UNIVERSITY OF CAMBRIDGE
DEPARTMENT OF ENGINEERING

EPSRC

IfM Centre for Industrial Sustainability

TransTextile Project Report

High Value Innovation for Industrial Textile Waste in Sri Lanka

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Cover image:
Collage of textile offcuts, the biggest textile waste problem in Sri Lanka's textile industry

Executive Summary

This report presents the results of the project TransTextile, an interdisciplinary innovation sandpit that addresses the textile waste issues in Sri Lanka in collaboration with the local industry and academia.

Purpose This research studied the feasibility of setting up an innovation sandpit in Sri Lanka that searches for the higher value opportunities from the post-production waste of Sri Lanka's top import industry: garment manufacturing. With help from an existing local contact point, a strong and extensive collaboration network was created ranging from Sri Lanka's top garment manufacturers, top engineering schools, and a design school as well as local upcycle designers, and to an environmental research NGO.

Impacts A five-phased collaboration process yielded five promising system-level waste solutions and they were presented at the final showcase event. This event attracted over 60 attendees from local industry and academia. It led lively discussions for positive follow-up engagement and action plans. The technology readiness levels, the scales of sustainability impact and target waste material of solutions vary from immediate applications (using up to 300-600 tonnes of unrecyclable PU foam offcuts or up to 18,000 tonnes/year of polyester offcuts), to mid-term applications (using 600 tonnes/year of denim offcuts), and to long-term applications (potentially consuming up to 5,000 tonnes/year of unrecyclable spandex mix fabric offcuts).

Fast, effective & competitive This 8-month long project demonstrated a high possibility of a waste innovation sandpit that delivers fast, effective and competitive solutions to sustainably tackle the waste problems in Sri Lanka. The research outcomes clearly call for a full-on implementation of such an interdisciplinary innovation sandpit: Frog Kissing Centre for waste innovation. The centre would provide both physical and virtual platform for innovators, engineers, designers, academics, entrepreneurs and industry practitioners to bounce their ideas and experiment with the waste for collective system-level solutions. Furthermore, it is recommended to expand the subject area beyond textile to a wider range of wastes that the local industries have troubles to deal with. While industry often exhausts possible answers within its realm of expertise, a fresh approach and new perspective from disparate industries may help conceiving possible solutions.

Contribution The sandpit would also help academia to understand the process and the enablers for interdisciplinary collaboration in developing countries. Equally, the process model would help local industry practitioners to establish the methods to find high value waste innovation solutions.the methods to find high value waste innovation solutions.

1. Waste Innovation Sandpit in Sri Lanka

Interdisciplinary Collaboration of Design, Engineering, Industry & Academia

TransTextile was an 8-month long feasibility study for an innovation sandpit to capture higher innovation opportunities for Sri Lanka's post-production textile waste in collaboration with local industry and academia. The project was funded by the UK Engineering & Physical Sciences Research Council (EPSRC)'s Global Challenge Research Fund (GCRF) Pump-Prime Grants that aims to support the development of research projects and knowledge exchange activities compliant with the Official Development Assistance (ODA) guidelines. With a strong support from existing local contact point, the project was designed and led by the Centre for Industrial Sustainability (CIS), University of Cambridge, UK.

Interdisciplinary Sandpit is where the experts across industry and research fields bring disparate insights and knowledge together to collaborate on creative innovations to solove problems that individuals were unable to address. In this project, A strong collaboration was formed among Sri Lanka's leading organisations from Expo, MAS, Hirdaramani to Brandix as well as the leading universities such as Moratuwa, Peradeniya and AOD. The project was conducted in 5 phases in Cambridge and Colombo.
The manufacturers sent the textile wastes to the innovation space: Cambridge-Expo Innovation Lab in Colombo, where engineering and design students gathered to run experiments with them.

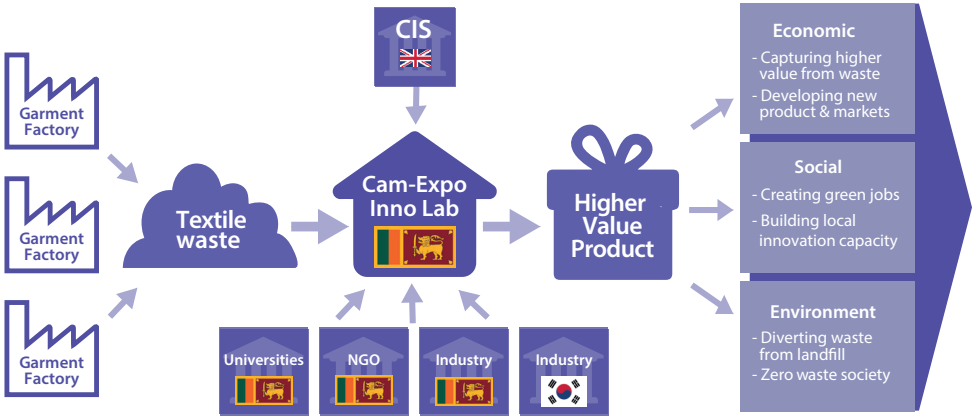
Centre for Industrial Sustainability (CIS) from University of Cambridge

CIS intermediated and nurtured the innovation process by providing systematic innovation structure, tools, knowhow, and a creative innovation environment. CIS also organised regular supervisions with industry experts and academics. As a result, five higher value product ideas were developed fulfilling the project objectives under the three pillars of sustainability:

• Economic sustainability
- Capturing high value from Sri Lanka's industrial waste
- Designing new business models for local entrepreneurs
- Identifying new markets for final products

• Social sustainability
- Building innovation capacity in Sri Lanka's local businesses and communities
- Creating hundreds of green jobs in Sri Lanka

• Environmental sustainability
- Diverting industrial waste from down-cycling/landfill
- leading to Zero waste society



Project TransTextile outline

Textile landfill site at the Biyagama Industrial Zone:
Sri Lanka generates minimum 44.100 tonnes of textile waste per year but there is no recycling facility to treat.

2. From Offcuts to Rupees

The garment industry is Sri Lanka's biggest manufacturing sector, contributing 61% of exports and 44% of GDP (2015). Sri Lankan garment industry especially focuses on sustainable manufacturing as part of its strategic competitiveness and takes pride in leading in sustainable garment manufacturing.

No recycling However, there completing a thorough loop of sustainability as there are no textile recycling facilities in the country to deal with the waste industry generates. In 2014, a total of 294,000 tonnes of textile was imported for garment making and on average 15-20% of fabric is left as waste leaving a minimum 44,100 tonnes of post-production textile waste. In the past, a substantial amount of them used to be exported to nearby countries such as China, Malaysia or Vietnam where textile recycling facilities exist. But the export option became too expensive or impossible to continue due to the anti-dumping regulations becoming more prominent in such countries since 2007. Alternatively, some of the synthetic waste is being sent to a cement company where it is incinerated as fuel in the cement kiln. Then again, it is currently the only solution to treat the hazardous wastes in Sri Lanka, and the increasing amount of waste thanks to the booming Sri Lanka's economic growth easily overflows their capacity, providing instability for the textile waste management. Furthermore, burning ultimately destroys the embedded value of textiles. Consequently, the textile waste ends up being illegally dumped or burned in the landfills.

Urgent call system-level waste solutions are urgently called for, and Sri Lanka's top garment manufacturers such as MAS, Hirdaramani showed high enthusiasm in supporting the attempts to tackle the problem together. MAS and Hirdaramani remained the key industry partners throughout the project and were pivotal in hosting the introduction workshops, providing the waste data & samples, expert advice during the experiment phase, and pursuing the follow-up commercialisation options together.

Cutting tables at the cut & sew facility: constantly cut out a stack of fabric generating various types and shapes of offcuts. The high speed pressure leaves the cut marking paper pieces and fabric go into the bin without separation.

4 Post-Production Textile Waste types

Excessive rolls

Factories normally order 1-5% extra fabric than required to prevent the potential slow down of production in case of faulty fabric. Since the excessive roll fabrics are often fed back into the next orders, this type of fabric waste is less problematic.

Rejected fabric

Damaged or faulty fabrics cannot be used in the production. The fabric printed with brand logo or design patterns are returned to the supplier or destroyed to comply with brand protection. Non-branded fabrics are sold at the local fabric market at a bargain price. The amount is also negligible.

Offcuts

Average 15-18% of total fabric are left after the panels are cut from large sheets. Various shapes and types of offcuts are often mixed all together becoming difficult to identify and recycle. Whereas cotton offcuts relatively easy to spin into recycled cotton yarn, the amount of unrecyclable synthetic blended offcuts are increasing. In particular spandex-mixed offcuts are hard to recycle. Companies pay high price to incinerate them at the cement kiln. Other than that, local micro businesses use them at a small scale: large pieces into children's wear and linear cotton offcuts made into strings to weave mats. Offcuts are the biggest waste in volume.

Rejected products

Finished products with fault or sample products that had served its purpose are being destroyed at the factory for brand protection. Whereas the faulty product rate is kept less than 1% thanks to the highly trained sewing skills, some of the destroyed sample pieces are sent to the local fabric market along with offcuts to be sold as craft materials for local businesses.

3. Cambridge-Expo Innovation Lab

An encouraging, innovative environment for experimenting fresh ideas was fostered through Cambridge-Expo Innovation Lab in Colombo. A 200m^2 space at the heart of Colombo was kindly provided at the ground floor of the headquarter building by the key project partner Expo Industrial Group who conceived the vision of creating a sustainability innovation space in Sri Lanka. The participating students and industry partners all were welcomed to the space throughout the project period for meetings, working, reviews, presentations and networking events.

Necessary working equipment was provided both through the partner companies' generous donations and the project budget. Expo Industrial Group provided working tables, chairs and air conditioning as well as the space, and MAS donated industrial sewing machines. Basic equipment such as projector, stationary, white board were purchased with the project budget. For more specifically required functions, project fund was provided to cover the fee to use the service, e.g. heavy prototype transportation, large format printing, laser-cutting. Most importantly, various types of fabric offcuts were provided in a large quantity from participating factories for students to experiment freely.

"This is going to be the next innovation. Sri Lanka has always tried to stay ahead of the game . For 30 years the country was affected by a civil conflict. Nevertheless this it has always been a centre for innovation in the apparel sector."

Nikhil Hirdaramani, Director of Hirdaramani Group

A collaboration-nurturing atmosphere was designed with care: educational materials and catered networking occasions. In terms of the educational environment, 11 posters were put up on the walls from the TransTextile outline, a circular economy framework, upcycle design business model case studies, an industrial symbiosis case study, future of manufacturing and to value mapping. Further more books about sustainable materials, and upcycle design were on display along with various upcycle design from the UK, Sri Lanka and South Korea.

Four times of catered networking occasions were made during the Phase 3 and 4: the Sri Lankan partners kick-off dinner, first student gathering, the Christmas party and the final showcase event. The food sharing helped creating a relaxed and friendly atmosphere for the participants and partners from disparate backgrounds to mingle easily. In addition, vegetarian foods were deliberately chosen for two reasons: leaving relatively small carbon footprint to help adopt consistent sustainability in work and life; representing the inclusive spirit of the collaboration sandpit: whoever you are! The food choice was well received and appreciated by the participants. During the events, ice-breaking introductions were constantly, with the importance of frog-kissing being explicitly emphasised and encouraged.

First student gathering at Cam-Expo Inno Lab at the heart of Colombo, Sri Lanka: The space and equipment was provided by key local industrial partners such as Expo Industrial Group and MAS. Students and industrial advisors used the lab as a creative working space throughout the project period.

Team X-pandex's product prototypes reviewe at the lab: Cambridge researcher and industry advisors from MAS and Hirdaramani. Interim review meetings were held at the lab every week. Lab was also used for socialising: catering is being laid out in the background for the Christmas party in the following evening. Students dressed up in Red & Green.

4. 5-Phase Innovation Process

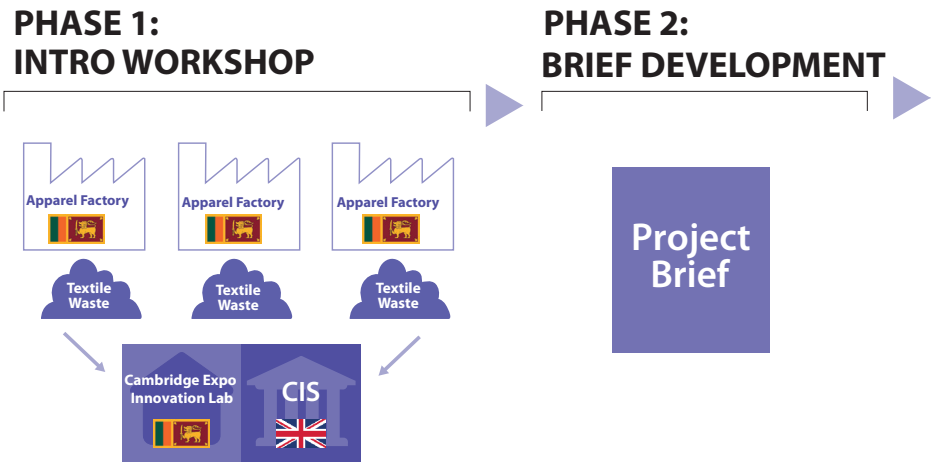
TransTextile adopted five-phased process of 1) Intro Workshops & Networking, 2) Project Brief Development, 3) Experiment, 4) Evaluation & Dissemination and 5) Roadmapping.

4.1 Phase 0 Kick-off & Scoping

This is a preliminary stage before the actual research take place in the first month of the project. Five Cambridge academics, the CIS graduate Dr. Lloyd Fernando, and the key Sri Lankan industry partner (via Skype) participated in the kick-off meeting in Cambridge. The overall project outline, objectives and specific context of Sri Lankan industry was briefed. The research direction and scope were also refined, e.g. how to balance the technology push and market pull. The workshop schedules were fine-tuned.

4.2 Phase 1 Intro Workshops & Networking

In the second month, a small CIS research team made the first visit to Sri Lanka. 10 days were spent to understand the Sri Lanka's industrial and cultural context of the textile waste, and to build local networks. A total of seven garment factory visits were made along with three introductory workshops at local garment manufacturers (MAS, Hirdaramani) and local design school (AOD). At the workshop, the background and objective of TransTextile were presented to gain their interest to take part, and to identify the challenges that the industry and upcycle designers experience with the textile waste. Lloyd Fernando continued to play a key role in successfully setting up of local partner networks based on his existing business networks.



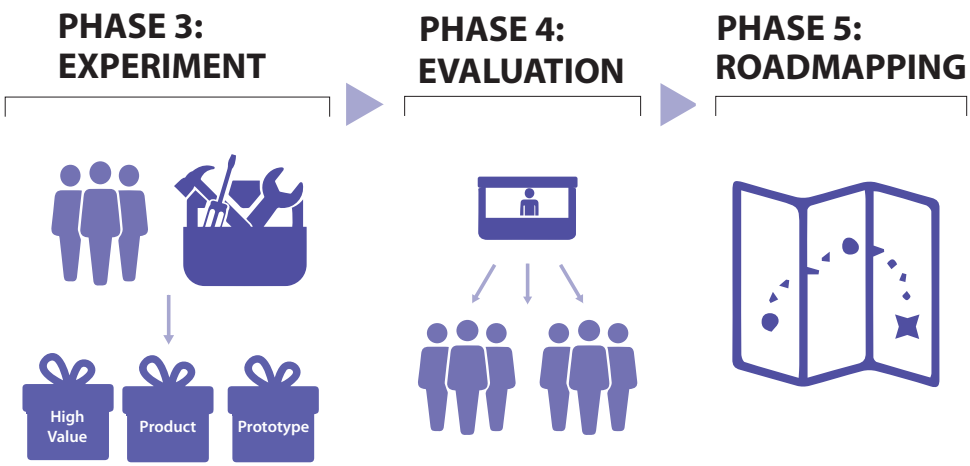
A number of activities took place during the Phase 1 resulting in a total of 49 connections with 14 organisations.

- 7 Factory visits
- 1 Landfill visit
- 1 Local fabric market visit
- 2 Industry workshops
- 1 Academic workshop
- 3 University meetings
- 3 SME meetings
- 2 NGO meetings

4.3 Phase 2 Project Brief Development

Based on the learning from the Phase 1, two workshops were held at the University of Cambridge and London College of Fashion (LCF) to debrief the learning and generate innovation catalysts in preparation for the next phase.

In Cambridge, the captured understanding from the visit was shared with six Cambridge academic from CIS and other research groups at the Institute for Manufacturing. At LCF, design brief development workshop was attended by sustainable fashion design academics and innovation consultant as well as the CIS research team. A number of new innovation ideas were discussed and a table of innovation catalyst was developed to form the basis of the brief for the experiment phase.



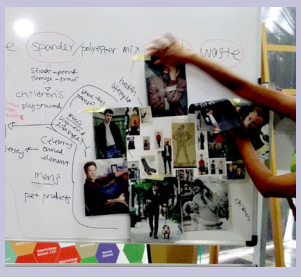
4.4 Phase 3 Experiment

Phase 3 was the most important and longest period of the project that has defined the key characteristics of the project.
The lead researcher from CIS was dispatched to Sri Lanka for three months to run the Phase 3. Based on the strong project partnership from the Phase 1, over 14 industry and academic experts and 20 students of various disciplines took part in the 11-week long experiment period.
Prior to the actual experiment, the first two weeks after the arrival were spent on the preparation including:

- Sri Lankan partners kick-off dinner
- Confirming student participation from three institutions
- Cleaning and equipping the venue: lightings, air-conditioner, stationary & haberdashery, product samples, projector, catering
- Scheduling with industry partners and academic advisors
- Gathering offcut samples from partner companies
- Arranging accommodation

In order to ensure the maximum interdisciplinary synergy in each team, students from textile process engineering, production engineering, chemical engineering, fashion design, interior design, product design and graphic design were carefully allocated for three project teams. The CIS researcher played an intermediating role by setting up a systematic innovation process, creating encouraging and supportive atmosphere, gathering participants together, and arranging weekly supervisions with industry experts and academics, providing constant feedback and innovation tools. Each team went through intensive collaboration activities to conduct a compact version of new product development process from ideation, market research, concept development, prototyping, durability testing, consumer survey and business model development.
The experiment followed six steps as follows.

Project briefing & team building → Ideation → Concept review



a) Project briefing & team building

Along with a talk about sustainable design and circular economy, the project outline and objective were introduced to students. Then, they were divided into three teams according to their disciplines and interests, and given team building tasks: choosing the team name and building a display unit using cardboards and offcuts.

b) Ideation

Each team was introduced to industry experts and ran through an ideation process. The image prompts and reverse assumption techniques helped each team explore and generate concrete innovation ideas to address specific contextual challenges that the industry and/or Sri Lanka society experience.

c) Concept review

Following the ideation stage, students started experimenting with waste materials with the machines at the university to explore the concepts around the ideas. They then brought them back for a review for industry experts to provide solid feedback on the developed concepts. Subsequently the discussed concepts were summarised and the next steps were disseminated via email.

d) Prototype review

Students carried on the experimentation and further developed prototypes ,and reviewed by industry and academic advisors.

e) Value mapping & Business model building

Based on the developed ideas, the Cambridge Value Mapping Tool and the Honeycomb Business Model tool were introduced to help them explore sustainable business model logics that carry the developed ideas.

→ Prototype review → Value mapping & business model building → Industry presentation

f) Industry presentation

Refined ideas and prototypes were presented to the core advisory group who have been supervising the innovation teams. It was to prepare for the final showcase to a bigger audience of Sri Lankan Industry practitioners in the following month.

4.5 Phase 4 Evaluation & Dissemination

The final outcomes of the project were consolidated and introduced to over 60 attendees at the final showcase in Colombo. The showcase programme included a brief introduction to TransTextile, innovation idea pitches, Prof. Steve Evans's talk on the Future of Manufacturing & Value Creation, a roundtable discussion and networking.

As well as the idea pitches, the CEO of a South Korean company was also invited to present their patented cutting-edge technology that effectively transforms an industrial quantity of textile waste into high quality construction panels. The invitation was well received among the industry attendees and snowballed to other industry contacts. The presentations were followed by a roundtable discussion where the project partners shared their thoughts and future plans. Toward the end, the importance of frog kissing for creating innovative ideas was emphasised and active networking was encouraged to the attendees over the food and drinks.

Final Showcase sketch: Prof. Steve Evans speaking about the High-Press Fibre Panel prototype with Prof. Lakdas Fernando, the founder of the textile education in Sri Lanka (Left); Mr. Jun Young Park presents about his new material to 60+ Sri Lankan audience (Right)

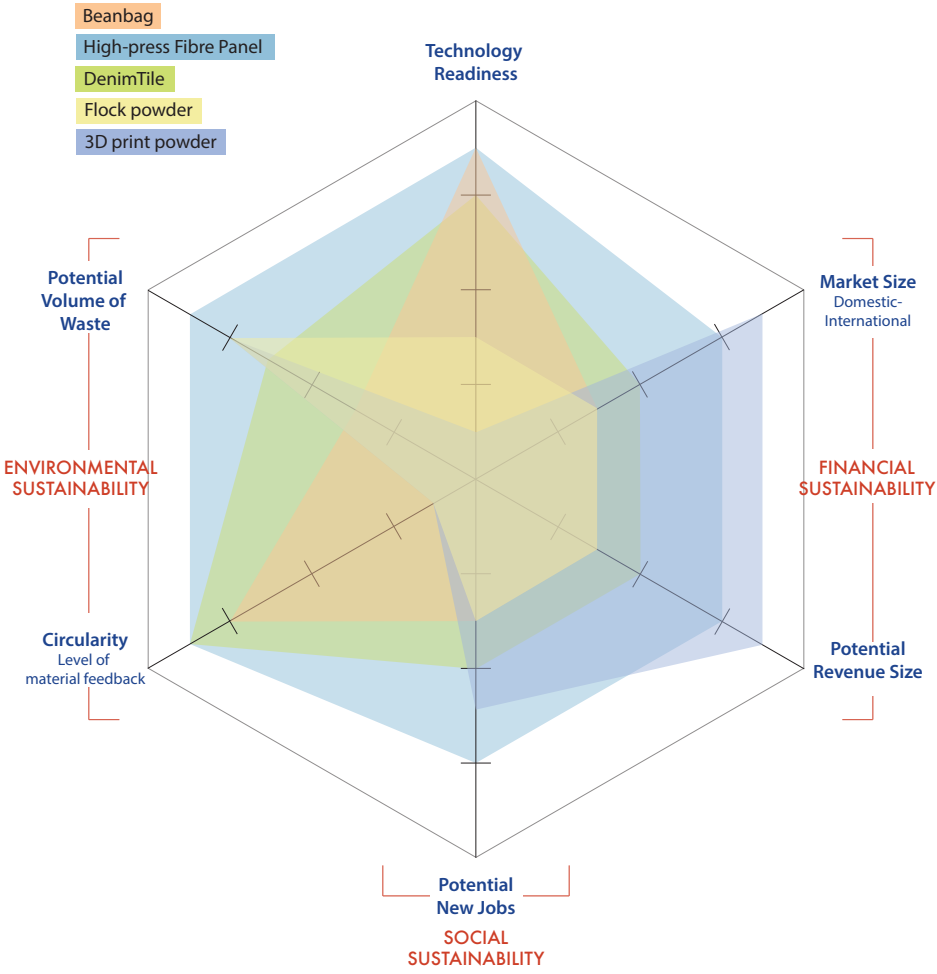
4.6 Phase 5 Technology Roadmapping

The project team returned to Cambridge consolidated the learning and outcomes into a final report. The innovation ideas were reflected using the Technology Roadmapping Template (Phaal et al., 2016)*. Technology Roadmapping helps capture the current situation and future trajectory of each idea (p. 19, 20,24). By going through several iterative processes, the learning was boiled down to a list of lessons for setting up an interdisciplinary innovation sandpit and future recommendations.

*While the Technology Roadmap is populated through workshops, this was used after technology development. Phaal, R., Kerr, C., Ilevbare, I., Farrukh, C., Routley, M., & Athanassopoulou, N. (2016). On 'self-facilitating'templates for technology and innovation strategy workshops.

5. Five innovation ideas

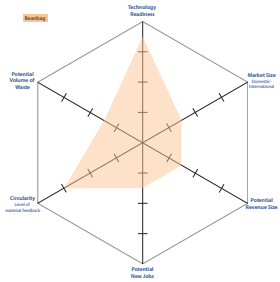
The project yielded five innovation ideas that cover a spectrum of technology readiness levels and a range of potential sustainability impacts. Each idea targets different textile waste types that respective company experiences difficulty to manage.



Spider Web Chart of five TransTextile ideas: comparison of six categories from technology readiness and the potential size of market size and revenue size (financial sustainability), created new jobs (social sustainability), and volume of waste and circularity (environmental sustainability).

SAMOSA bean bags

Samosa Beanbag provides a sustainable lifestyle solution using unrecyclable PU foam offcuts from the bra manufacturing process. This idea uses basic technology, hence the readiness level is the highest, involving a 3-stage process, i.e. shredding the PU foam offcuts in two sizes; sewing 3D samosa (or pyramid) shape outer shell and an inner pouch; and filling the inner pouch with the shredded foams, Samosa Beanbag is a casual and comfortable sitting solution of interest to the Sri Lanka's growing lifestyle product market from home to hotels, schools and offices. From the sustainable perspective, Samosa Beanbag is believed to bring environmental benefits of diverting 300-600 tonnes/year of PU foam offcuts from landfill and contributing to circular economy through a take-back and repurposing the materials by leasing scheme. Samosa Beanbag business idea is also anticipated to generate between 156 and 312 M Sri Lankan Rupees per year. Society-wise, this new innovative approach to add value to the unrecyclable waste material is expected to contribute to customer education, and job creation and job diversion from landfill collection, therefore improving the reputation for business customers.



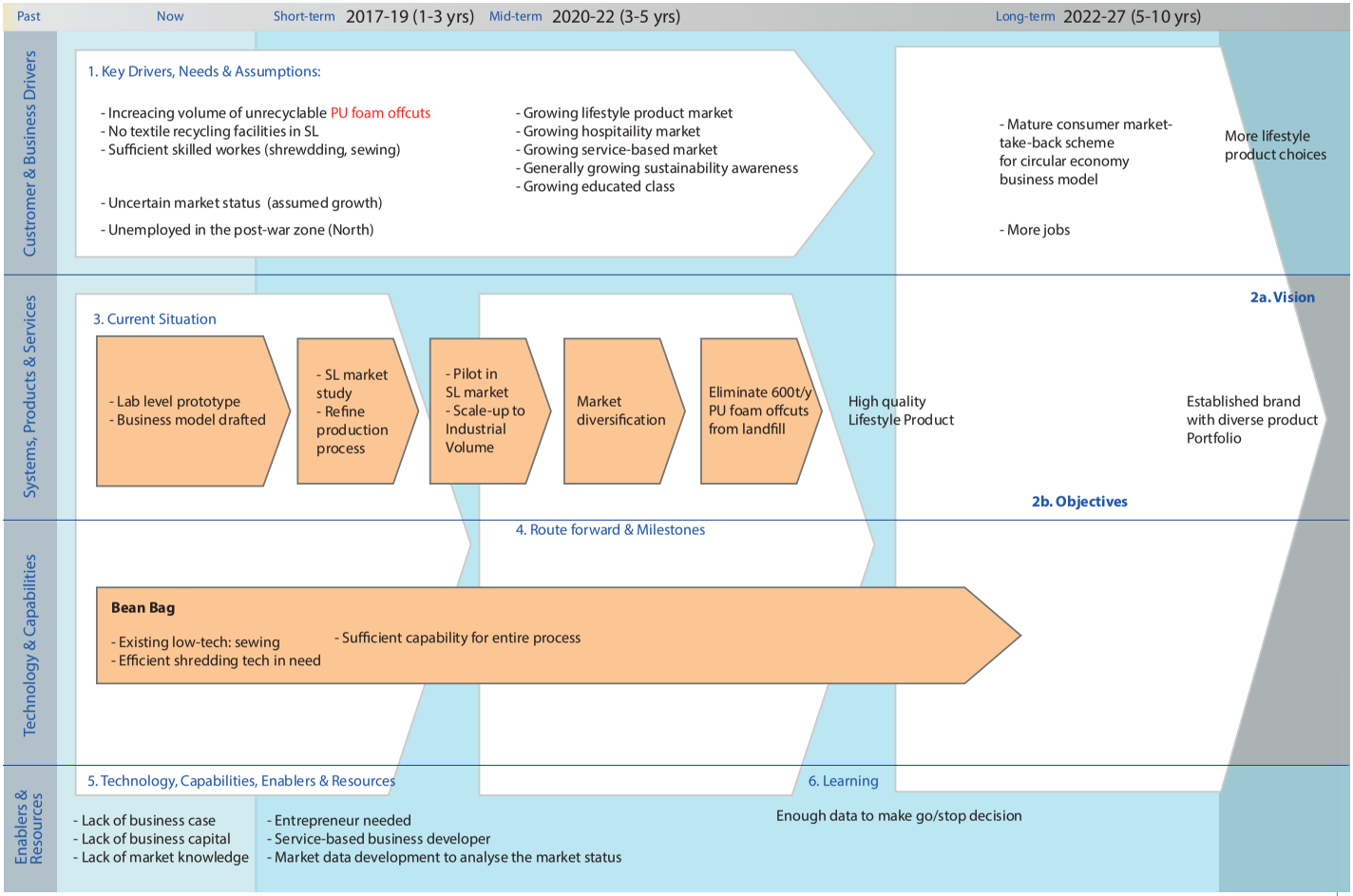
Tech Roadmap

Samosa Beanbag is currently one of the top two at the highest technology readiness level. Once a clear market analysis and production process refinement take place, sufficient capability will be ready to the industrial level can be possible within the next 3-5 years. Finding local entrepreneurs and service-based business developer will enable a circular economy business.

Developed by Team X-Pandex

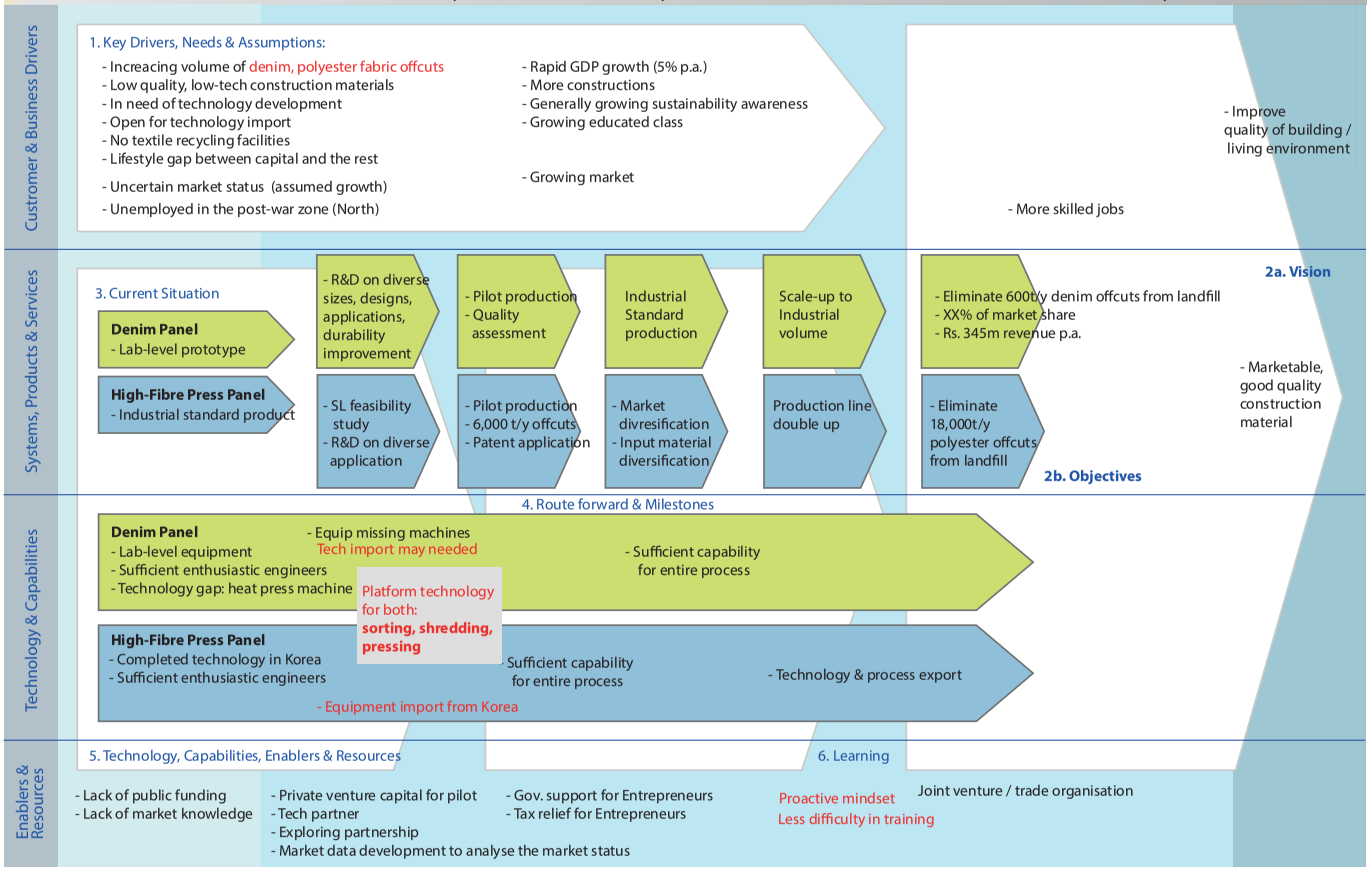
10:6 scale Samosa Beanbag prototypes presented at the Final Showcase (left), unrecyclable PU foam offcuts from bra manufacturing is the target waste material (right)

Topic: Beanbag: Technology Roadmap for new product development using textile waste in Sri Lanka



Topic: Denim panel, High-press Fibre Panel Technology Roadmap for new product development using textile waste in Sri Lanka

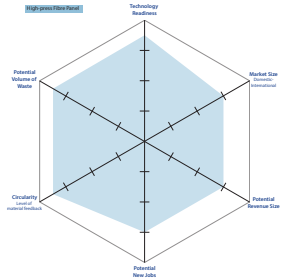
Past | Now | Short-term 2017-19 (1-3 yrs) | Mid-term 2020-22 (3-5 yrs) | Long-term 2022 (5-10 yrs)



* Two Ideas are coupled in one page depending on the level of technology readiness, and by doing so platform technologies that can benefit more than one idea has emerged.

High-Press Fibre Panel

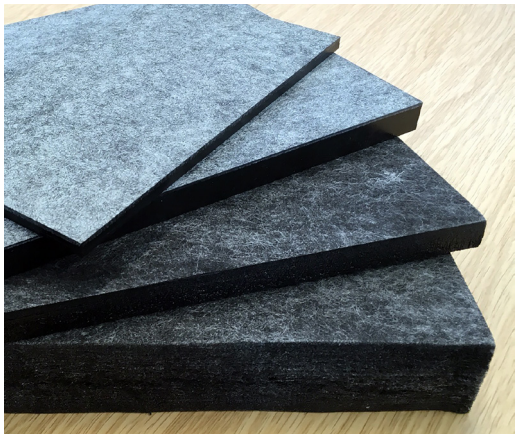
High Press Fibre Panel is a sustainable replacement for construction panel materials with a range of advantages. Its 6 -step fabrication process transforms polyester offcuts into high quality, high performance, and competitive panels without adding any bonding medium, which often the reason why the material fails to close the loop at the end of the lifecycle. The panel comes in various sizes (up to 2.4x1.2m), thicknesses (4-30mm), densities (up to 1.18 g/cm3) whereas 13% lighter and 300% stronger than High Density Fibreboard. The key characteristics of the panel range from high durability, price competitiveness and circularity, to flame/ water/chemical resistant to noise / heat absorption and no formaldehyde emission. The company is explicitly planning to provide jobs to the physically/ mentally challenged in some part of the process, this will enhance the potential size of its sustainability impact in every aspect.



Tech Roadmap

The technology development has been completed in Korea and at the industrial standard production stage. As well as technology import from Korea, a contextual feasibility study is required in the Sri Lanka's market, industrial, climatic and geographical context. In the mid-term, pilot production can start with 6,000 t/y waste consumption to triple up in 5 years.

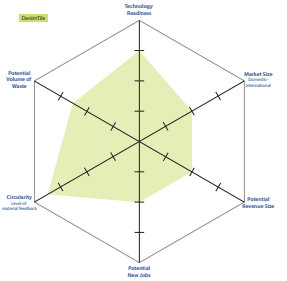
Developed & patented by Sejin Plus Ltd.



High-Press Fibre Panel comes in various sizes, density and thickness to cater for different purposes from wall panel, roof insulation, flooring, etc. (left), polyester offcuts are the only material that makes this versatile panel (right)

DenimTile

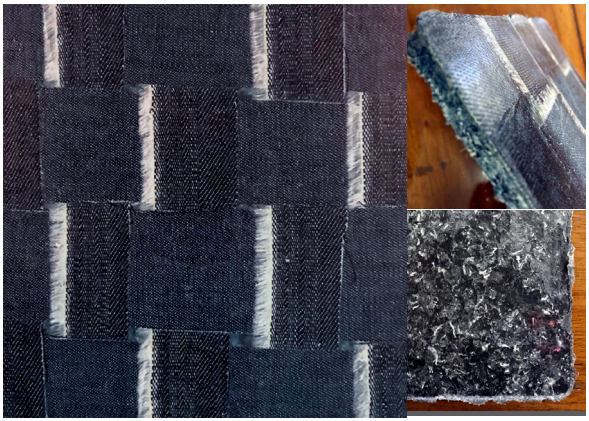
DenimTile is a decorative, sustainable interior decoration solution that use denim offcuts and LDPE as an answer for Sri Lanka's growing high-end interior design market. Allowing for various applications including decorative wall cladding, ceiling panels, partition board, kitchen pantry top, and flooring, the DenimTile idea was developed by two project teams to maximise the offcut consumption at a large scale and a high speed. Involving several machines (shredding machine, heat press and cooling mould) and materials (linear denim offcuts, shredded non-segregated offcuts, and shredded LDPE), two teams respectively figured out the best ratio between fabric offcuts and shredded plastics, and the unique-looking for higher value and durability. The anticipated sustainability benefit spans environmental benefit of 600 tonnes/year of fabric offcuts and LDPE diverted from landfill and a reduction of need for virgin material; financial benefit of a revenue of 345 M Sri Lanka Rupees/year; and social benefit of job being created and diversified from landfill collection, skill and income for local women from weaving, LEEDS certification for buildings.



Tech Roadmap

The technology development is currently completed and tested at the lab level. In the short-term, further research and improvement will allow a pilot production within 3 years. While sharing platform technology in sorting, shredding and pressing with High-Press Fibre Panel, some high tech equipment import may be needed.

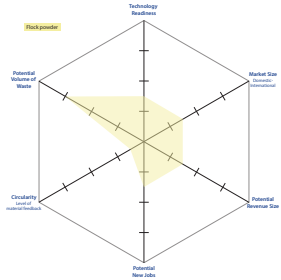
Developed by Team Urban Jungle & Team Ecohomb



(From left clockwise) Denim tile front with woven denim offcuts. The woven structure reinforces the durability of the tile; sideview showing the layered structure of woven top sheet of linear selvedge denim fabric and shredded bottom sheet, the shredded bottom layer can maximise the unweavable shaped offcuts; denim offcuts is the main material (50%) as well as shredded LDPE (50%); the backview of the tile of shredded offcuts.

Flock powder

Flock powder and 3D printing powder share the same technology and waste material of grinding spandex-mixed offcuts. Flock Powder was put forward as a large scale solution to consume the increasing amount of unrecyclable textile waste offering a sustainable alternative for conventional flock powder for premium package, scratch proof surface, toys and oil spill machinery. Resulting from a 4-stage production process, it involves the segregation and the shredding of synthetic fabric offcuts, their grinding into 30 mesh duct and the flocking of the surface with silicon. Applications are deemed limitless, ranging from sound absorption and vibration isolation, cushioning and shock isolation, and light absorption to mechanical impact energy absorption to the reduction of friction.

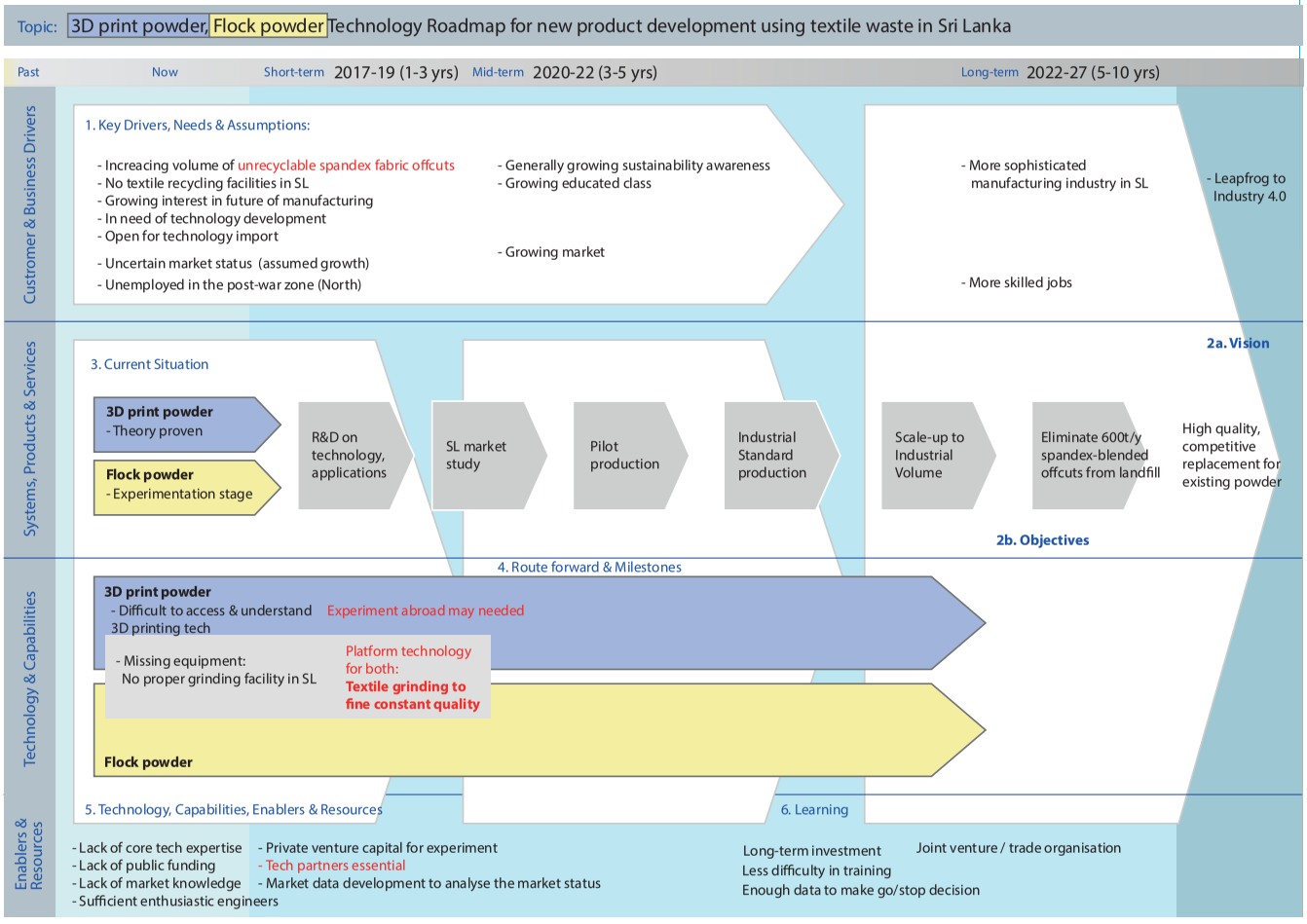


Tech Roadmap

The technology is second least ready and at the experimentation stage. Currently the research team has difficulty in finding a high performance equipment of grinding technology within the country. Nevertheless, after the initial R&D investment and activities, a wide range of industrial applications is anticipated.

Developed by Team Ecohomb

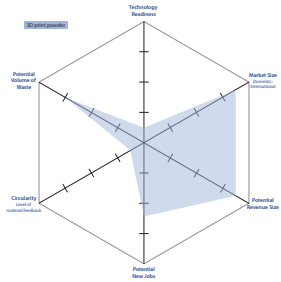
The flock printing adding premium value to clothes is one of many possible applications for flock powder (left); the flock powder idea is to add value to the currently unrecyclable spandex-mixed textile waste. Grinding allows any shapes and sizes of offcuts (right)



* Two Ideas are coupled in one page depending on the level of technology readiness, and by doing so platform technologies that can benefit more than one idea has emerged.

3D Printing powder

Textile-based 3D printing powder made of unrecyclable spandex offcuts ground into fine powder is the most stretched and least technology-ready idea among the five. Once the optimum grinding level is achieved, binder jetting or powder bed fusion are proposed as a possible 3D printing methods among the seven ISO standard ones. With further technical investigation, it is anticipated to become a sustainable feedstock that would help Sri Lanka leapfrog to Industry 4.0. The market is promising, with 25% yearly growth rate and deployable across a wide range of industries.



Tech Roadmap

The technology is theoretically proven only. International 3D technology partnership is essential due to the lack of resource and access to hands-on experiment to understand the technology. Long-term investment will be the key enabler. Thanks to the high level of engineering education, job training will be less difficult.

Developed by Team Ecohomb

Binder jetting or powder bed fusion are proposed as a possible 3D printing methods among the seven ISO standard ones. (left); 3D printing is based on the same principle as flock powder as in the grinding currently unrecyclable spandex-mixed textile waste in any shape and colour. (right)

6. Lessons on interdisciplinary waste innovation

The project demonstrated a high possibility of a waste innovation sandpit that delivers **fast, effective** and **competitive** solutions to sustainably address the waste problems in collaboration with local industry and academia. The below three lessons are captured during the attempt in Sri Lanka.

The critical role of local network hub

Building enthusiastic and strong local networks was made possible hugely thanks to CIS's existing local network link: the recent CIS graduate, Dr. Lloyd Fernando. He is the director of Expo Industrial Engineering in Sri Lanka, and shared the project vision of an innovation space in Sri Lanka with the research team. Hence he opened his extensive and close business contacts for the team to connect with. His introduction certainly paved the way for the research team. He also motivated Sri Lanka's key industry and academic players to get on board, facilitating a snowball effect on expanding the project partner pool. After the initial connections, Dr. Fernando has stepped away letting the research team to nurture and explore the networks, but kept on guiding on the liaison with local participants to help avoid possible mistakes or misunderstanding due to the cultural difference.

Systematic but agile adjustment to manage uncertainty

The research team adopted an action research method and was prepared to expect the unexpected circumstances as it was operating in a new cultural environment. While the phase-based approach and prepared teaching materials and sustainability tools helped the research team gear up the systematic outline of the project, agile adjustments were constantly made in response to the local conditions. For example, the review schedules had to change due to the monthly national holidays, and the project became open source-based as opposed to exclusive solutions to specific companies, as it was realised that some solutions could not be operated independently. Although the process and approach are now tested and considered to be replicable in different country, the room for agile adjustment must remain substantially open.

Gentle and passionate drive for collective effort

The research team paid special attention to understand the best approaches to engage with eclectic Sri Lankan partners and to inspire collective passions toward the sustainability goal.

First, the research team made it clear that the basis of the project was on the collective effort to help each other to attain the sustainable future for all, not on the one-way delivery of knowledge from the university. This helped the Sri Lankan partners gently open their mind and to take part with pride.

Second, being briefed that students are very talented but can appear shy, the research team constantly encouraged them to be bold and wild. Students found the encouragement inviting, and remained extremely passionate about the project throughout the project period. Also, the non-judgemental, friendly environment without hierarchical pressure helped them relax and build new friendships with new interesting people from different backgrounds under a common passion for sustainability. It smoothly led them to enjoyable collaborations and discussions.

Third, by borrowing equipment* other than the basics, an ample amount of the project budget could be allocated for networking instead of purchasing expensive machines. Active arrangement of networking occasions helped the participants feel welcomed to build long-term collaboration relationships and friendships in pursuit of the same goal.

*Special thanks to Dr. Randika Jayasinghe for kindly allowing us to use your machines!

7. Future recommendations

Reflecting on the project learning, the below six points are recommended to help establish sustainable innovation in a way that continues and causes real-life impact at a scale.

Frog Kissing Centre ගෙම්බා හබා සිප for Waste Innovation

Jointly invest and build a physical and virtual place where innovators, engineers, designers, academics, entrepreneurs and industry practitioners come together and experiment with system-level solutions with the waste. It is recommended to expand the subject area from only textile to a wider range of wastes that the local industries have troubles to deal with. Companies provide their industrial waste of various types and universities jointly develop multi-disciplinary collaboration courses and curriculum to create innovative solutions for waste at a system-level. The joint investment will secure the long-term incubation of innovations that can collectively address the waste issue at the national level.

While industry often exhausts possible answers within, a fresh approach from a disparate industry could bring in solutions from a different lens. The sandpit would help academia to understand the process and the enablers and inhibitors for interdisciplinary collaboration in developing countries. Equally, the process model would help local industry practitioners to establish the methods to explore high value innovative solutions for their industrial waste problem.

National-level Industrial Waste Inventory

Conduct and update the industrial waste inventory in Sri Lanka that shows the clear picture of the national waste from volume, types and to trends. The gathered data will play a critical role for the innovators to understand the present conditions of industrial waste generation in Sri Lanka and map out the future solutions that will promote the industrial symbiosis in Sri Lanka.

Dragon's Den Waste Innovation Competitions

Run nation-wide innovation competitions on a regular basis that anyone can enter with innovative business idea that add higher value to the waste and provide sustainable solutions. If run on a regular basis, this will accelerate the innovation spirit in the country, and create an interest to look at waste differently.

In-depth Market studies

Conduct an in-depth market studies using professional market researchers to identify the routes and the potentiality of the developed ideas. Whereas enough technology push has been presented during the process, not enough market pull has been identified properly.

Local entrepreneur

Find business-minded people who see the market potentiality of the developed ideas, and who are willing to get them off the ground. It has been identified that the garment manufacturers are ready to provide the waste materials but find it risky to run disparate business that is out of the core business boundary of the company.

Pilot plant

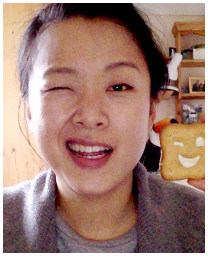
Run a feasibility study to set up a pilot plant to mass-manufacture the High-Press Fibre Panel developed by Sejin Plus. While many local partners acknowledged its huge sustainability potentiality, a list of realistic aspects need to be scrutinised before moving on to the industrial level scale-up in Sri Lanka. The study list includes the financial viability, legal regulations, governmental supports, potential investors, market condition and technical adaptability.

TransTextile People

University of Cambridge

Prof. Steve Evans CEng
Steve is the director of research at Centre for Industrial Sustainability, Institute for Manufacturing, University of Cambridge, conducting research into how industry can bring ambitious environmental and societal sustainability goals into practice. His research seeks a deep understanding of how industry might change, with a duel emphasis on urgent & practical change now, and system-level change that offers hope for a sustainable future. He has a black belt in Judo.

Ian Bamford
Ian is the commercial director at Centre for Industrial Sustainability, Institute for Manufacturing, University of Cambridge. Ian is passionate about the need to ensure research outcomes are converted into tools that businesses can use, and are adopted in volumes sufficient to create a system-wide change.



Dr. Curie Park
Curie is the lead researcher of project TransTextile, working as a research associate at Centre for Industrial Sustainability, Institute for Manufacturing, University of Cambridge. Before her PhD on sustainable design strategy, she worked as a practicing designer running a product design studio. Her research interest is in creating substantial positive impact through design of product, process, business models and industrial systems. She pursues leading a sustainable yet playful life.

Expo Industrial Group

Beauno Fernando
Beauno is the founder and Chairman of Shore 2 Shore: aBrand Packaging, manufactures of Apparel Labeling, Packaging and Textile Transfer. He is the leading partner of the project. He is actively investing in sustainable materials, digital manufacturing & eco-factories. He is one of the chairs at the Sri Lanka Apparel of Joint Apparel Associations Forum.
"TransTextile initiated bringing knowledge to Sri Lanka and Industry on exploring system-level solutions to post-production textile waste."

Dr. Lloyd Fernando
Lloyd is The director of Shore 2 Shore and a CIS graduate in industrial sustainability. He played the critical role in facilitating the Icoal network. He is passionate about co-creation, innovative creative products, empowering the workforce and fostering learning.
"TransTextile created an eco-system for industry leader and academics to come together and collaborate. It enabled the development of news skills & exploration of waste solutions and uncover new value creation opportunities."

MAS

Dhanujie Jayapala
Dhanujie is a project Lead of Environmental Sustainability at MAS CAPITAL, and one of the the major contributors from MAS.
He is an Electrical and Electronic Engineering bringing technology to the Sustainability Field. His fields of interest are in Solar PV, Waste Recycling, Energy Monitoring and Data Analytics.

Ranil K.A. Kularatne
Ranil is a Project Lead of Environmental Sustainability at MAS CAPITAL.
He is an experienced Environmental / Health, Safety and Environmental Management Specialist. His special areas of expertise are waste management, EIAs, ERAs, effluent management and occupational health and safety management.

Thiwanka De Fonseka
Thiwanka is the Executive of sustainability team, MAS Intimates, with a diverse expertise from Forestry and Environmental Management and chemistry. His research interests include sustainable waste management, fabric recycling and water quality.
Thiwanka is happy about TransTextile because fabric and foam waste are one of his key research areas.
"It was a great privilege to consult on TransTextile I wish to continue the good work in the future."

HIRDARAMANI

Nikhil Hidaramani
Nikhil is a director at Hirdaramani International Group which designs, manufactures and exports clothing to internationally renowned clients around the world. As the sustainability champion of the group, he was the keen supporter of TransTextile. He tries to reinforce the sustainable innovations in every aspect of the business practice.

Demith Gooneratne
Demith is the Environmental Sustainability Manager at Hirdaramani International Exports (Pvt) Ltd., with 7+ Years' Experience in the Apparel Sustainability field. His interest ranges from environmental protection, renewable energy and resource efficiency driving better sustained manufacturing processes within the apparel and other related industries. He is an active participant of SAC membership working on advancing the evaluation schemes of Higg 2.0 and 3.0 to better suit the industry.

National Cleaner Production Centre Sri Lanka

Samantha kumarasena
Samantha is the CEO of National Cleaner Production Centre (NCPC) Sri Lanka. NCPC is the foremost non nonprofit cleaner production solutions provider in Sri Lanka, which was first established by UNIDO in 2002. He promotes resource efficient & cleaner production in various industry & business sectors in Sri Lanka.

House of Lonali

Lonali Rodrigo
Lonali is the founder and designer behind House of Lonali, the social enterprise of the ethical brand 'Lonali'. Graduating from the University of Northumbria with a BA (Hons) first class Degree in Fashion Design, she decided to take the challenge of starting her own social enterprise House of Lonali, providing Ethical fashion to the Sri Lankan market.

University of Moratuwa

Dr. Nirmali de Silva
Nirmali is a senior lecturer and the course director of Fashion Design at University of Moratuwa.
She well connected to the Textile, Apparel and Crafts Industry in Sri Lanka and has experience in working with overseas Universities to strengthen Sri Lanka's textile education. She is a PhD from Leeds University and a Fellow of the Textile Institute. She has rich experiences in advising students in Technology, Fashion and Design

University of Peradeniya

Dr. Maheshi Danthurebandara
Maheshi is a senior lecturer at department of chemical and process engineering at University of Sri Peradeniya. She has a wide range of experience in solid waste management, wastewater treatment, life cycle assessment, life cycle costing, Landfill mining (LFM), Enhanced Landfill Mining (ELFM), biotechnological processes including aerobic and anaerobic digestion, membrane technology, process engineering and environmental engineering.

University of Sri Jayewardenepura

Dr. Randika Jayasinghe
Randika is the head of the Department of Engineering Technology at University of Sri Jayewardenepura and the project coordinator of "Australian-Sri Lankan University partnerships funded and led by the University of Western Australia. In the partnership, she develops community-based recycling businesses". The partnership was partly located at the UoM where she generously opened the facilities to the TransTextile students.

C Shapes

Chaminda Diaz
Chaminda is an upcycle jewellery designer reusing various types of paper as the base material. He was trained in Belgium, where he grew his passion for sustainability. He creates beautiful abstract shapes and wonderful finishes from ordinary materials.

Team X-Pandex

Dakshitha Weerasinghe
Dakshitha is a textile process engineering graduate from University of Moratuwa.
He believes the world can change for the better which is why TransTextile project is critical for a country like Sri Lanka especially in light of recent events.

Asanga Weththasingha
Asanga is a textile process engineering graduate from University of Moratuwa.
"'Trans-textile Project' is a very special project in my university career where I was able to create a deep impression about the need of sustainability to the current textile industry within Sri Lanka. I was able to be a small but valuable part among the people who actually has the love towards the environment"

Nayomi Kumarapperuma
Nayomi is a textile and clothing technology engineering graduate from University of Moratuwa. She is currently Working at MAS Active (Development and Innovations) as a Management Trainee.
As a nature lover, she would like to contribute further in sustainability projects. She does not want to see beautiful places being spoiled due to dumping of garbage. "Really I hate to see that!" She loves travelling, hiking, camping and reading.

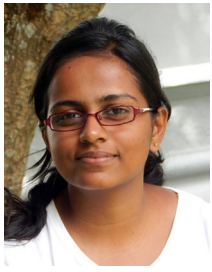
Sapthika Jacob
Sapthika is a final year fashion design and product development student at University of Moratuwa. She worked at MAS as in intern.

Urban Jungle

Lakni Edirisooriya
Lakni is a final year fashion design and product development student at University of Moratuwa. She runs her own eco-friendly slippers brand. She is very concern about nature as she loves nature more than anything.
"TransTextile is great opportunity to develop our inner skills and also I learned lots of things about sustainability. Curie and team gave the right guidance with a friendly manner. I'm glad to have worked with them."

Ilham Reyaz
Ilham is a graphic design and art student at Academy of Design (AOD) in Colombo. He believes that sustainable design is the future and is very much at the heart of everything he does.
"The Transtextile project helped me meet like-minded friends and open valuable insights into the practicality of developing and creating a sustainable product."

Nuwan Dissanayake
Nuwan is a final year fashion design and product development student at University of Moratuwa. He worked at MAS as in intern.



Ruwani Prasangika
Ruwani is chemical & process engineering graduand from University of Peradeniya.
"TransTextile is good opportunity and I think we should implement the solution practically".

Himal Muwanwella
Himal is a textile process engineering graduate from University of Moratuwa. He was one of the most enthusiastic engineers who experimented day and night at the lab wit the Denim Tile idea.
He is currently working as an innovation engineer at Noyon Lanka.
"Transtextiles is not just a project but about everyone's responsibility."

Harsha Moragollegedara
Harsha is an undergraduate of fashion design and product development at University of Moratuwa.
"TransTextile was a great opportunity to share with each other. Sustainability is an upcoming trend in the world. The solutions that we found from this project will be successful for the textile waste in the apparel industry."

Rasindu Punchihewa
Rasindu is a textile process engineering graduate from University of Moratuwa.
He is a young engineer who would like to make Sri Lanka a better country. He was another key member who eagerly experimented day and night at the lab.

Auchitya Weerasinghe
Auchitya is an interior design student at AOD. As a focused and talented desgign studetn, she brought the designer's sharp eyes to the project by conducting thoughtful customer survey and analysis.

Team Ecohomb

Hansadhi Munasinghe
Hansadhi is an undergraduate of fashion design and product development at University of Moratuwa.
"It was a great experience as an undergraduate to share knowledge through teamworking. Sustainability is one of the increasing customer trends in the macro market. TransTextile gives better and profitable solutions for the global waste problem in the garment industry."

Raashidha Haque
Raashidha is a textile process engineering graduate from University of Moratuwa. She believes that sustainability is the driving force and the trend of the world.
"Transtextile was one of the best chances to work with multidisciplinary people. Glad that I could lead the Ecohomb group and thankful for Transtextile for making me be a part of finding solutions for one of the most prevailing issues in Sri Lanka."

Nayomi Shalika Weerasekara
Nayomi is a chemical & process engineering graduate from University of Peradeniya. She is currently working as a Chemical Engineer at BioNutri International (PVT) LTD.
"TransTextile was a very important project to enhance the environmental sustainability. I enjoyed it a lot and got a huge international experience with new relationships with people from different disciplines."

Thilina Abhayarathne
Thilina is a textile process engineering graduate from University of Moratuwa. He is a keen engineer with a passion for experimentation until he finds the right answers with materials.

Champika Thusitha
Champika is a textile process engineering graduate from University of Moratuwa.
"It was a great opportunity to take part in TransTextile. I learnt lots from our research and enjoyed it."

Rasmeda Gopalakrishnan
Rasmeda is an interior design student at AOD. She has brought funky product ideas that engages Sri Lanka's cultural icon: elephants. Later she handcrafted the prototypes.

Hiroshan Weerawardena
Hiroshan is a product designer, graduate from Product Design, University of Moratuwa. He is working as the research assistant for the community-based recycling businesses project that Dr. Randika runs. He is interested in new methods to develop more innovative products with a more sustainable approach.

Ruth Weerasinghe
Ruth is a fashion design student at AOD. She took part in the market study and experimented with the offcuts to sew them into bags.

Acknowledgement

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EXPO INDUSTRIAL ENGINEERING

HIRDARAMANI GROUP

MAS CHANGE IS COURAGE

Sejin Plus (주)세진플러스

- Sri Lankan Academic Partners

University of Moratuwa
Wisdom is all wealth

AOD

University of Peradeniya
Sri Lanka

- Sri Lankan & UK Advisors

centre for sustainable fashion

lonali

BOI SRI LANKA

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wrap

Lanka Leather Fashion Ltd.

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