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I am an Industrial Designer with extensive experience in collaborative innovation and sustainable product design. Presently, I hold the position of Assistant Professor in the Department of Design at the Indian Institute of Technology Guwahati. My doctoral research explored Design for Sustainability, specifically focusing on the development of scale-appropriate agricultural equipment. My academic journey began with a Bachelor's degree in Industrial Design from IIT Guwahati, followed by a Master's degree in Integrated Product Design from the Technical University of Delft, Netherlands, culminating in a PhD from IIT Guwahati.

I co-founded the Sustainability and Social Innovation Lab at the Department of Design, IIT Guwahati, which aims to redefine systems for sustainable human consumption and production. Our design interventions strive for a profound transformation of the consumption structure. The lab is an active participant in the Learning and Education Network in Sustainability (LeNS), a global consortium of over 150 universities dedicated to sustainability. A significant portion of our work focuses on sustainable product-service development projects within the agricultural sector.

My expertise lies in Design for Sustainability, emphasizing the integration of environmental considerations into the design process. This includes Agricultural Product Design, aiming to improve the efficiency and sustainability of farming tools and equipment. I'm deeply involved in Lifecycle Assessment to measure the environmental impacts of products throughout their lifecycle. My work in Sustainable Product-Service System Design seeks to create innovative solutions that blend products and services for better sustainability. Additionally, my efforts extend to Medical Product Design, prioritizing user safety and environmental considerations. My strong foundation in User Experience Design and Human-Centered Design ensures that our products are not only sustainable but also user-friendly and responsive to human needs.

At IIT Guwahati, I teach various courses including System Design for Sustainability, Usability Engineering, User Research Techniques, Product Detailing, Interaction Design, Design Management, and Plastics and Composites. I have also developed a MOOC course on System Design for Sustainability for the SWAYAM platform, sponsored by MHRD.

Over the past few years, my professional journey has taken me across India, Bangladesh, and the Netherlands, collaborating with organizations such as ABB, Philips, Infosys, MIDCO, VU Medical University Amsterdam, Conpax Verpakking, Beat Belly, Botanische Tuin Delft, ACC Ltd, and numerous educational institutes and NGOs worldwide.

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From Consumers to Changemakers: The Impact of Social Innovation on Sustainability Practices

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1.1. A Closer Look at Sustainability

The imperative for design for sustainability emerges from the urgent need to address the intertwined challenges of environmental degradation, resource depletion, and social inequities, necessitating a comprehensive and integrated approach (Manzini, E. and Vezzoli, C., 2003). This necessitates a shift towards sustainable consumption and production (SCP), which aims to decouple economic development from environmental degradation and improve the quality of life for all (UNEP, 2018). SCP emphasizes not just technological innovations or efficiency improvements but also a systemic re-evaluation of the ways in which goods and services are consumed, produced, and disposed of (Mont, O. and Plepys, A., 2008).

The emphasis on consumption practices, rather than solely on production, as the focal point for achieving long-term sustainability benefits marks a pivotal shift in the approach to sustainable development. This perspective underlines the realization that production patterns are driven by consumption demands, implying

that changes in consumption behaviors can lead to more significant and systemic environmental and social benefits (Cohen, J, M., 2005). The SCP framework, intentionally placing 'Consumption' before 'Production', underscores this paradigm shift, highlighting the need to address the root causes of unsustainable practices through altering consumer behaviors, preferences, and patterns (Tukker, A. et al., 2017).

Research indicates that focusing on consumption practices offers a broader array of levers for achieving sustainability, including reducing the demand for resource-intensive goods and services, promoting the use of more sustainable products, and encouraging lifestyles and consumption patterns that are in harmony with ecological limits (Thøgersen, J. and Schrader, U., 2012). This approach aligns with the understanding that sustainability is not only a matter of how goods and services are produced but also fundamentally about what is consumed, in what quantities, and how the consumption of these goods and services impacts the environment and society (Spaargaren, G. and Cohen, M., 2009).

Moreover, the SCP approach fosters innovation in policy, market mechanisms, and consumer engagement strategies, aiming to facilitate a transition towards sustainability by integrating economic, environmental, and social dimensions (Mont, O. and Plepys, A., 2008). By focusing on the 'C' before the 'P', SCP emphasizes the role of consumers in driving demand for sustainable products and services, thereby influencing production practices and contributing to a more sustainable economy (Heiskanen et al., 2005).

In the SCP framework, social innovation becomes critical, offering new solutions that are socially accepted and widely adopted, addressing the complex challenges of sustainability transitions (Westley, F. et al., 2014). Social innovations are instrumental in reshaping societal norms, practices, and relationships, thus playing a crucial role in facilitating the transformative changes required for a sustainable future (Murray, R., Caulier-Grice, J. and Mulgan, G., 2010).

Here are some examples illustrating how social innovation contributes to SCP:

1. **Sharing Economy Platforms: Services like car-sharing (Zipcar) and tool libraries promote the use of shared resources among multiple users, reducing the need for individual ownership and consequently diminishing the environmental impact associated with production and consumption. This model encourages efficient use of resources and helps in lowering carbon footprints (Botsman, R. and Rogers, R., 2010)**
2. **Circular Economy Models: Companies like Patagonia, through their Worn Wear program, encourage the recycling and resale of used clothing, extending the lifecycle of products and reducing waste. This model challenges the traditional linear economy of "take-make-dispose" by keeping resources in use for as long as possible (Stahel, R, W., 2016).**
3. **Community-Supported Agriculture (CSA): CSA schemes where consumers buy shares of a farm's harvest in advance, directly support local agriculture, reduce food miles, and promote sustainable farming practices. This model fosters a**

closer connection between consumers and producers, encouraging more responsible consumption patterns (Feenstra, G., 1997).

4. **Sustainable Energy Cooperatives: Initiatives like the community wind farms in Denmark or solar cooperatives in Germany demonstrate how collective investment in renewable energy can provide sustainable alternatives to fossil fuels. These cooperatives empower communities, promote local energy independence, and contribute to the transition to a low-carbon economy (Walker, G. and Devine-Wright, P., 2008).**

5. **Zero-Waste Stores: Retail outlets that eliminate packaging and encourage customers to bring their own containers address the issue of waste generation at its source. By promoting bulk buying and sustainable packaging alternatives, these stores support waste reduction and raise awareness about the environmental impacts of packaging (Milios, L., 2017).**

6. **Digital Platforms for Sustainable Lifestyles: Apps and websites that offer information on sustainable living, such as how to reduce energy use, find local sustainable food sources, or promote upcycling and recycling, help spread knowledge and encourage sustainable behaviors among a wide audience (Hilty, M, L. et al., 2006).**

These examples demonstrate the diverse ways in which social innovation can facilitate the shift towards more SCP patterns. By challenging existing norms and practices, social innovations offer pathways for societies to transition towards sustainability. Therefore, the integration of design for sustainability (DfS) with a focus on SCP, underpinned by strategic social innovation, is vital for tackling the

multifaceted challenges of sustainability transitions and advancing towards a more sustainable and equitable world (Geels, W, F. et al., 2015).

1.1.1. Developed versus Emerging Economy

According to a comprehensive literature review by Wang, C. et al. (2019), the differences in SCP practices between developed and emerging economies are significant. Developed economies often lead in implementing SCP through advanced technological innovations, stringent environmental regulations, and high consumer awareness about sustainability. These economies have the financial and institutional capacity to invest in cleaner production technologies and promote eco-friendly consumption patterns. SCP policies in developed countries are usually integrated into broader sustainability and green economy strategies, focusing on reducing environmental impacts, enhancing resource efficiency, and fostering sustainable lifestyles among affluent populations.

On the other hand, emerging economies face different challenges and priorities. In emerging economies, SCP practices are shaped by the urgent need to balance economic growth with environmental sustainability and social inclusiveness. These economies face the dual challenge of addressing current environmental degradation while preventing future unsustainable practices as they industrialize and urbanize. Emerging markets are characterized by rapid urbanization, which presents both challenges and opportunities for SCP. Urban centers in these countries are exploring innovative SCP solutions in areas such as waste management, sustainable mobility, and energy efficiency, often leapfrogging to sustainable technologies. The implementation of SCP in emerging economies often involves bottom-

up efforts, focusing on small and medium enterprises (SMEs), informal sectors, and community-based initiatives. There is a growing emphasis on local solutions, traditional knowledge, and the involvement of local stakeholders in designing and implementing SCP practices.

Thus, at the Sustainability and Social Innovation (SSI) lab at the Department of Design of IIT Guwahati, we are driving sustainability through social innovation for SCP for our unique socio-economic circumstances. In this guest editorial, we will present some of the innovative work that we have been conducting in the domain of sustainability and social innovation. Our work is geared towards the specific needs of emerging economies like India, where the challenges of sustainability are intertwined with issues of social equity and economic development.

1.2. Exploring Sustainability through Social Innovation at SSI Lab

The SSI Lab was set up at the Department of Design in 2015 with the aim to foster sustainability across the three foundational pillars of sustainability: social, economic, and environmental. Myself and my colleagues Prof. Ravi Mokashi Punekar and Dr. Pankaj Upadhyay, together conceptualized the lab. We were funded by an Erasmus+ project and joined the international group of labs called Learning and Education Network in Sustainability (LeNS) in 2017 (LeNS-International., 2018) to further expand our research and collaborations.

Our initiative is aligned with the SCP's emphasis on integrating sustainability into consumption and production patterns, focusing on

both the end-use of products and services and their lifecycle impacts. The SSI Lab aims to serve as a hub for research and development in DfS, thereby contributing to the broader agenda of SCP by addressing the intricate balance between meeting human needs and ensuring the ecological integrity of our planet.

The objectives of the lab are multifaceted and designed to create a significant impact in the field of sustainability:

1. Infrastructure and Guidance for Student Projects: By offering the necessary infrastructure and expert guidance, the lab supports student projects that are aligned with DfS principles. This effort is crucial for nurturing a new generation of designers who are well-versed in sustainability challenges and solutions.

2. Training for Local Institutions and Bodies: The lab conducts training sessions aimed at disseminating knowledge and skills related to DfS among local institutions and bodies. This initiative is instrumental in building local capacity to implement sustainable practices across various sectors.

3. Research and Case Studies Development: Engaging in research related to DfS, Sustainable Frugal Design, and the development of case studies through project execution, the lab contributes to the academic and practical understanding of sustainability. These activities help in identifying and refining effective strategies for integrating sustainability into design practices.

4. Course Material Development: The creation of course materials related to DfS ensures that educational programs are

equipped to teach sustainability concepts effectively, preparing students to tackle future sustainability challenges.

5. Tools and Methodologies for DfS Implementation: Developing tools and methodologies tailored for the implementation of DfS in diverse contexts—including emerging, marginalized, and industrialized settings—is critical for the widespread adoption of sustainable design practices. This approach recognizes the need for context-specific solutions in achieving sustainability goals.

6. Forming Global Research Partnerships: The lab endeavors to establish collaborations with researchers worldwide to amalgamate diverse knowledge, methodologies, and insights. By doing so, it aims to cultivate a rich, global ecosystem that supports the development and dissemination of SCP interventions tailored to various local contexts. This global network facilitates the exchange of best practices and innovative solutions, ensuring that the pursuit of sustainability benefits from a broad spectrum of cultural, economic, and environmental perspectives.

7. Partnering with Local and Global Industries: Recognizing the critical role of industry in the transition towards sustainable practices, the SSI Lab seeks to forge partnerships with both local and global industries. The goal is to co-create SCP solutions that are specifically designed to meet the unique sustainability challenges and opportunities within different industrial sectors. These collaborations are pivotal in translating sustainability research into practical, scalable solutions that can be integrated into the core operations of industries, thereby driving systemic changes in production and consumption patterns.

In the following section and chapters, we showcase our industry collaborations that merge Design with Sustainability, illustrating the tangible impacts of our initiatives. Subsequently, we delve into our contributions to theoretical advancements in academia, elucidating their influence on SCP insights. These theoretical advancements are the result of our industry projects and PhD research. Additionally, we outline the innovative tools we have crafted to facilitate DfS across diverse contexts, enhancing practical application and effectiveness.

1.2.1. Sustainable Agricultural Mechanization

Sims, B. and Heney, J. (2017) describe sustainable, agricultural mechanization (SAM) "as mechanization that is economically feasible, environmentally sensitive and socially acceptable." Food and Agricultural Organization of the UN (FAO., 2016) describes SAM as: "Sustainable agricultural mechanization covers all levels of farming and processing technologies, from simple and basic hand tools to more sophisticated and motorized equipment. It eases and reduces hard labor, relieves labor shortages, improves productivity and timeliness of agricultural operations, improves the efficient use of resources, enhances market access and contributes to mitigating climate-related hazards. Sustainable mechanization considers technological, economic, social, environmental and cultural aspects when contributing to the sustainable development of the food and agricultural sector." Thus, it suggests that the farm mechanization design process should follow a system-oriented design approach that connects the "technical, economical and engineering aspects" of machinery design with the allied service ecosystem. The allied service ecosystem should contain "linkages and inter-dependencies with other sectors" which will together offer a holistic view of conducting agriculture.

At our lab we are committed to bridging this need for small farms of developing countries through development of SAM as well as theory (Banerjee, S. and Punekar, M, R., 2020)(Banerjee, S., 2021).

1.2.1.1. Redesign of Two-Wheel Power Tiller Based Bed Planter for Bangladesh - Empowering Bangladesh's Rural Farmers and Machine Manufacturers

This project was part of the 'Cereal Systems Initiative for South Asia – Mechanization and Irrigation' (CSISA-MI) funded by the USAID Mission in Bangladesh. It embodies a participatory design approach to achieve SCP. The social innovation that participatory approach brings to this scenario is the fact that a mechanization project gave farmers, machine operators as well as illiterate or semi-literate stakeholders a say in how to design a mechanization ecosystem. This project focused on the redesign of a two-wheeled power tiller-based Bed Planter and its associated ecosystem (training, manufacturing, distribution, pricing, etc.) suitable for low-income farmers in rural Bangladesh. It exemplifies how SCP principles can be interwoven with human-centered design methodologies. By actively involving the consumers comprised of the farmers, machine operators, and local service providers, and the producers comprised of the small-scale manufacturers in the design process, the project not only aimed to address the immediate technical and ergonomic challenges associated with agro-machinery but also sought to empower the local farming and manufacturing community in making more sustainable choices.

The participatory design process facilitated a deep dive into the needs, aspirations, and constraints of the stakeholders, ensuring that the solutions were not only technologically sound but also socio-

economically sustainable. Through semi-structured interviews, contextual inquiries, co-creation workshops, and mock training sessions, a comprehensive understanding of the local ecosystem was developed. This approach not only led to the design of a more effective and accessible Bed Planter but also strengthened the local manufacturing capabilities, creating employment opportunities and fostering a sense of ownership and empowerment among the rural farming communities.

The project highlights the critical role of participatory design in achieving SCP goals. By giving voice to the local farmers and stakeholders in the design process, the initiative demonstrates how tailored, scale-appropriate technological interventions can significantly enhance agricultural productivity and sustainability, marking a significant step forward in the journey towards sustainable rural development of a region. The key takeaway from this project is published at (Banerjee, S. and Punekar, M, R., 2020). The learnings from the project also resulted in development of a methodology and a set of guidelines for SAM of small farms of developing countries (Banerjee, S., 2021) and is detailed in the next sub-section. Figure 1 and 2 show the first prototype of the machine being tested in field and the CAD model respectively.

Fig. 1 First prototype being tested on field.

Fig. 2 CAD model of the bed planter attachment

1.2.1.2. G-SAM (Guidelines for Sustainable Agricultural Mechanization)

From the above-mentioned project and several other such projects (Sustainability-and-Social-Innovation-Lab., 2024), we concluded that for achieving SAM of small farms of developing countries, we need to connect social innovation, SCP and the three dimensions of sustainability in the following manner:

1. **Social Dimension: Improve the livelihoods and well-being of small-scale farmers by developing agricultural mechanization solutions that are not only accessible, affordable, and user-friendly but also aspirable. Thus, we need to bring in:**
    - **Inclusive Stakeholder Participation: Engaging a wide spectrum of stakeholders, including farmers, local service providers, and technical staff of the manufacturer, in the design process creates a socially inclusive platform, leading to machinery that is more squarely aligned to the needs and constraints of the end-users, thus promoting greater social equity in agricultural communities.**
    - **Empowerment through Local Manufacturing: Benefits such as fostering local skills through training programs and the creation of manufacturing guidebooks, supports community development and capacity building, enhancing social cohesion, providing local employment opportunities, easier access to customized machinery and cheaper and faster repairs and maintenance.**
    - **Empowering Illiterate and Semi-literate**

Stakeholders: By valuing all forms of knowledge and communication styles, the design process empowers these stakeholders, ensuring that their voices are heard and their needs as well as aspirations considered, reducing social disparities.

- **Training and Capacity Building**: The development of training programs as part of the machinery's service ecosystem builds local competencies and supports knowledge transfer, contributing to social sustainability by elevating skills and expertise within the community.
- **Training for Manufacturers' Workers**: Ensuring that local workers are trained adheres to the principles of decent work and human rights, contributing to a more equitable society.

Economic Dimension: Ensure that the adoption of agricultural mechanization is financially viable for small-scale farmers and contributes to their economic prosperity through:

- **Sustainable Product-Service Systems**: The focus on designing PSS rather than standalone products suggests an innovation in business models where services (such as machinery leasing) are offered in conjunction with products. This can reduce the economic burden on individual farmers, increase access to advanced technology, generate employment and promote more efficient use of resources, aiding economic sustainability.
- **Improving Livelihoods**: Designing machinery that is cost-effective and increases agricultural productivity directly

influences the economic well-being of farmers by potentially increasing their income, hence contributing to economic sustainability.

- **Economic Empowerment**: Establishing local manufacturing capabilities for precision components of agricultural machinery can stimulate local economies, reduce repair times, decrease costs, and create jobs, thereby improving the overall economic well-being of communities.
- **Logistics and Inventory Planning**: These elements suggest the development of new systems for efficient resource management, which can have knock-on economic benefits by reducing waste and optimizing production and service provision.

3. **Environmental Dimension**: Ensure the conservation of natural resources, reduction of environmental degradation, and promotion of sustainable farming practices by incorporating the following elements into our design process:

- **Positive Agronomic Impact**: By examining the impact of machinery on soil, water, and biodiversity, and optimizing for sustainability, the design supports environmental stewardship and resource conservation, directly benefiting the environmental sustainability of the service ecosystem. Both short and long-term benefit needs to be taken into account.
- **Lifecycle Assessment Approaches**: Incorporating assessments that consider the full lifecycle of the machinery ensures that environmental considerations are factored into

design decisions, which can result in reduced ecological footprints of agricultural practices.

- **Sustainability Assessment through Checklist:** Designers need easy to use tools which can help evaluate the environmental impacts of machinery across its lifecycle. LCA using databases requires higher amount of data and expertise, which is missing in the context of small farms of developing countries. Checklist based assessment can promote the creation of machinery that is more resource-efficient, generate less waste, and reduce negative ecological impacts, while being simpler to implement in low resource contexts.
- **Visual Tools for Conceptualization:** SAM needs multiple stakeholders to be able to together visualize a large number of factors and their complex interactions, like that between agricultural practices and environmental impacts, fostering more responsible decision-making and awareness regarding environmental conservation. Using visual tools can aid stakeholders in doing these tasks and conceptualizing for SAM.

A multi-stakeholder approach to social innovation leverages the interconnectedness of social, economic, and environmental dimension of sustainability. In the broad service ecosystem associated with agricultural machinery, one needs to integrate the following:

- **Extension Services Providers:** Those who provide training and support to farmers on the use of machinery contribute to social sustainability through capacity building and educational initiatives.

- **Local Supply Chains:** Developing a local supply chain for components and maintenance can drive economic sustainability by keeping more financial resources within the community.
- **Policy Makers:** Their role in creating conducive environments for sustainable practices, like providing subsidies or tax incentives for sustainability-oriented agricultural machinery, plays into economic sustainability.
- **NGOs and Community Organizations:** These groups often fill gaps in education, training, and social welfare, contributing to the social dimension by ensuring equitable access to resources and support structures.
- **Environmental Regulators:** They are essential for ensuring that environmental concerns are integrated into the design and deployment of agricultural machinery, thereby shaping environmental sustainability within the service ecosystem.

By intertwining social innovation with sustainability, our research emphasizes the need to design not just for technical efficiency but for comprehensive sustainability that respects and enhances the social fabric, economy, and environment of agricultural communities. Thus, we developed a tool called G-SAM (Guidelines for Sustainable Agricultural Mechanization) (Table 1), which provides a framework for incorporating sustainability principles into the assessment, design, development, and implementation of SAM (Banerjee, S., 2021,

pp 101-122). Figure 3 shows how G-SAM guidelines show up to aid in assessment.

Table 1. Structure of G-SAM

Dimension	Criterion	Impact Category
Environmental Dimension	**System Life Optimization**	**Soil**
		Water
		Biodiversity
		Productivity
		Agricultural Machine Characteristics
		Service Level
		System Level
	Optimization of Resource Management	**Soil**
		Water
		Material Cycles
		Agricultural Machine Characteristics
		Service Level
		System Level
	Transportation/ Distribution Reduction	**Agricultural Machine Characteristics**
		Service Level
		System Level
	Waste minimization/ Valorization priority	**Material Cycles**
		Waste
		Agricultural Machine Characteristics
		Service Level
		System Level
	Conservation/ Biocompatibility	**Water**
		Energy
		Agricultural Machine Characteristics
		Service Level
		System Level
		Soil
		Energy
		Air
		Waste
		Agricultural Machine Characteristics
		Service Level
		System Level
Economic Dimension	**Market position and competitiveness**	**Agricultural Machine Characteristics Service Level System Level**
	Profitability or added value for companies	
	Added value for customers	

	Long-term business development or risk	
	Partnership or Co-operation	
	Macroeconomic effect	
Social Dimension	Empower or valorize, local resources	Agricultural Machine Characteristics Service Level System Level
	Improve social cohesion	
	Favor or integrate, weaker and marginal strata	
	Enable a responsible and sustainable consumption	
	Improve equity and justice in relation to stakeholders	
	Improve employment and working conditions	

Fig. 3 Screenshot of the G-SAM assessment page.

Building upon the holistic framework established for SAM, we next delved into exploring the application of similar principles within a broader socio-economic context, the revitalization of local production practices through the lens of social innovation and design. The next section delves into the nuanced challenges and opportunities presented by the need for resurrection of "Making" practices amongst people of developing economies like India. It is crucial for fostering environmental stewardship, cultural preservation, and economic viability, especially in rural and semi-urban areas of emerging economies.

1.2.2. Design for Motivation to Facilitate the Adoption of Assisted Self-Production in Emerging Economies

The revival of “Making” practices in emerging economies, particularly within rural and semi-urban contexts, presents a significant opportunity for addressing a multitude of sustainability challenges (Pattnaik, K, B. and Dhal, D., 2015). These challenges range from labor migration and environmental pollution to the loss of cultural heritage and the consequences of unsustainable urbanization. Our PhD scholar, Ms. Prarthana Majumdar, in her thesis, defines the concept of “Assisted Self-Production” (ASP) to articulate the Making practices in the Emerging Economies. She argues that it is a pivotal strategy, aiming to rekindle local production practices that are environment-friendly, culturally relevant, and economically viable. This approach not only supports SCP goals but also aligns with the broader aspirations of social innovation. (Majumdar et. al, 2019).

Social innovation, in this context, refers to the creative and community-driven solutions to societal problems, often leveraging local knowledge, materials, and traditions. ASP acts as a vehicle for social innovation by enabling communities to harness their intrinsic resourcefulness, creativity, and entrepreneurial spirit. This is particularly relevant in the backdrop of the historical trajectory of consumerism in countries like India, where colonial legacies and subsequent economic liberalization have shaped unique consumption and production patterns.

In her thesis she further argues that due to the current wave of consumerism and Indian education system, the youth are moving away from Making. The move is happening as they don't find any intrinsic motivation in the process of Making. Thus, she explores how Design can play a role in bridging the gap between the potential of ASP and its adoption within communities. In her research, she outlined the importance of design in motivating and facilitating the uptake of ASP practices, especially among the youth. Her study explores how design can be employed to embed intrinsic motivations into products and product service systems (PSS) that resonate with the target communities and motivate them to re-adopt Making (Figure 4). This approach is grounded in the understanding that sustainable behaviors are more likely to be adopted and sustained when they are intrinsically motivated.

The framework she developed, named "Catalyst: Design for Motivation to Induce Behavior Change," emphasizes the psychological components of behavior change, specifically focusing on motivation (Figure 5). By adopting theories like Ryan and Deci's Self-Determination Theory and Csikszentmihalyi's Flow Theory, the framework guides designers in creating products and PSS that are not only appealing but also meaningful to the target audience. The methodology encourages designers to delve deep into the community's perceptions of competence, autonomy, and relatedness needs, using these insights to craft designs that are slightly more challenging than the users' current skill levels, thereby engaging them in a process of learning and mastery.

Using the Catalyst framework, expert as well as novice designers designed Making tools and workshops for school children. The designers found her framework very useful and effective for designing

products with motivation embedded in it. We tested these tools and workshops with school children and found them to be very effective in motivating the teenagers in making with their hands and engaging in creative activities. The teenagers kept challenging themselves into going beyond what was asked them to achieve in the workshop.

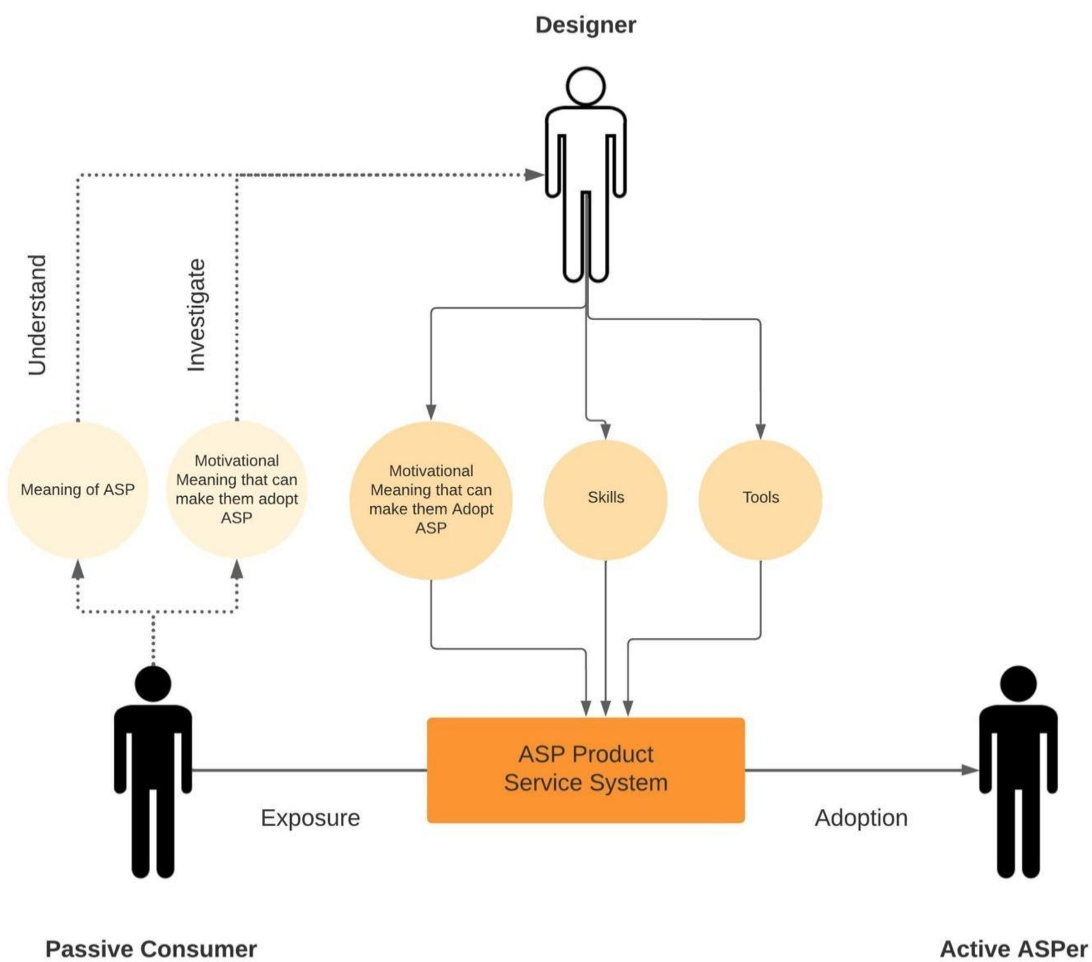

Fig. 4 Schematic showing the pathway of behavior change induced by providing new meaning to an ASP practice and considering the skills and materialities of the practice.

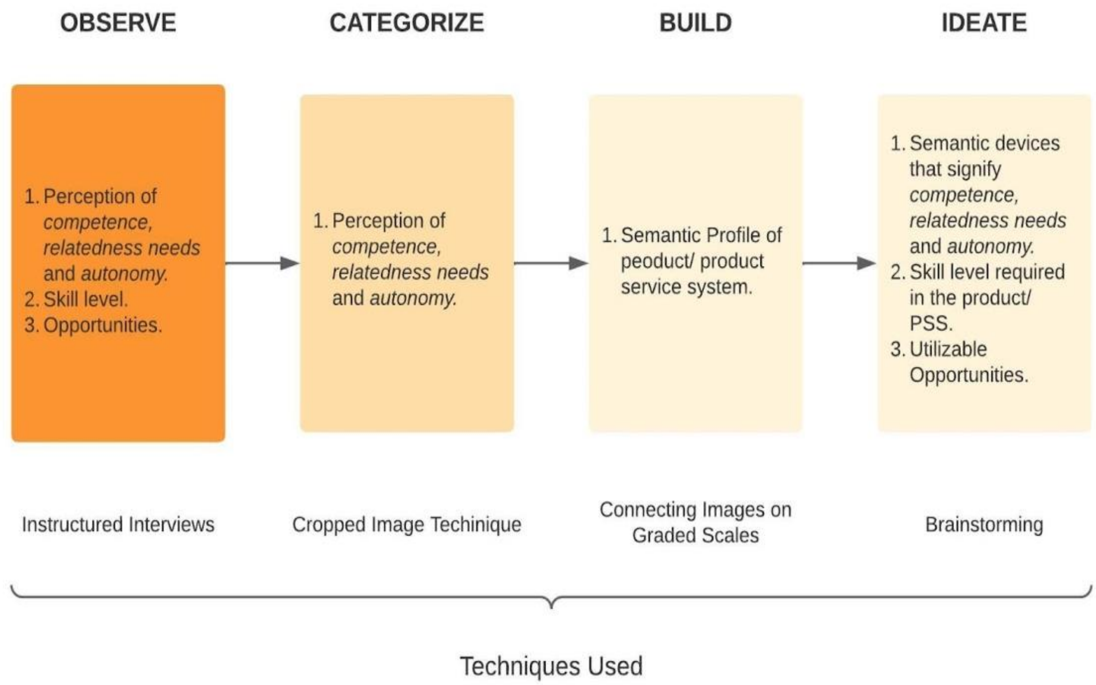

Fig. 5 The steps of the framework that aids designers in understanding motivations and embedding them in products/ PSS.

1.2.3. Bringing Social Innovation, SCP, and Design Together: Reimagining Craft Education

Mr. Shivram Kumar, yet another PhD scholar at SSI Lab is looking at Making from a different angle. His research started with the question, what happens once one has decided to adopt Making for a living or in other words has decided to enter the crafts sector? How is the craft education in India? Is it in tune with todays needs and realities?

Craft has always been an integral part of the cultural heritage and economic asset of various regions in India. Traditionally, handicrafts emerged as utilitarian products catering to local markets, and they carry the identity of the people who create them. However, in today's India, the craft sector is facing a challenge as the teaching-learning

methods of the past are not aligned with the needs of the current generation. This has led to a lack of adequate preparation among the younger generations to see craft as a potential means of earning their livelihood.

Craft education in India needs to evolve to meet the demands of the modern world. It should integrate traditional techniques with contemporary design and marketing approaches. The focus should be on equipping the younger generation with the skills and knowledge required to thrive in the craft sector and make it a sustainable source of livelihood. This transformation in craft education will not only preserve the cultural heritage and identity but also contribute to the economic development of the regions.

In order to address this pressing issue, Mr. Shivram Kumar's research is exploring the current state of craft education in India and its alignment with the present needs and realities. The aim is to reimagine the craft education system that can effectively prepare and motivate the younger generations to pursue careers in the craft sector. By combining social innovation, sustainable consumption and production, and design thinking, the research seeks to overhaul the existing craft education framework and make it more relevant and appealing to today's youth.

His research looks at craft education as a pedagogy-andragogy-heutagogy continuum as described below in Table 2.

Table 2. Craft education as a pedagogy-andragogy-heutagogy continuum.

Aspect	Pedagogy	Andragogy	Heutagogy
Definition	The art and science of teaching children.	The practice of teaching adults.	Self-determined learning.
Learner Role	Passive recipients of knowledge.	Active and self-directed.	Highly autonomous and self-determined.
Teacher Role	Authoritative figure, primary source of knowledge.	Facilitator of learning.	Mentor or facilitator provides support.
Learning Focus	Curriculum-based, standardized objectives.	Problem-centered, relevance to life.	Development of learner capability, critical thinking.
Approach	Didactic, structured lessons.	Flexible, responsive to individual needs.	Encourages exploration, inquiry, creation of knowledge.
Contextual Example	Basic Craft Skills: Introducing young or new learners to fundamental craft techniques and safety procedures. Ideal for foundational skills that require initial direct instruction and close supervision.	Intermediate Craft Skills: Suitable for adults with some experience or knowledge, focusing on improving skills and learning new techniques. Emphasizes practical application and problem-solving within craft projects.	Advanced Craftsmanship: Ideal for experienced craftsmen pursuing mastery or innovation within their craft. Encourages self-directed projects, research, and development of new methods or designs.

From SAM to local production had been an amazing journey for us and then we decided to broaden our perspective, extending into the critical area of disaster resilience through Disaster Risk Management

(DRM). Now, in Section 2.4, we explore how Design for Sustainability (DfS) in Disaster Risk Management (DRM) incorporates these overarching principles to create resilient infrastructures and communities capable of withstanding, adapting to, and recovering from disasters. This section underscores the critical importance of integrating environmental, economic, and social dimensions into DRM, thereby not just responding to disasters but proactively enhancing community resilience. Through the lens of Community-based Disaster Risk Management (CBDRM), we see the embodiment of participatory action research methodologies, which emphasize local knowledge and engagement in disaster preparedness activities.

1.2.4. Design for Sustainability in Disaster Risk Management

DfS studies are increasingly recognized for their critical importance in the context of DRM, offering a holistic approach that integrates environmental, economic, and social dimensions into the design and development of resilient infrastructure and communities. DfS emphasizes the creation of systems, processes, and products that not only meet current needs without compromising the ability of future generations to meet theirs but also enhance the capacity to withstand, adapt to, and recover from disasters. Realizing the importance of this synergy, I have joined the Centre for Disaster Management and Research (CDMR) at IIT Guwahati.

As part of this new role, we at SSI Lab have initiated research in CBDRM. CBDRM is a participatory approach that engages communities in disaster risk reduction (DRR) activities. This approach is rooted in participatory action research methodologies, enabling communities to identify and mitigate their own vulnerabilities. (Sim, T., Dominelli, L.

and Lau, J., 2017). The Sendai Framework for Disaster Risk Reduction 2015-2030 underscores the significance of CBDRM, advocating for multi-sectoral engagement in Disaster Risk Reduction (DRR) (Sim, T., Dominelli, L. and Lau, J., 2017)(Aitsi-Selmi, A. et al., 2015).

We currently have two PhD scholars working on CBDRM. Ms. Aradhna Moktan is focusing on how CBDRM can be integrated within sustainable settlement design frameworks. The aim of this research is to develop an interdisciplinary, integrated framework that explicitly connects principles of CBDRM with sustainable settlement design. Integrating CBDRM principles into settlement design ensures that communities are better prepared for, can more effectively respond to, and recover from disasters quicker. This approach leverages local knowledge and engagement in disaster preparedness activities, thereby enhancing the resilience of communities to withstand adverse events. The development of such a framework can guide policymakers and planners in integrating disaster risk reduction and sustainability principles into urban and rural development plans. This can lead to more coherent and effective policies that address the interconnected issues of disaster risk, environmental sustainability, and community well-being. The figure 6 shows the pillars for effective and sustainable CBDRM which can be incorporated into various aspects of sustainable settlement design.

Another PhD scholar, Mr. Pankaj Kavidayal, who is also 2nd in Command, 1st Battalion, National Disaster Response Force (NDRF), Assam, is exploring the role of women in CBDRM. His research aims to understand the unique contributions and challenges faced by women in disaster risk reduction processes in North-east India which is prone to several natural disasters from earthquakes, landslides, cloud bursts to annual floods. The region is also inhabited by

communities from several ethnic backgrounds who have their own cultural practices and social dynamics. (J. Moreno and D. Shaw, 2018) Research emphasizes the unique position of women in disaster scenarios, where they can be both victims and critical agents of change. Studies indicate that women's involvement in disaster preparedness and response can significantly enhance community resilience and recovery. The North-Eastern region's vulnerability to natural disasters is compounded by its complex socio-political landscape, with issues ranging from ethnic conflicts to inadequate infrastructure. This complexity necessitates a nuanced approach to DRM that incorporates the perspectives and needs of women. Also states like Meghalaya, Manipur, and Mizoram show lesser degrees of gender inequality, which could influence DRM is certain way. Hence, the topic attracted our curiosity.

Fig. 6 Pillars for effective and sustainable CBDRM

In Sections 2.1 through 2.4, we have traversed a comprehensive landscape that outlines a blueprint for sustainable development across various domains—from SAM and ASP to the reimagining of craft education and integrating DfS into DRM. Each of these sections, in its own right, underscores the necessity of adopting a holistic approach that harmonizes technological advancements with traditional knowledge and participatory design to address the multifaceted challenges of our time. Section 2.5, on the other hand, introduces a critical dimension to our sustainable development discourse: Enhancing Product Sustainability through Disassembly-Oriented Design and End-of-Life Management. This section underscores the imperative of incorporating considerations for the end of life (EoL) of products right from the design phase, aligning with the principles of a circular economy.

1.2.5. Enhancing Product Sustainability through Disassembly-Oriented Design and End-of-Life Management

Product designers can create sustainable products, reduce waste, and decrease costs associated with disposal by considering factors such as the ease of disassembly, the use of environment-friendly materials, and the ability to reuse or recycle components. End of life (EoL) options for a product include landfilling, incineration, recycling, composting, repurposing, and remanufacturing. Disassembly is an important EoL option for products, especially those with hazardous materials or components that are difficult to recycle or dispose of. However, disassembly can be challenging, as products are often not designed with disassembly in mind, making the process time-consuming and labour-intensive.

Incorporating disassembly into the product embodiment design process is critical for ensuring optimal EoL performance and reducing the environmental impact of products. It also aids in creating circular economy-oriented products that maximize the potential for material reuse and recycling to minimize environmental impact.

We created a methodology termed Design for Optimal End-of-Life Performance (DfOEP), which mandates that during the embodiment design phase, product designers must account for a product's environmental footprint at its EoL. Essentially, this method encourages designers to expand their traditional focus on aesthetics, functionality, and production criteria to include considerations for the disposal or recycling of the product after its service life concludes. By implementing DfOEP principles during the product embodiment design phase, a company can create sustainable products, reduce waste, and decrease costs associated with disposal.

The novelty of the DfOEP analysis method developed by us are as follows:

1. ***We developed a comprehensive methodology for identifying a "Disassembly score" for a product which can be used to improve the embodiment design in an iterative manner.***
2. ***We created a graphical representation schema for presenting a product's disassembly sequences.***
3. ***We have developed a three-layered cost-benefit analysis methodology to optimise EoL performance, while considering three strategies: disassembly, recycling, and disposal, as well as the effect of the region where the EoL management and treatment is taking place. What sets our cost-benefit analysis apart is that it allows designers to choose which layer they would like to perform***

the analysis on. The layer of analysis can depend on the amount of time and EoL information available.

- ***In layer one, the designer can input the Design Bill of Materials (D-BoM), along with the material specification and weight, then select the disposal and recycling scenario, and segregate the product into sub-assemblies and components. Thereafter, a cost analysis (comparing labour cost versus scrap value) informs the designer about the profitability of the disassembly process. An analysis of the eco-cost of disposal versus recycling gives an idea of the best EoL strategy for each sub-assembly or component of the product.***
- ***In layer two, the designer can use the disassembly sequences already generated and perform a cost-benefit and eco-cost analysis per sequence to identify the most optimal and profitable sequences.***
- ***In the third layer, we propose an EoL Indexing method using a multi-criteria decision-making process called Analytical Hierarchical Process (AHP) to factor in various other factors that cannot be otherwise computed using an utility function. One such factor is the total cost of disposal, which can vary greatly depending on a number of factors, such as the time required to complete the process, the environmental impact created by the disposal (including factors such as air and water pollution, the release of greenhouse gases, and the impact on local ecosystems), and the value of the material being disposed of. In cases where the material has significant value or could be put to use in another way, the cost of disposal could potentially be offset by the revenue generated***

from recycling or repurposing the material. The EoL Index converts these multitude of factors into one index value, which helps in making appropriate decisions.

Applying these methodologies to various products, we achieved the following major outcomes:

- ***Disassembly architecture and sequence diagrams for the product***
- ***Disassembly score for the product***
- ***Key parts and subassemblies that could be redesigned based on the results***
- ***Alternate disassembly sequences***
- ***Cost-benefit analysis of the alternate disassembly sequences***
- ***Disassembly cost comparisons considering different regions***
- ***Recommended EoL strategies for disassembly and design of the product***

The analysis results can be used to redesign the product for better EoL impact. Moreover, the methodology used is robust and scalable, making it applicable to products from various industries. We have tested and validated our approach on a range of products, including electronic devices, automotive components, and household products. The DfOEP methodology is explained below in Figure 7-9.

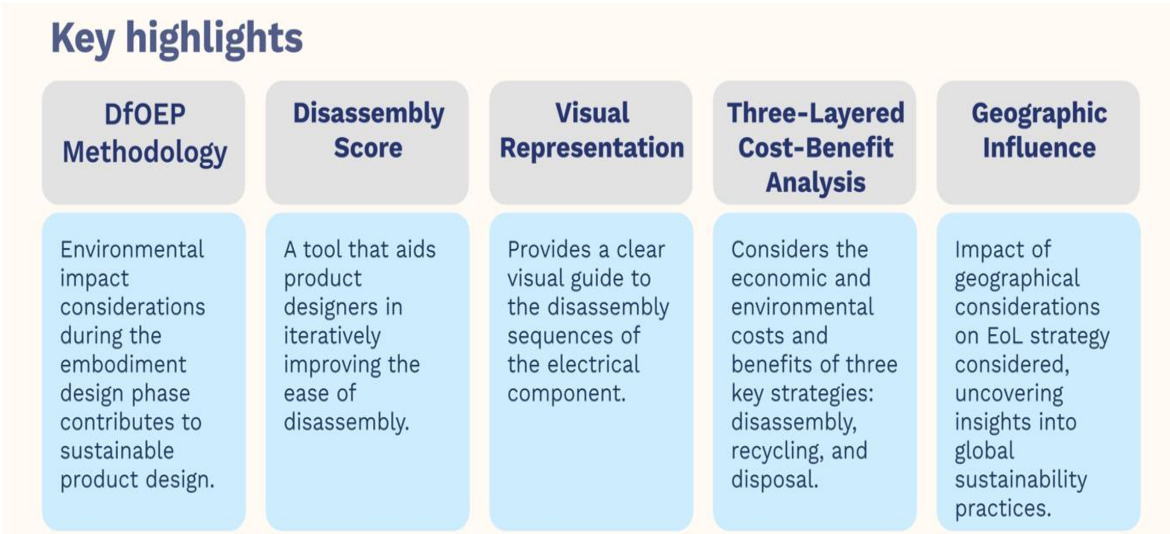

Fig. 7 Key highlights of the DfOEP methodology.

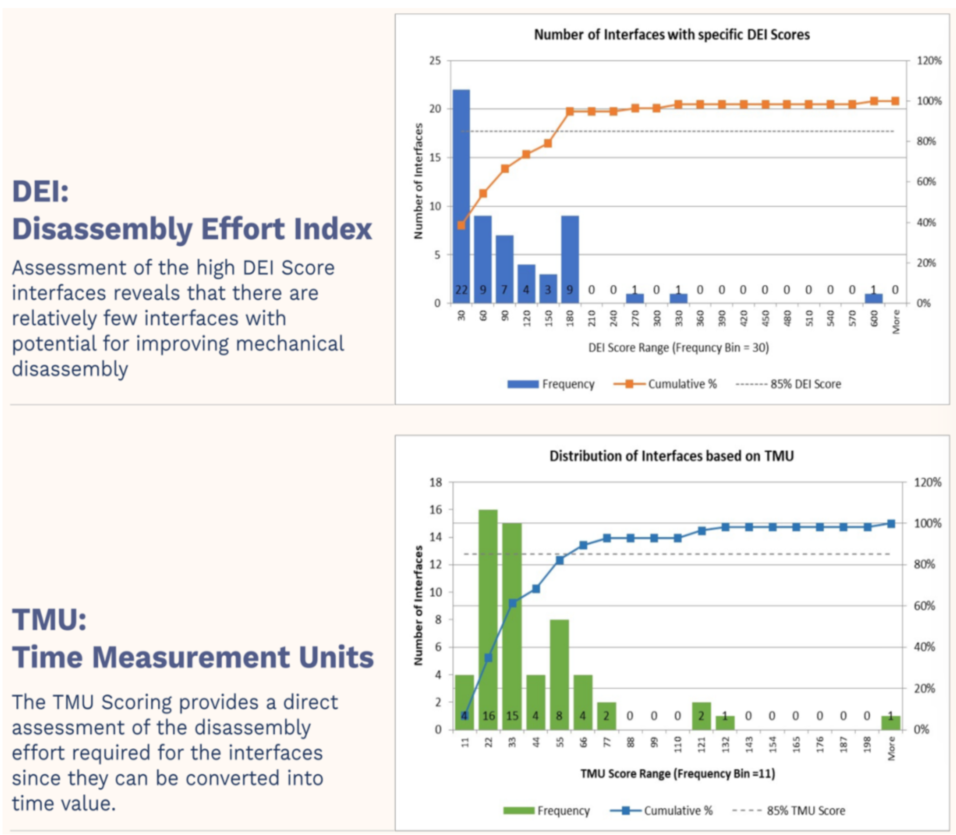

Fig. 8 Disassembly index graph generated using the DfOEP algorithm helps in iteratively improving the product's disassembly-ability. The TMU graph helps in strategizing the re-design focus for a product so that overall the disassembly time can go down.

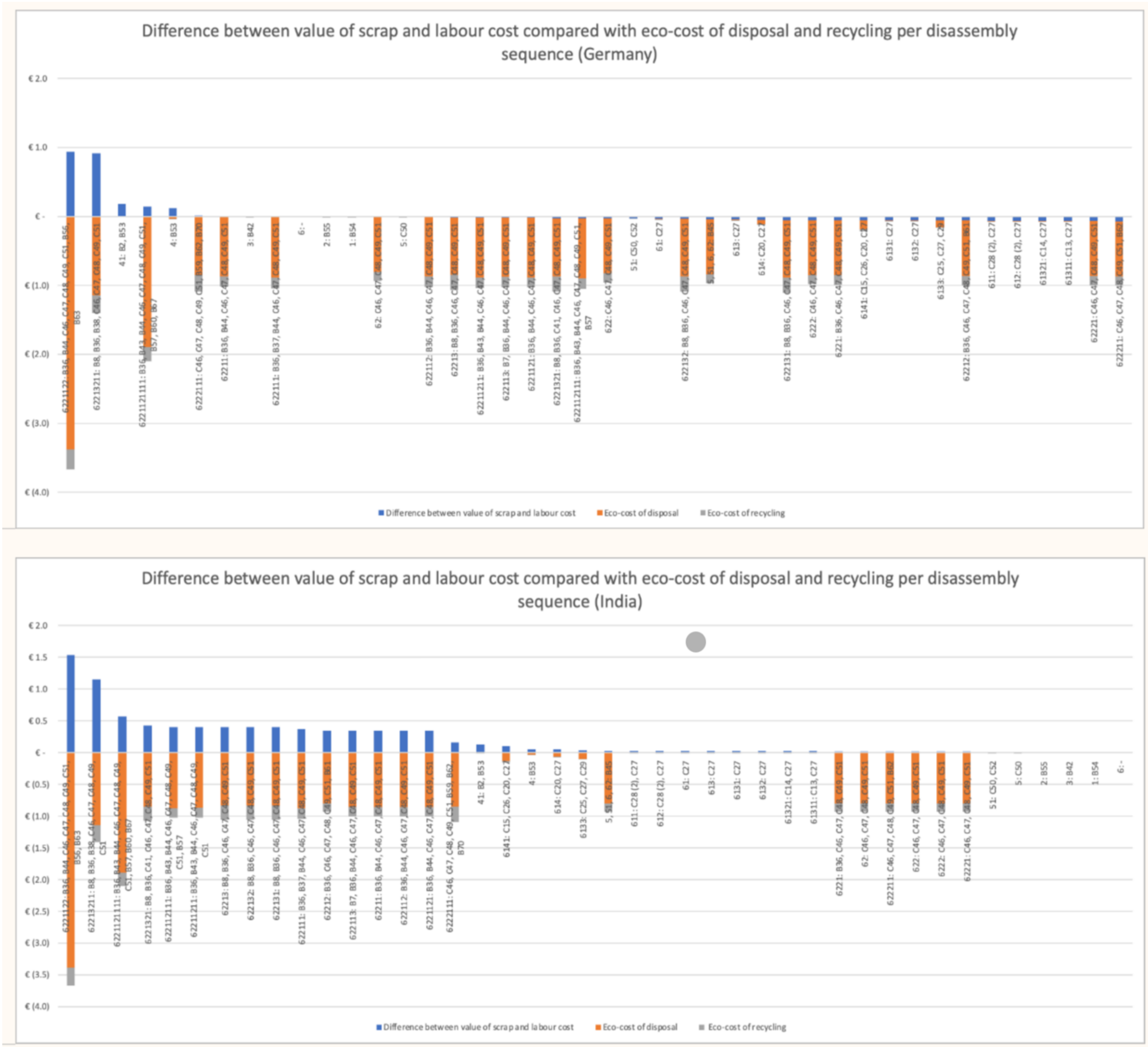

Fig. 9 Graphs plotted using DfOEP algorithm comparing the difference between scrap value and labour cost of disassembly, eco-cost of disposal and recycling for different geographies.

1.2.6. The Role of Our Research in Sustainability

In conclusion, our research at the SSI Lab plays a pivotal role in addressing the complex challenges of sustainable development. By bridging the gap between traditional practices and modern sustainability needs, we are not only contributing to the academic discourse but also providing practical, actionable solutions that have

a tangible impact on communities, industries, and ecosystems. Our focus on social innovation, sustainable agricultural mechanization, assisted self-production, craft education, disaster risk management, and disassembly-oriented design underscores our commitment to an integrated approach to sustainability that encompasses social, economic, and environmental dimensions.

Our work exemplifies how innovative practices and collaborative efforts can lead to significant advancements in sustainable consumption and production (SCP). Through participatory design, community engagement, and the development of inclusive, scalable models, we are empowering communities, influencing policy, and fostering a culture of sustainability that resonates with diverse stakeholders. Our research not only contributes to the theoretical underpinnings of SCP but also demonstrates the transformative potential of social innovation in creating sustainable futures.

The SSI Lab's endeavors highlight the necessity of interdisciplinary collaboration and the importance of contextual, culturally sensitive approaches to sustainability. As we continue to explore, innovate, and implement, our research serves as a beacon for sustainable development, inspiring others to join in the collective effort to build a more sustainable, equitable, and resilient world. Through our work, we underscore the critical role of academia in driving social change and contributing to the global sustainability agenda.

The subsequent chapters in this issue present the work our researchers are doing to tackle pressing sustainability challenges.

Join us in this exciting journey!

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