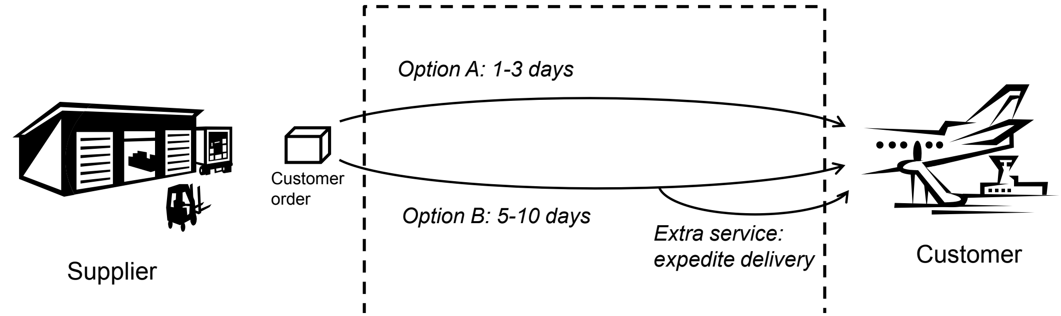
- *Aalto University (Finland)*
- *Research Center for Automatic Control - CRAN*
- *University of Cambridge*
- *Katholieke Universiteit Leuven*
- *University de Valenciennes / Lille Nord du France*
- *University of Groningen (Netherlands)*
- *Universtiy of Bremen*
- *Universite Politehnica of Bucharest*
- *Universit of Porto*
- *Czech Technical University*
- *Oxford University*
- *+ others e.g. Physical Internet movement in USA/Canada,*

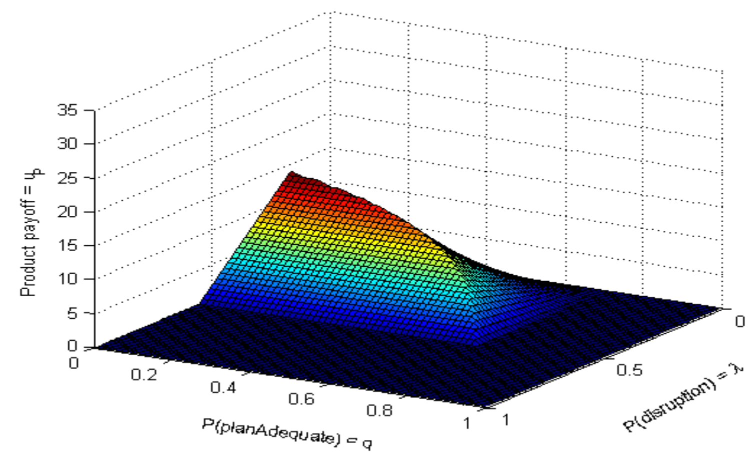
Overview

- Introduction: Examples of “Product Intelligence”
- Industrial Rationale
- Product Intelligence?
- Research Issues
- Examples of Developments
- Deployment Challenges

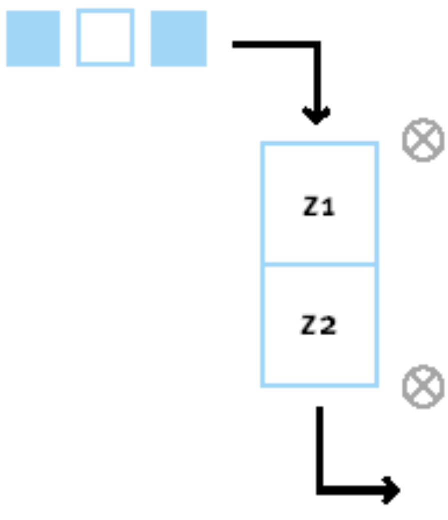
Product Intelligence Benefits Modelling



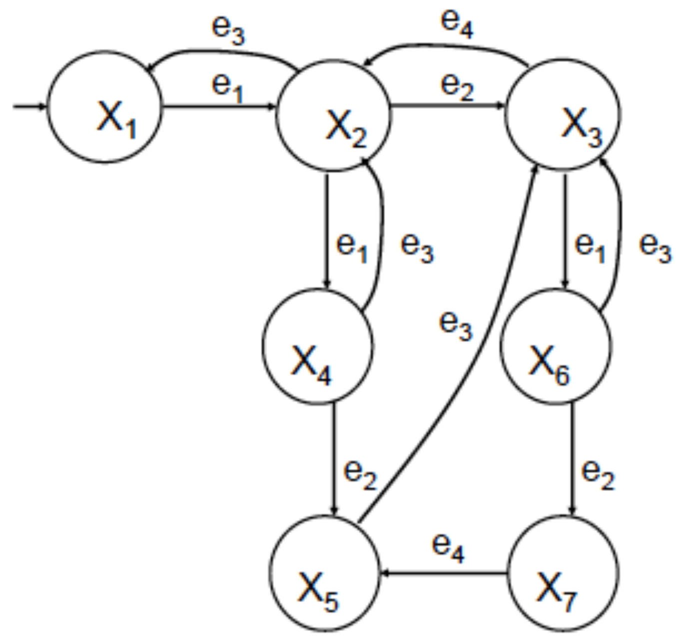




Product-Oriented Process Modelling

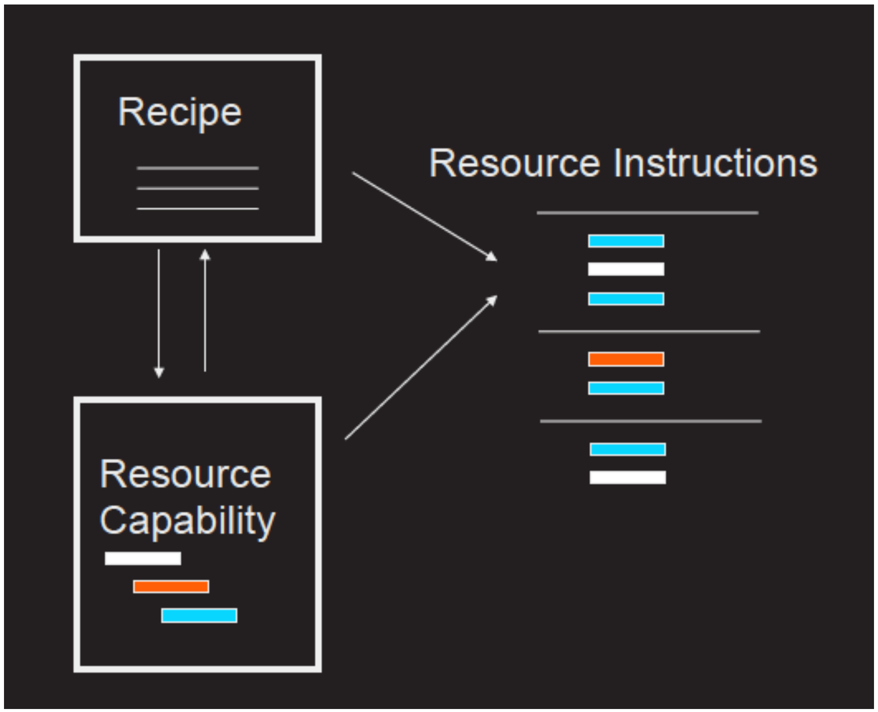


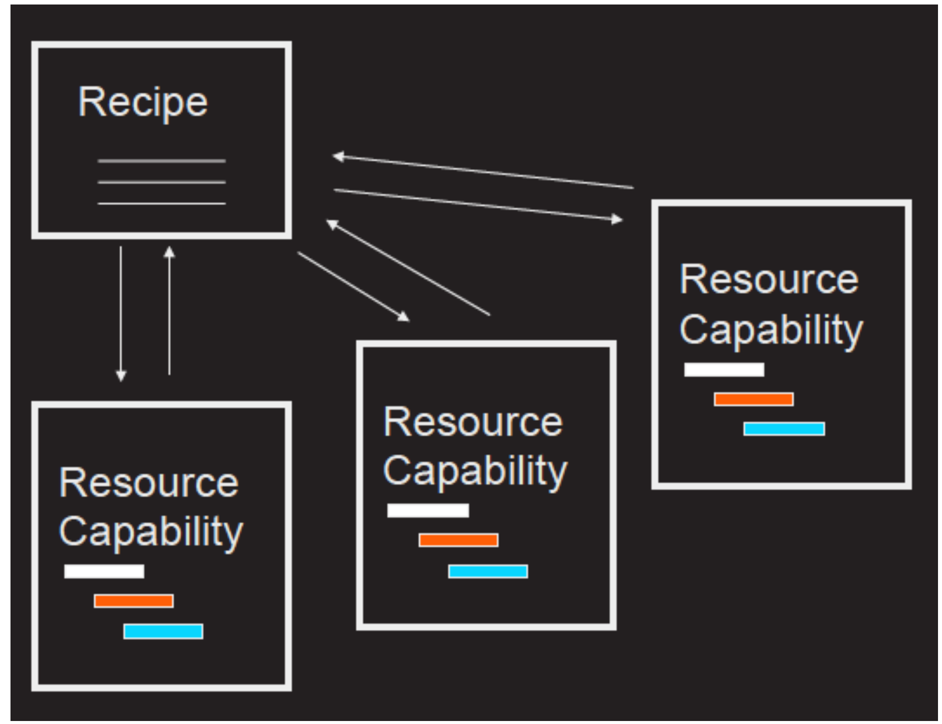
(B)



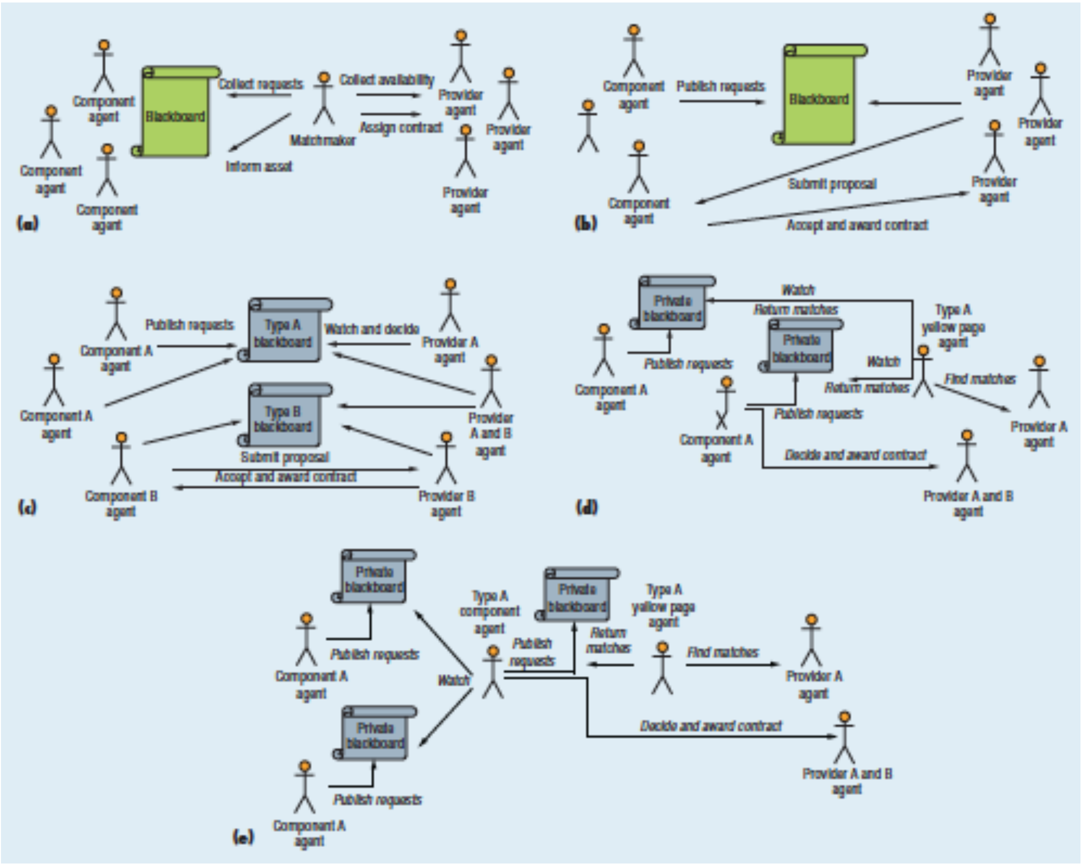
Sensor Type	E_{po_o}	E_{po_uo}	E_{pt_o}	E_{pt_uo}
Proximity Sensors	$\{e_1, e_3\}$	$\{\varepsilon\}$	$\{\varepsilon\}$	$\{e_2, e_4\}$
Identity Sensing	$\{e_1, e_3\}$	$\{\varepsilon\}$	$\{e_2, e_4\}$	$\{\varepsilon\}$

Product Languages





Architecture Selection



Selection Criteria

- Computational intensity
- Communications burden
- Decision making complexity

Operational Performance

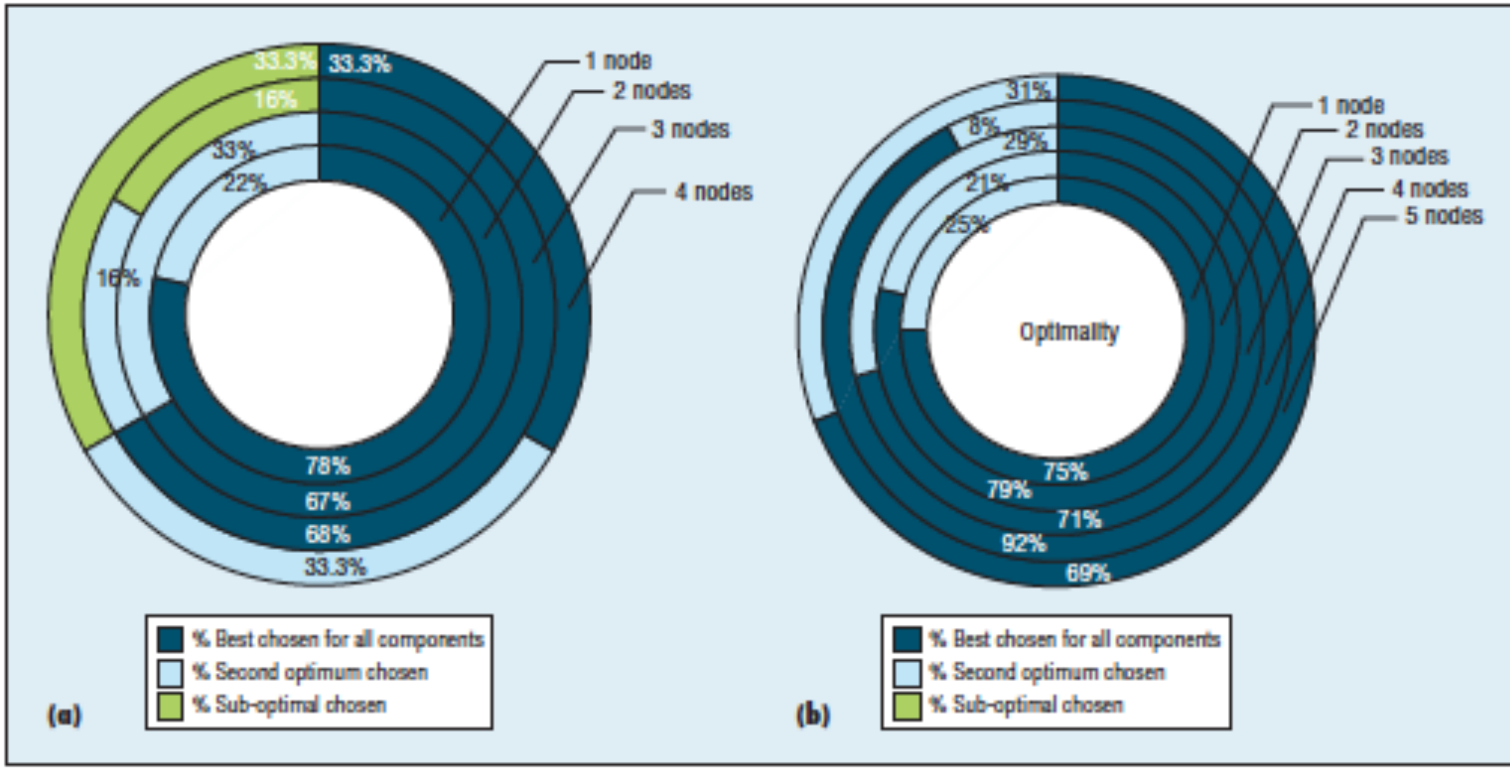
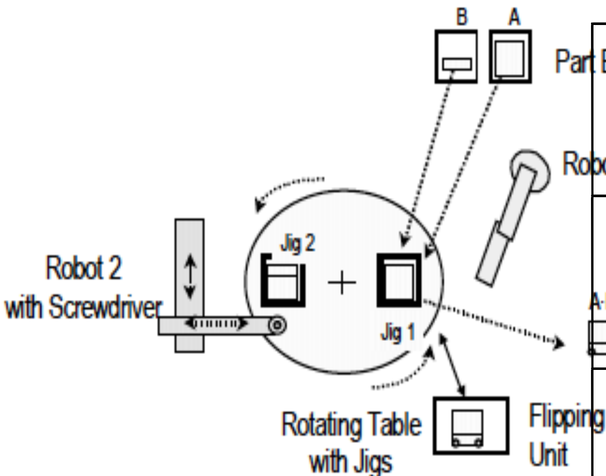


Figure 4. Solution optimality. (a) Optimal decisions versus the number of component agents, and (b) optimal decisions versus the number of provider agents.

System Performance



	IP Driven Control	Conventional Control
Configurability (design)	103	220
Configurability (implementation)	2407 (1585)	497
Reconfigurability-Extension	Strategy: 1.24 Development: 1.1	Strategy: 1.54 Development: 1.62
Reconfigurability-Reuse	0.95	0.4

IfM Distributed Information And Automation Lab

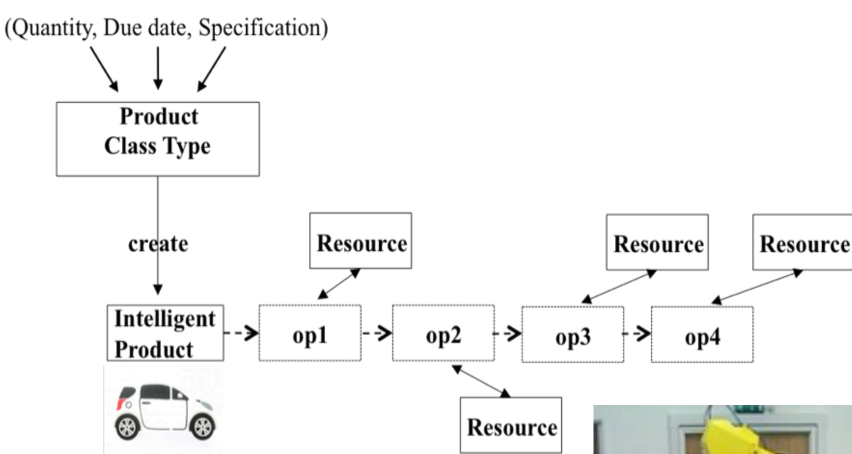
UNIVERSITY OF CAMBRIDGE

Overview

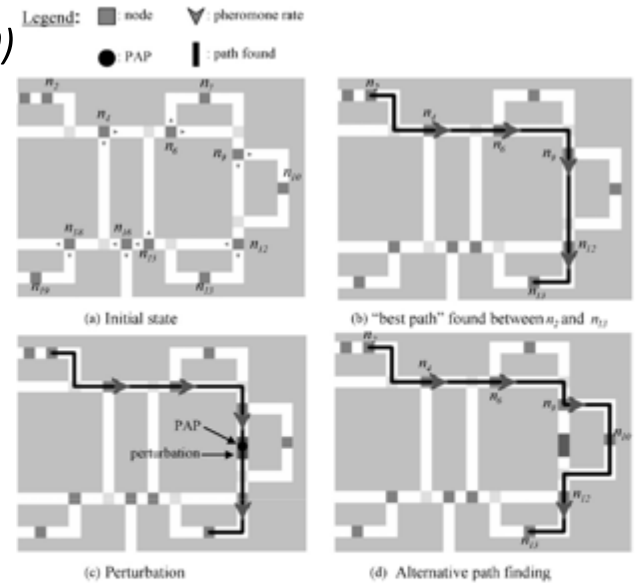
- Introduction: Examples of “Product Intelligence”
- Industrial Rationale
- Product Intelligence?
- Research Issues
- Examples of Developments
- Deployment Challenges

PI Developments in Manufacturing

(Chirn et al., 2002)

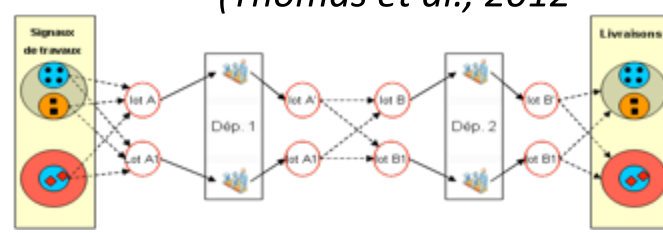


(Sallez et al., 2009)



(Morales-Kluge et al., 2011)

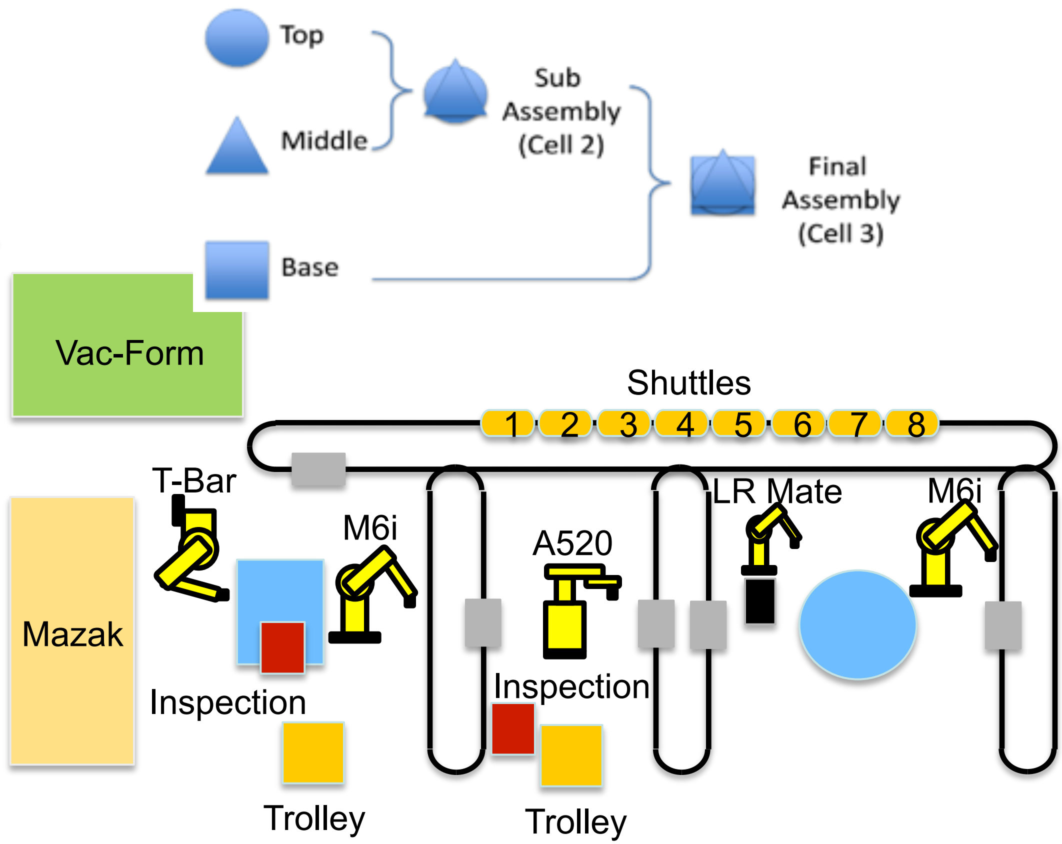
(Thomas et al., 2012



Distributed Information
And Automation Lab

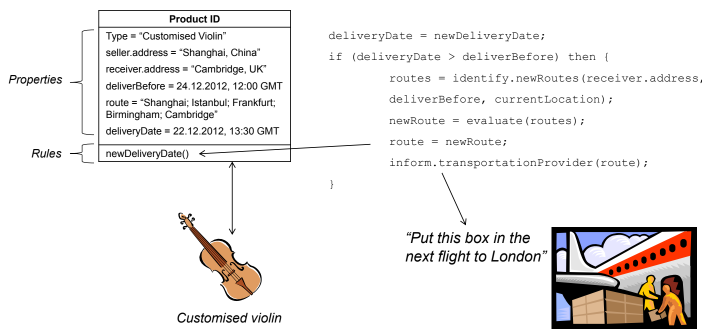
UNIVERSITY OF CAMBRIDGE

Eg: Intelligent Orders and Parts Production



PI Developments in Logistics

(Giannikas, McF 2012)



(Meyer et al, 2009)

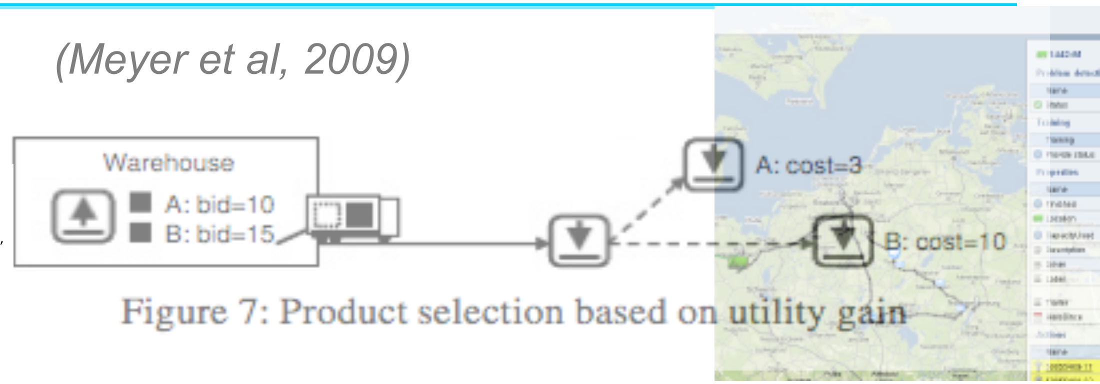
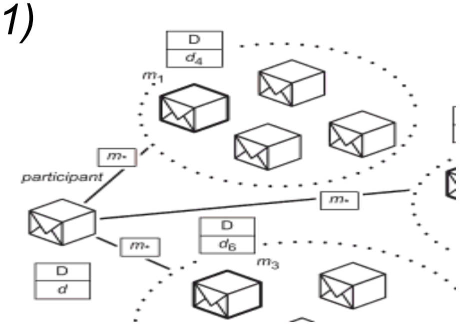
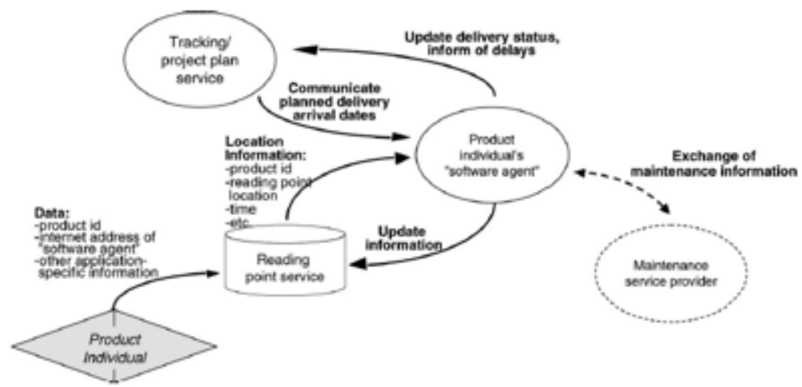


Figure 7: Product selection based on utility gain

(Schuldt, 2011)



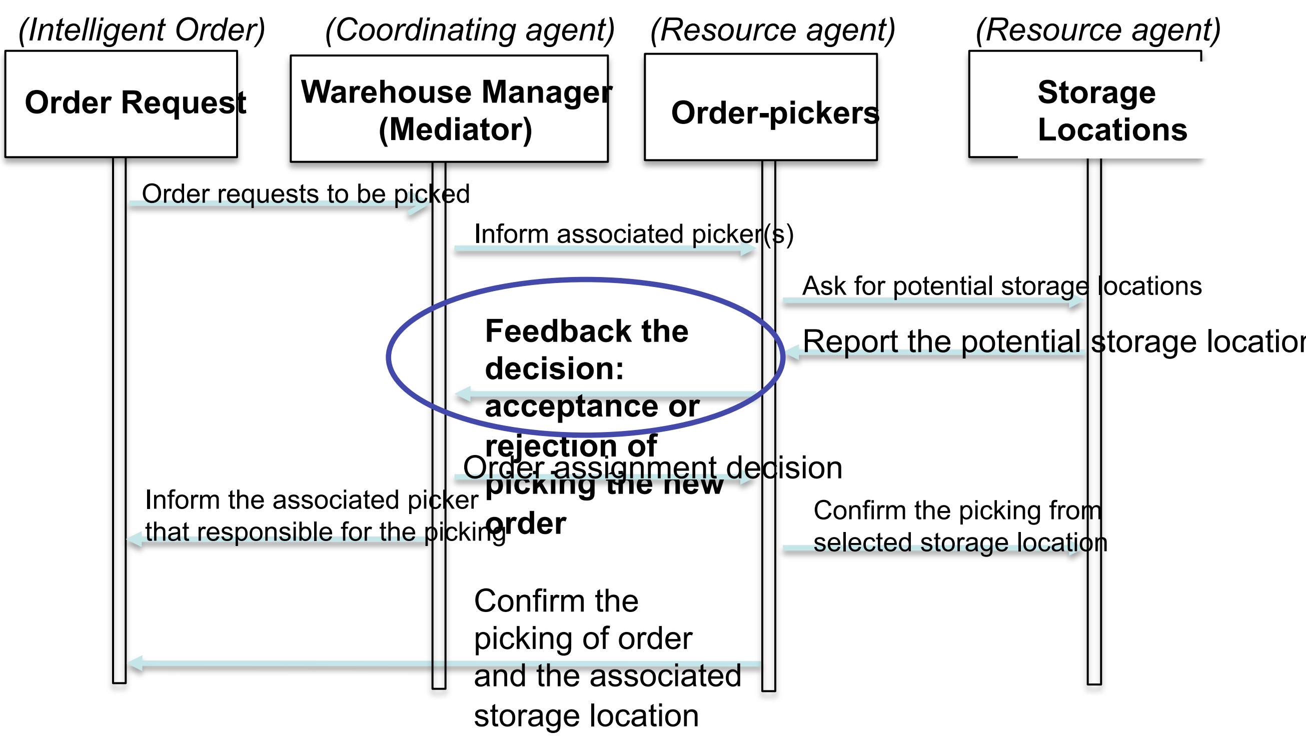


(Karkkainen et al, 2003)

Distributed Information And Automation Lab

UNIVERSITY OF CAMBRIDGE

Eg: Intelligent Warehouse Order Picking



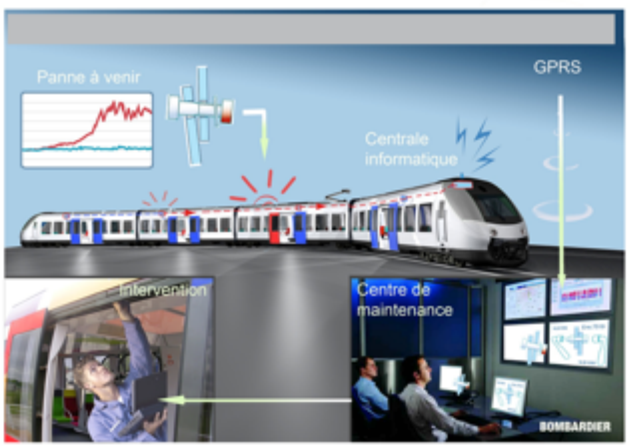
Distributed Information
And Automation Lab

UNIVERSITY OF CAMBRIDGE

PI Developments in Services

(LeMortellec et al, 2012)

(Parlikad et al, 2008)

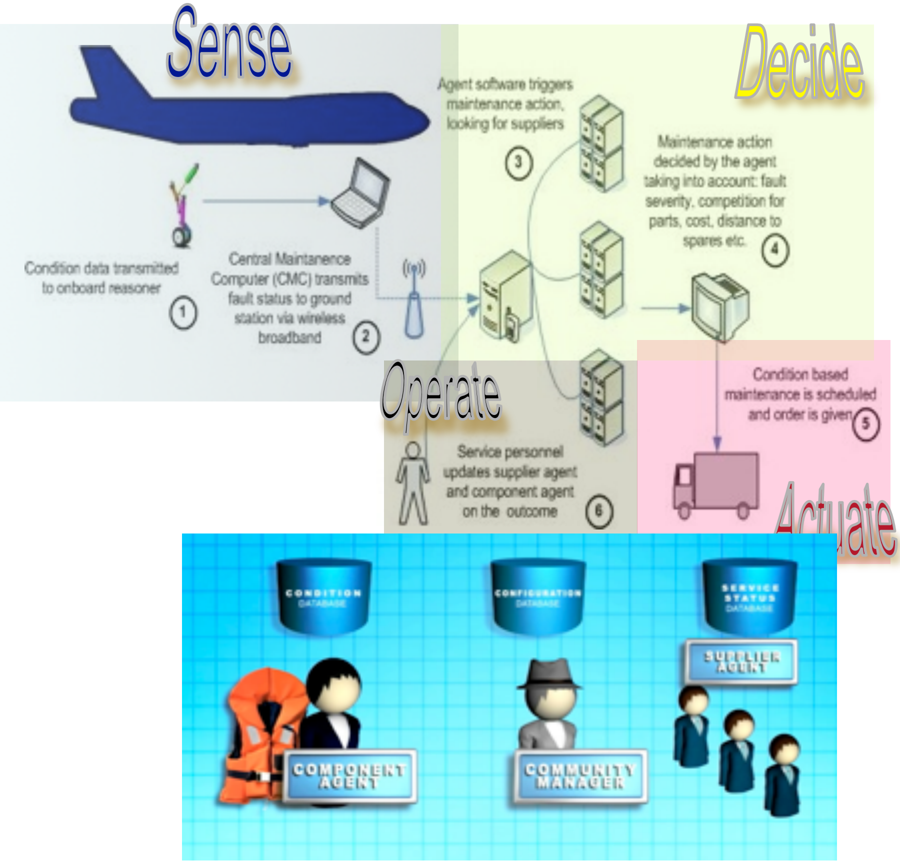


(Brintrup et al, 2010)

Eg: Self Organising Spare Parts Management

- Problem: System to manage ever increasing complexity in spare parts ordering across multiple supplier

- Approach: Treating aircraft components as intelligent products which trigger own repair and replacement. Multiple software agent architectures trialled



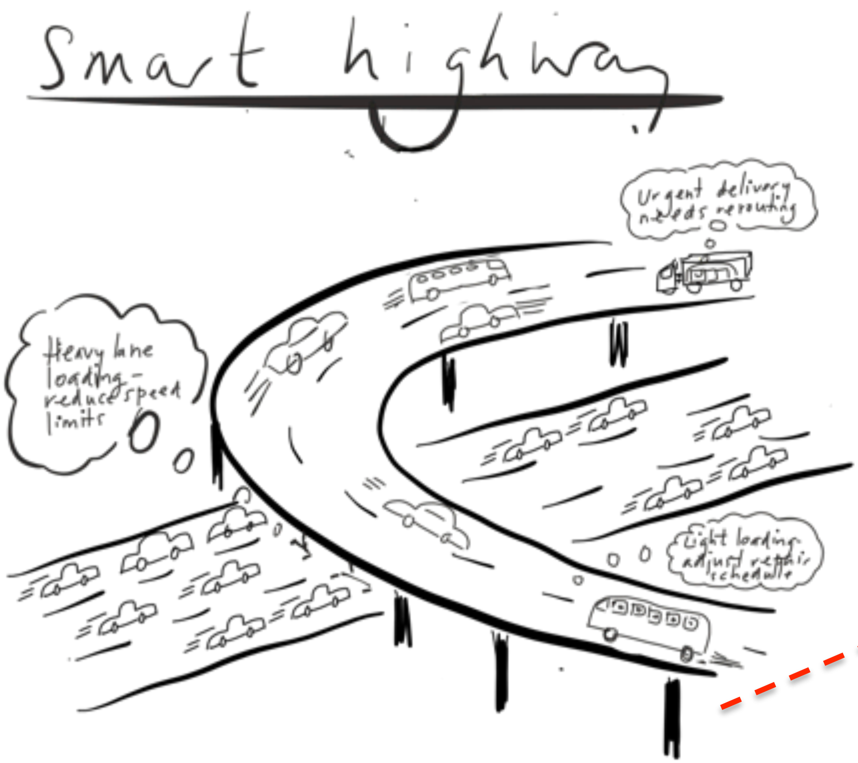
PI Developments in Construction

Cambridge Centre for
Smart Infrastructure and Construction

IfM Distributed Information And Automation Lab

UNIVERSITY OF CAMBRIDGE

Eg: IoT Smart Highway Project



RedBite

Overview

- Introduction: Examples of “Product Intelligence”
- Industrial Rationale
- Product Intelligence?
- Research Issues
- Examples of Developments
- Deployment Challenges

Deployment Challenges: Barriers

- *technical feasibility:* scalability, stability, compatibility
- *economic viability:* quantitative benefits specific to IP approach
- *operational practicality:* Ability to deploy IP concept! deployability with existing IT environments?
- *cultural acceptability:* acceptance as opportunity by providers, high level of transparency

Some Recent References

- D. McFarlane, V. Giannikas, and W. Lu. Intelligent logistics: Involving the customer. *Computers in Industry*, 2015. Forthcoming. doi: 10.1016/j.compind.2015.10.002
- D. McFarlane, V. Giannikas, A. C. Wong, and M. Harrison. Product intelligence in industrial control: Theory and practice. *Annual Reviews in Control*, 37(1):69–88, 2013
- V. Giannikas, W. Lu, D. McFarlane, and J. Hyde. Product intelligence in warehouse management: A case study. In V. Marik, J. L. M. Lastra, and P. Skobelev, editors, HOLOMAS 2013: 6th International Conference on Industrial Applications of Holonic and Multi-Agent Systems, volume 8062 of Lecture Notes in Computer Science, pages 224–235. Springer Berlin Heidelberg, 2013
- V. Giannikas and D. McFarlane. Product intelligence in intermodal transportation: The dynamic routing problem. In H.-J. Kreowski, B. Scholz-Reiter, and K.-D. Thoben, editors, *LDIC 2012: 3rd International Conference on Dynamics in Logistics*, Lecture Notes in Logistics, pages 59–69. Springer Berlin Heidelberg, 2013
- D. Kola, V. Giannikas, and D. McFarlane. Travel behaviour applied in freight transportation using intelligent products. In *CCCA 2012: 2nd International Conference on Communications, Computing and Control Applications*, pages 1–6, Marseilles, France, December 2012
- D. McFarlane, V. Giannikas, A. C. Y. Wong, and M. Harrison. Intelligent products in the supply chain - 10 years on. In *INCOM 2012: 14th IFAC Symposium on Information Control Problems in Manufacturing*, pages 655–660, Bucharest, Romania, May 2012
- R. Cuthbert, V. Giannikas, D. McFarlane, and R. Srinivasan. Repair services for domestic appliances. In *Service Orientation in Holonic and Multi-agent Manufacturing, Studies in Computational Intelligence*. 2015.
- López, T., Ranasinghe, D., Patkai, B., & McFarlane, D. (2011a). Taxonomy, technology and applications of smart objects. *Information Systems Frontiers*, 13, 281–300.
- Brintrup, A., McFarlane, D., Ranasinghe, D., Sanchez Lopez, T., & Owens, K. (2011). Will intelligent assets take off? Toward self-serving aircraft. *IEEE Intelligent Systems*, 26, 66–75.
- Brintrup, A., Ranasinghe, D., McFarlane, D., & Parlikad, A. (2008). A review of the intelligent product across the product lifecycle. In *International conference on product lifecycle management*.
- McFarlane, D., Sarma, S., Chirn, J. L., Wong, C. Y., & Ashton, K. (2003). Auto ID systems and intelligent manufacturing control. *Engineering Applications of Artificial Intelligence*, 16, 365–376.
- Wong, C., McFarlane, D., Zaharudin, A., & Agarwal, V. (2002). The intelligent product driven supply chain. *IEEE international conference on systems, man and cybernetics* (Vol. 4, pp. 6). IEEE.