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Regenerative by codesign: An innovation design framework for Operations and Supply chains transformation, just equitable sustainability

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Abstract. The purpose of this paper is to explore the results of the Sustainable Circular Transformation (SCT) framework used to study *How to transition to regenerative Operations and Supply Chains (O&SC) for just equitable sustainability?* This is done via two in-person workshops which employed reflection on the codesign process and methods. The codesign method was found to foster collaborative engagement and energised coproduction, critical reflection, dialogue and innovative insights. The SCT design considerations were found to have strong relevancy and usefulness, for the O&SC community, including academics and industrialists interested in regenerative manufacturing. Contributions include a step-by-step description on how to facilitate this type of interactive workshop, the results are summarised in terms of the design process and codesign methods which can be used to benefit O&SC as well as sector specific investigations, through engaging working groups, leadership and broader for employee education purposes.

Keywords: Sustainable Circular Transformation framework, codesign, co-creation, regenerative manufacturing, systems, operations and supply chains.

1 Introduction

This paper focuses on the application of the Sustainable Circular Transformation (SCT) framework proposed by [1], in which 12 interwoven systems design characteristics are argued to be fundamental to regenerative systems' transition for outcomes of just equitable sustainability and clustered under the four categories: 1) Meta: Systems level change over the long term, visions and values for sustainable circular society, Nuanced policy, adaptive mindsets; 2) Social: Education-learning new skills and acquisition of knowledge, access to information, progressive technology development and sustainable consumption (mindset); 3) Economic: new and diverse economies, equity and equality, sustainable production (mindset); 4) Natural environment: Sustainable production (industrial model).

In SCT, an important role is played by each cluster and its design considerations, which together represent ways of fulfilling sub-systems and strengthens the overall systems transformational capabilities, its impact and values in a particular context. It is the natural environment cluster represented by the change in sustainable production and conceptually represented by the Circular Economy (CE)’s three key R strategies, reduce, reuse and recycle, which can be expanded to include the 10 Rs [2] altering the interconnected social-business-nature relationship and disrupting an entire place-based system.

Furthermore, despite the importance of transformational CE concepts and theories, as needed to guide regenerative manufacturing and design, they are not easily adapted for practical applications and implementation [3, 4]. Practical design action frames, which reframe the issue-response space for regenerative processes and outcomes of sustainability, are lacking although urgently needed for manufacturing to collaboratively codesign and meet new research agendas. A reframe of the issue-response space can help guide and inspire a research process, enable abductive reasoning, reflection and evaluation through processes of change [5, 6] leading to innovative practical manufacturing outcomes.

In this paper, regenerative manufacturing is defined as: “a systemic transformation which improves the well-being of the human and non-human stakeholders in the operations and supply chain”, which is in line with previous researchers [7]. Regenerative manufacturing is a core component of regenerative systems transformation and represents the change in an industrial model for futures of sustainability, regenerative pathways, changes in the human-nature relationship and designing for more than human. Regenerative manufacturing is core to achieving regenerative Operations and Supply Chains (O&SC).

To achieve manufacturing that optimises the human-nature relationship [8] for the wellbeing of humans and non-humans we focus on the SCT framework as proposed by [1] with 12 design considerations.

These interwoven characteristics associated with the realisation of a systemic regenerative transformation [9] are designed to combat climate change, regenerate society and nature, serve more than human life, and promote futures of sustainability [10, 11].

This paper presents the results of two in-person codesign workshops and their design process [12, 13] to address the urgent need for regenerative manufacturing and its design. Participants collectively explore the opportunities and challenges presented by the SCT framework and its relevance and usefulness for the manufacturing and design communities interested in regenerative systems transformation and its implementation. The research question addressed in this paper is: *How to transition to regenerative Operations and Supply Chains (O&SC) for just equitable sustainability?*

2 Literature Review

2.1 Sustainable circular transformation framework (SCT)

SCT was proposed by [1] as an approach which can be used to reframe [5] the systemic regenerative transformation of societies, as spurred by the CE for futures of just equitable sustainability. This SCT theory adopts a balanced systems approach, as advocated for the CE [14], which is necessary to accelerate the systems shift [15], enhance people's well-being, and restore the natural environment [1]. Previous CE approaches, such as the [16] butterfly, have limitations [17] that can slow down transformational progress, lead to more efficient practices and abandonment [18] rather than intentionally intervening to improve the well-being of humanity and nature [19]. The SCT framework aims to address these issues, it is composed of 12 interwoven design considerations, which are clustered into four categories.

Understanding theories helps participants grasp the dynamics of transitional systems [20]. While many CE transformational theories are not easily applicable in practice and generally focus on the technical aspects [3]. To address this issue, this paper explores the value and opportunities of a practical prototype SCT framework, its added value, and its potential impact within the manufacturing and design communities (see Figure 1).

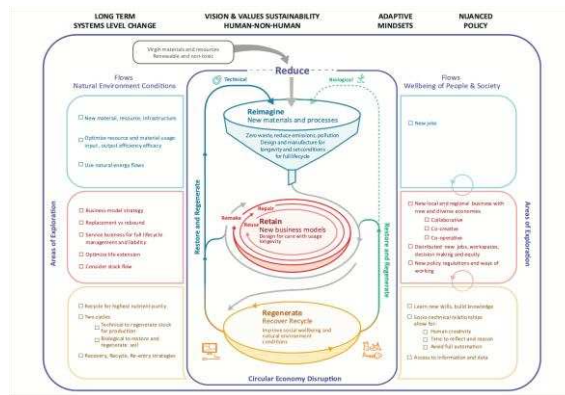


Fig. 1. Prototype SCT Framework, adapted from [21].

The CE presents a regenerative industrial approach [22] and this research has indicated that the SCT framework with an integrated CE has potential to guide systemic regenerative transformation. It is essential that manufacturing moves towards regenerative manufacturing and contributes to the broader systems shift which aims to tackle climate change and improve the wellbeing of human and non-human.

2.2 Codesign

Designing for regenerative manufacturing and real-world impact [23] challenges diverse stakeholders to rethink the interconnectedness of technological disruptions within the CE and their links to socio-economic, natural and political systems [24] with pluriversal outcomes [25]. To reshape manufacturing and design processes, it is essential to critically examine new relationships between people and nature, a more-than-human approach [26], thereby foregrounding core participatory design values [27]. These include outcomes that enable “deeper local impact”, based on everyday ways of being and doing, and that recognise the “socio-material and political engagements” [27]. The SCT aims to guide users to collaboratively explore these relationships through research and implementation.

This paper reflects on the SCT framework and employs codesign methods, recognises the critical contributions of participation and shared inquiry to the co-production of knowledge. The design process prioritises active democratic engagement among participants to question structures and content and to inspire direct first-person innovative dialogue [28]. A safe and trusted environment is created that supports participants in exploring the complex entanglements of systems transformations, for regenerative manufacturing and its design.

The key codesign method used in the workshop, “Unpredictable encounters”, draws on the collection of codesign methods [30]. Slight adaptations have been made to the original method to maximise independent, unbiased critical reflection and dialogue. This method has been used to meet the previously described codesign requirements and to enable rich exploration of the proposed framework among participants.

3 Methodology

Two 90-minute in-person codesign workshops were conducted with a total of 31 participants, comprising academics and industrialists, in January and March 2026. A codesign process, drawing from the principles of a double diamond [31] through exploratory creative expansion and contraction with codesign methods builds sequentially from individual reflections through to cocreation and coproduction.

There are four exercises which follow the introduction of an SCT framework: 1) individually participants identify sector relevancy; 2.1) Each participant to capture the SCT framework through a drawing and description in their own words and within their own environments on a card; 2.2) Cards shared as stimulus for collaborative dialogues and concept ranking; 3) Small group critical reflection, coproduction with focus on framework identification added value, impact opportunities and iteration; 4) Group feedback and open discussions. Participants generate data through exercises and data collection is facilitated by the researchers.

Analysis includes pattern identification and theme building. Exercise 1: Count number of relevant sectors and their diversity. Exercise 2: Identify the forms of perceived usability, while Exercises 3 and 4 used deductive content analysis to deepen, strengthen theme understandings (guided by SCT 12 design considerations). The research was conducted and synthesised by two researchers. Workshops’ characteristics

and participants are summarised in Table 1. Academics were O&SC Professors, post-docs, research associates, PhD students at different UK and overseas Universities. Industrialists were managers at major UK/Europe and global manufacturers – directors of innovation and board members.

Table 1. Workshops' characteristics and participants.

Location	Date	Participants
Workshop 1: UK rural location.	13/01/2026	19 academics and 6 industrialists, sub-total: 25
Workshop 2: European Business school.	17/03/2026	6 academics
		Total: 31

4 Results

During the workshops, it was found that there were also advantages in the chosen codesign methods. A summary of the codesign process by sequential exercises is given in Table 2. The prototype framework built on the 12 design considerations was found to be relevant to eight sectoral groupings (Figure 2, left). This demonstrates that the framework is expected to be relevant to a broad set of sectors. Further research is required to identify the contributions to each sector. Example of four cards (Figure 2, right) demonstrates the ability of participants to describe the SCT framework, composed of 12 design considerations, through image and text, noting that the levels of interpretation are viewed through specific sector examples, business mindset evolution, and broader European policy making.

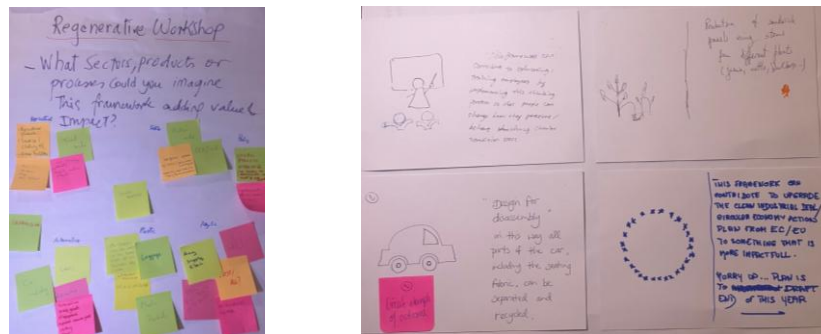


Fig. 2. Examples of the sectors (left) and cards (right) proposed by the participants which the SCT framework could add value and impact.

Table 2. Summary of the design process.

Stakeholder	Production	Ex. No.	Questions for participants	Results	Details	Levels of engagement
Individual	Material contribution for codesign, coproduction.	1	What sectors, products or processes could you imagine this framework adding value and impact?	Eight sector groupings (Fig. 2, left)	Agriculture; Textile, Policy, Plastics, Shipbuilding, Automotive, Design, Supply chains.	High relevancy associated with participants situated experience.
		2.1	How can you describe this framework using an image and text (systems format)?	Each participant produced a card with an image and systems description	Examples of cards (Fig. 2, right).	Strategic reflection level: weaving local experience and strategic impact.
Co-production	Music starts then after a few minutes it stops: Serial multiple dynamic spontaneous dialogue and card content ranking in pairs. Small groups (typically, 5-6 people per group).	2.2	Reflect, review and discuss: Score the system description.	Distribution of ratings: mode at 4. Most popular responses for scores between 3 and 4.	Cluster scores per category, e.g.: 1-2, 3-4, and 5.	Fast, energised, critical reflections, develop broader, deeper perspectives, further questions.
		3-4	Identify added value and impact opportunities.	Implementation clarity among experienced innovators: More explanation with examples can benefit junior participants	Key added value: Leadership, product working groups, manufacturing, Education, people and society, visualization: simple for everyone. Opportunity: storytelling; examples-policy in cities, operationalise.	High energy coproduction. Areas identified for framework iteration and explanation.

5 Discussion: Reflections on the design process

This paper addressed: *How to transition to regenerative Operations and Supply Chains (O&SC) for just equitable sustainability?* The following points highlight the outcomes from the codesign process:

- Multiple sector application: The individual reflection on the applicability of the SCT framework revealed that each participant could imagine using it for their own purpose and could identify its usage across multiple sectors. Addressing issues of theoretical complexity by providing a practical framework to guide implementation for regenerative pathways across a broad range of sectors [4].
- High relevancy: There was a clear indication that the SCT framework had relevance for participants sectoral regenerative transformation. It could be captured by each participant and described and drawn in their own words and within their own environments, be their sectors, nations, regions or hyper-local. Indication that it could be realised within participants own environments – localising it. In achieving this, meeting systems level change by integrating developments across multiple dimensions and aspects for sustainability practice [19]. Building on its relevancy and usefulness.
- The workshop format with the SCT framework acted to change the environment in which people act [32] which led to changes in behaviour. Participants were spurred on by the framework itself, which was found to use inspirational language, such as, “Reimagine”. Its language was integral to the workshop and transferred participants beyond the now to what might be. Respondents acknowledged that this made them feel different, with greater purpose and opportunity to contribute to what comes next. By accompanying it with activities that most participants infrequently engage with daily, such as drawing, translating frameworks to systems statements and building strategies in a fun setting with music, helped to build participants’ trust and their engagement in the environment, which led to further learning and development [29]. This setting met codesign principles for collaborative democratic coproduction in addressing the unpredictable complex issues of climate change albeit remote from the actual implementation [27,28], which led to:
 - Speedy collaborative, critical reflection: The application of the SCT framework led to depth and breadth of understanding, multiple perspectives and provided opportunities to share ideas: The sharing of descriptions and drawings in pairs, supported all participants to have a voice and to democratically contribute to the process, enabling both individually and as a group to dive deeper and broader into the application and its meanings. Both the drawing and the description helped support greater understanding in the framework and its implementation. This process inspired “Ah Has” moments, in terms of how it could be utilised. Demonstrating how the choice of design methods and the process together helped to unravel complex transformational theory often voiced as barriers for practical implementation and an emerging research field [4,26].

- Rich innovative dialogue: The ability to critically and independently reflect on the concept cards led to rich, inspiring and innovative discussions among each pair –the room was alive with participants dialogues, gesticulations and thoughts– which were then transferred into buoyant small groups for further development among another set of actors. The introduction of music as a way of incorporating movement and fun in the process helped the interactions to be more relaxed and less intimidating during the “unexpected encounters”.
- The SCT framework represents a unique approach with added value for industrialists and researchers: The ability to integrate the social, economic, natural environment and political aspects as bounded by a place-based system provided a valuable checklist, and an organisational method to think about the relationships between the socio-ecological-technical – materials – economics and political.
- Diverse representation of the SCT framework: The workshops provided fertile ground for participants to come up, contribute and share a range of representations from sector specific knowledge to improving policy making. Acting as a starter framework to develop specific sectors and develop proposals.

6 Conclusions

It was found that the design process and codesign methods among the O&SC community provided a rich, meaningful, democratic exploration of regenerative manufacturing as probed by the 12 SCT design considerations and their interactions. The design process quickly enabled the participants to dive deep and strategically, foster collaborative engagement, energised coproduction, inspiring innovative dialogue and insights with critical reflection into a systems transition to regenerative manufacturing. Among O&SC community, academic and industry representatives, there was a common interest in regeneration, sustainability and more than human futures, with the interwoven characteristics of social, economic, natural environment and political as proposed by the SCT framework. This framework design considerations were found to have strong relevancy and usefulness; and add value to current approaches with opportunity for improved impact across broader systems characteristics.

The implications of the application of the SCT framework for regenerative manufacturing research and practice are summarised as follows: (1) It contributes to and benefits the relationship between humanity and nature; (2) It raises awareness of connectivity for a systems shift – across the social economic natural environment and political; and (3) It is expected to benefit leadership, working groups, educating employees, and wider society. Furthermore, the codesign process enables a rapid introduction into an alternative framework to design for regenerative manufacturing.

The limitations of this study include: the relatively small sample of participants from two workshops, which were conducted among subject experts in the field of O&SC. The locations of both workshops were in Western Europe, and participants were mostly academics. So, there is potential for expansion of the application to other regions and participant types. Also, the focus was on O&SC community, further research could be expanded to other communities. Furthermore, specific sector domains

could be focused on, e.g. food, apparel, etc. with associated issues further discussed and explained. Further research is required on systems approaches and frameworks to guide innovation and design to enable regenerative systems transformation, whereby regenerative manufacturing is a core contributor to transformation. Potential considerations could be the lessons learnt from previous research and applications of regenerative agriculture [33] and how it can inform regenerative manufacturing and design in future.

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