Ways to Circular and Transparent Value Chains

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Abstract. The purpose of this paper is to increase the knowledge about the implementation of circularity and other sustainability approaches in value chains. The objective is to develop roadmaps for the implementation of digital Circular manufacturing (CMA) and Social-life cycle (S-LCA) assessments in Textile and Clothing (TC) value chains. Implementing these digital assessments in TC value chains can increase their transparency, by validating that product manufacturing safeguards worker wellbeing and the environment. TC is one of the sectors with most critical social and environmental impacts. The roadmaps were developed through a Design Science methodology, combining: i) case studies to understand the practical problem, ii) literature study on CMA and S-LCA to develop the roadmaps, and iii) action research to iteratively apply the roadmaps to the cases and refine them with participants in an EU project, representing the entire TC value chain. The EU project is developing digital sustainability assessments with Blockchain functionality for increased data trustworthiness. This study aims to contribute to theory, practice, and public policies by providing a validated overview of the status, barriers, goals, and systematic activities for the implementation of CMA and S-LCA in TC value chains and for increased sustainability.

Keywords: Circular economy · Sustainability · Value chain transparency

1 Introduction

Nowadays, companies need to cope with increasing requirements of environmental and social sustainability from policymakers and customers, including requirements to increase the circularity and transparency of industrial value chains. However, the journey from linear value chains with a focus on economic sustainability, to circular value chains that also address environmental and social sustainability, is an exciting, yet tumultuous journey for many companies. This is also the case for the Textile and Clothing (TC) sector, the 4th highest 'pressure category' in the EU in terms of use of primary raw materials and water, while Food is the highest [1]. Unlike the food sector, most of the pressure and impact linked to TC occurs outside the EU, making the value chain circularity and transparency goals even more challenging. The TC production typically takes place in developing countries with lower production costs, but also lower environmental standards and working conditions. It is estimated that less than 1% of all textiles worldwide are recycled into new textiles [2]. Moreover, it is reported that nearly 10%

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of the chemicals used in the TC sector are of potential concern to human health and that due to poor working conditions, almost 6% of the TC workers get injured every year [3]. As customer awareness about sustainability is growing, the TC sector is witnessing a plethora of companies claiming that they supply sustainable products. However, due to low-value chain transparency, the current anti-counterfeiting methods are suboptimal, thus enabling an unfair playing field for the suppliers that do comply with stricter sustainability requirements [4].

Roadmaps are acknowledged as important strategic planning methods that include the activities required to cope with challenges and achieve major advances in an area [5] such as the one of circular value chains. The circular economy is one of the concepts in the sustainability field that is truly embraced by the business community. In recent years, research studies provided more support to practitioners that are implementing circular strategies than earlier [6, 7]. Nevertheless, these studies have addressed the TC sector to a lesser extent, especially concerning the exploitation of methods and digital technologies for increased value chain transparency. Moreover, earlier studies have a limited focus on assessments as a point of departure for continuously improving value chain circularity and transparency [7]. Thus, the purpose of this study is to increase the knowledge about the implementation of digital sustainability assessments in the TC value chain, for increased circularity and transparency. To this end, the paper proposes two roadmaps that were developed in close collaboration with participants in the EU innovation project, TRICK [8], which represent the whole TC value chain. TRICK is developing five digital sustainability assessments, with Blockchain functionality for increased data trustworthiness. This paper addresses the CMA and S-LCA assessments.

2 Research Design

The research strategy has been Design Science, as described by Holmström et al. [9]. This strategy is recommended both for the development of methods with enhanced practical relevance—such as roadmaps, and for the development of the theory (e.g., [9, 10]). As Design science is a multi-method strategy, this study combined case studies, a systematic literature review and action research. First, to understand the practical problem of the case companies, we studied the industrial user needs, as well as barriers and enablers of these user needs. Second, a literature review was conducted, on the topics of CMA and S-LCA. Third, preliminary roadmaps were developed based on the literature. They were structured into common topics in the roadmap literature: current state, policies, barriers (to circular and transparent value chains), and goals and activities on the way towards the vision. Third, over a 6-month period, the roadmaps were iteratively applied to TC cases and refined together with the partners—through the action research method. To this end, workshops, semi-structured interviews, and a survey were conducted with project partners representing the TC value chain. The value chain actors included traditional and technical TC manufacturers, yarn and fibre producers, an online retailer of second-hand clothing, a platform provider for the sourcing of TC production, a recycling company, a customs agency, service and platform developers, and research partners.

3 Literature Background

3.1 Circular Manufacturing Assessment for the TC Sector

The Current State. Compared to linear manufacturing, circular manufacturing is a system of ideally, endless reutilization, remanufacturing and recycling of resources and goods. The 10R-framework (refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, recover) provides a basis for identifying manufacturing circularity [11]. The most common methodology to assess circularity is Life Cycle Assessment (LCA) [12]. While LCA shows great advantages in assessing the environmental impact, it has difficulties in capturing the variation of cycles and interplay of different lifespans [13]. The CMA is an assessment based on material flow and input-output analyses, which can address a wide array of environmental and economic variables through the product lifecycle [14]. CMA indicators for environmental and financial impact may include: air emissions, water and solid wastes, hazardous and toxic materials, environmental accidents, as well as the cost of materials, energy, waste, and environmental accidents [15]. However, the CMA analyses are still not commonly adopted by practitioners.

Policies. Relevant policies for CMA are the ISO 14040 and BS 8001 standards, Global Recycle Standard and the EU Ecolabel. ISO 14040 addresses environmental management and the LCA principles and framework, while BS 8001 provides a framework for implementing circular economy principles in organizations.

Barriers. The lack of a performance index is one of the main barriers to CMA implementation [16], as the method can only focus on a single or few performance indicators. The complexity of circular economy and manufacturing requires multi-dimensional indicators [17]. Moreover, the low CMA standardization makes it difficult to compare CMA results. There is also a lack of universal tracking and tracing technologies and the systems for monitoring circular indicators in the industry are immature or non-existent. Digital technologies are needed to aid manufacturers and recyclers in tracing and evaluating the lifespans of sold commodities, and in forecasting the collection frequency, and the quantity and value of returned merchandise [15].

Goals. The Sustainable Development Goals (SDG) that can support the development of specific KPIs for CMA are SDG 12—Target 12.5 and SDG 17—Target 17.16.

Research and Development (R&D) Activities. The latest literature reviews within circular manufacturing in TC emphasise that future research needs to [12, 14, 15]:

- Identify multi-dimensional performance indicators for CMA,
- Develop and standardize CMA methods, and
- Develop digital technologies to track and trace materials in the TC industry.

3.2 Social Life Cycle Assessment for the TC Sector

Current State. The TC actors may have social impacts, like poor rates of pay and working conditions, long working hours, child labour, frequent industrial accidents, and

limitations to freedom of association [18]. However, consumers are increasingly aware of social impacts and are willing to pay more for sustainable TC products. S-LCA is the methodology recommended by the UN for the assessment of the social impacts of products and services across their life cycle [19]. Examples of S-LCA databases are PSILCA and SHDB.

Policies. Currently, there are more than 450 environmental and sustainability labels [20]. Relevant policies for the S-LCA that the UN recommends, include [19]: UN's Guiding Principles on Business and Human Rights from 2011, Good Weave label, Fairtrade, Rainforest Alliance label, SA8000 Standard, ISO 45001, Global Reporting Initiative, and the Accountability 1000 Assurance standard.

Barriers. Barriers to the implementation of digital S-LCA and social protection in the TC value chains may include [19, 21, 22]:

- Parts of the necessary data are not available.
- The S-LCA experts transform the data in a way that invalidates or distorts it.
- The data are not reliable because of human errors or bias during collection.
- Data do not relate well to the concept being measured, that is it is not valid.
- The study context has changed, limiting the validity of the collected data.

Moreover, it may be difficult and very costly to get site-specific social data about all actors in the value chains [19]. Finally, there might be a vested interest in value chain opacity, to defend local production—especially in developing countries [21].

Goals. The goals that UNEP recommends include the SDG Targets 1.1, 3.9, 4.7, 5.1, 5.5, 8.5, 8.7, 8.8, and 10.2 [23]. These goals/targets can inform the development of specific KPIs for the S-LCA implementation.

R&D Activities. Activities that can be relevant for the implementation of the digital S-LCA in TC value chains, include further research addressing the questions: What are the appropriate scope and the minimum data quality required to properly assess the social impacts from a life cycle perspective?; How to ensure that the assessment results are relevant in the local context and for the affected stakeholders?; What are the considerations for the integration of S-LCA results in a Life Cycle Sustainability Assessment?; How can the root causes of social impacts/performances be identified and addressed?; and How can S-LCA be considered for decision-making at the policy and industry sectors level? [19].

4 The Roadmaps from Linear to Circular Value Chains

Figure 1 presents the roadmaps for the implementation of the digital CMA and S-LCA in the TC sector, for increased value chain circularity and transparency. The roadmaps are based on results from the case studies, literature study, and action research, including short/mid/long-term goals and activities for the period between 2021 (first year of the

Current situation/ barriers	Activities/ goals by 2024	Activities/ goals by 2028	Activities/ goals by 2031
Circular development initiatives in the Textile & Clothing sector focus mainly on take-back management schemes and recycling., while the design for circularity has potentially the strongest impact in changing the TC sector from linear to circular. Manufacturing companies need support in automatically analyzing production data and life cycle data of products to evaluate circularity. *Policies:* ISO 14040, BS 8001 standards, Global Recycle Standard (GRS) and the EU Ecolabel	- Develop methods to evaluate circular manufacturing and introduce multi-dimensional performance indicators - Develop methods and digital technologies to identify circular value chain and provide feedback on circular performance potentials - Develop methods and digital technologies (such as blockchain) to enable transparent value chains and traceability of materials	- Refine and standardize methods to assess manufacturing and the multi-dimensional performance indicators - Develop platforms to share securely material data between value chain actors - Support a wide range of Textile & Clothing companies to use the CMA as a strategic tool, to reach their circularity potential, and to form new and optimized value chain connections and business networks.	- Further research on integrating traceability and material circularity potential in the product design processes. - Further research on the implementation of customer awareness campaigns to promote Circular Economy goals and behavior for circularity.
CIRCULAR MANUFACTURING ASSESSMENT			
Barriers: - Lack of a performance index is one of the main obstacles - Lack of standardization and acceptance of circular manufacturing assessment method - Lack of universal tracking and tracing technologies and immature or non-existent monitoring systems for assessment indicators for industry.	*Goals for environmental benefits:* >20% closed-loop recycling in Textile & Clothing. 25% open-loop recycling (e.g., composites). >5% materials recycled from other industries. 40% more end-of-life clothing collected for recycling 40% more sales of 2nd hand traditional clothing. >35% increase of reuse cycles for workwear.	*Goals for environmental benefits:* Implement the legal obligation to separate the collection of waste textiles in the EU by 2025. 30% closed loop recycling in Textile & Clothing. 30% open-loop recycling. 10% recycled materials from other industries. 60% more end-of-life clothing collected for recycling, and >50% more sales of 2nd hand traditional clothing.	Goals for environmental benefits: 40% closed-loop recycling. 50% increase of reuse cycles for workwear. Substantially reduce waste generation through prevention, reduction, recycling, and reuse - by 2030. Enhance the multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology, and financial resources e.g., in developing countries.
Textile & Clothing actors may have impacts, like poor rates of pay and working conditions, long working hours, child labor, frequent industrial accidents, and limitations to freedom of association. However, consumers are increasingly aware of social impacts and are willing to pay more for sustainable products. *Policies:* UN's Guiding Principles on Business and Human Rights, UNEP S-LCA Guidelines, ISO 45001, SA8000 standard, Fairtrade, Global reporting initiative, Good Weave label, Rainforest Alliance.	- Define the specifications of the S-LCA software with the industrial users, addressing its scope and minimum data quality. - Develop the concept and pilot and iteratively validate and refine them with industrial users, addressing the software's integration with existing S-LCA databases, site-specific data, and the Block-chain-based traceability platform. - Publish the digital S-LCA on the marketplace.	-Effective methods for supplier selection, assessment, and development, including transparency, and worker inclusion. -New business models based on socially sustainable products, and public procurement of such products. -Disseminate S-LCA results to consumers (e.g., on the labels) and other stakeholders. - Research addressing "How can S-LCA be considered for decision-making at the policy and industry sectors level?" and "What are the considerations for the integration of S-LCA results in a holistic Life Cycle Sustainability Assessment?"	-Further research addressing the question "How can the root causes of social impacts/ performances be identified and addressed?" -Include social sustainability in school education and workers' training. -Implement a holistic Life Cycle Sustainability Assessment. -Further dissemination of the S-LCA results to consumers and other stakeholders.
SOCIAL-LIFE CYCLE ASSESSMENT			
Barriers: - Interest in value chain opacity, to de-fend local production. - Difficult to get site-specific social data about all value chain actors. - Lack of time or financial resources to collect necessary data. - Unreliable data because it is collected or transformed in a way that invalidates it.	*Goals for social and health benefits:* - The IT system provides 100% access to data to evaluate the Social and Ethical protection of workers in the traditional/ technical Textile & Clothing value chain, including recycling. -The value chain actors comply 100% with the UN's Guiding Principles on Business and Human Rights.	*Goals for social and health benefits:* - The labor rights are protected, and all workers have safe and secure working environments. - No child and forced labor, and no modern slavery and human trafficking in the value chain. - Ensure women's equal opportunities for leadership, at all decision-making levels.	*Goals for social and health benefits:* - Ensure that all workers acquire the knowledge and skills needed to promote sustainable development. - Eradicate extreme poverty and achieve equal pay for work of equal value for all value chain workers.

Fig. 1. The roadmaps from linear to circular TC value chains

TRICK project) and 2031. The roadmaps' vision that the participants agreed on is: "A strong EU industrial ecosystem, by engaging all the smaller TC value chain actors in the evolution to circular and transparent value chains, and by enabling them to easily find the services and support needed for the adoption of the new production paradigms."

5 Discussion

This section discusses the roadmaps from Fig. 1 in light of the feedback from the value chain actors in the case studies, and the current literature.

CMA. The TC sector needs to shift toward a circular mindset, applying design for circularity, being transparent about the actual and potential circularity performance, and improving take-back and recycling schemes in its global, complex value chains. The acceptance of secondary product life cycles in terms of imperfections in recycled products, and consumers' perceptions of reduced hygiene need to increase according to the informants in the case studies. The barriers are social and cultural rather than technical, highlighting the importance of increasing consumer circularity-awareness and consumer education during the shift from linear to circular products. CMA is a needed tool both from a technical and a social perspective.

The roadmap illustrates steps towards reaching the 10-year goal of substantial reduction of waste generation and of increased use of secondary resources for material circularity, both textile to textile, and textile to other material. The short-term activities and goals focus on developing methods to evaluate circular manufacturing and introduce multi-dimensional performance indicators. Thereby, digital technologies such as Blockchain can enable transparent value chains and the traceability of materials. However, the methods and applications of Blockchain and tracing platforms are still in an immature development phase. Apart from the CMA, the roadmap KPIs are based on the SDG goals and the feedback from informants. By 2030, the TC value chain actors should substantially reduce waste generation through prevention, reduction, recycling, and reuse, thus facilitating and increase of closed-loop recycling to 40%, and an increase of reuse cycles for workwear to 50%. Moreover, the implementation of CMA into product development tools and processes, and the increase of consumer knowledge on circularity are listed as long-term R&D activities. These are pointing towards the awareness and circularity level needed to reach the chosen SDGs.

S-LCA. The goals and activities that the informants selected for the 2021–2024 period are those of the TRICK project, which is active in the same period. They are related to the development of the digital S-LCA, and its integration with existing databases, site-specific data, and the TRICK traceability platform. Moreover, they address the demonstration of the Digital S-LCA in TC value chains.

For 2024–2028, the goals are: i) the labor rights are protected, and all workers have safe and secure working environments, ii) no child and forced labor, and no modern slavery and human trafficking in the value chain, and iii) ensure women's equal opportunities for leadership, at all decision-making levels (based on SDGs 8.8, 8.7, 8.5, and 5.5). One of the mid-term activities is implementing effective methods for supplier selection, assessment, and development, including within social and ethical transparency. "The

producers that intend to be transparent find the way to gather the necessary [assessment] data, typically by selecting the appropriate supplier", commented an informant from the fiber producer, thus acknowledging the importance of supplier selection. Other selected activities are developing new business models based on socially responsible products and disseminating S-LCA results to the consumer market and other stakeholders. The results can be displayed on the product labels, as recommended by the proposed policies. Moreover, as future R&D activities, the informants suggested identifying the considerations for the integration of S-LCA results in a holistic Life Cycle Sustainability Assessment. Through the digital CMA and S-LCA, TRICK addresses the environmental and social pillars of the sustainability concept. In the future, these can be integrated into a software for a holistic Life Cycle Sustainability Assessment, which should also include the Life Cycle Costing assessment, for the economical sustainability pillar [19].

Selected goals for 2028–2031 include achieving equal pay for work of equal value for all value chain workers, and eradicating extreme poverty, currently quantified as less than $1.25 a day (based on SDG 8.5 and 1.1) [23]. Another long-term goal is ensuring that all workers acquire the knowledge and skills needed to promote socially sustainable development (SDG 4.7). Thus, one of the selected activities for the producers is to continue developing their suppliers on a long-term basis, so that worker training and inclusion methods are implemented in the value chain wherever necessary. The TC actors and policymakers should increasingly include the social sustainability topic in school education, worker's training, and awareness-raising campaigns, along with ecological and economical sustainability [24]. This would facilitate a high consumer demand for socially and environmentally responsible products and would reinforce sustainable attitudes in producers. Policymakers can further encourage responsible business behaviour by providing financial and non-financial incentives for the procurement of socially and environmentally responsible goods (ibid.).

6 Concluding Remarks

The purpose of this study was to increase the knowledge about the implementation of digital sustainability assessments in the TC value chains, for increased circularity and transparency. The study proposes roadmaps for the implementation of digital CMA and S-LCA assessments. The roadmaps are based on a systematic literature study and are developed in close collaboration with the project participants in the EU project, TRICK [8], which represent the whole TC value chain. Implementing these digital assessments in TC value chains can increase their transparency by validating that product manufacturing safeguards worker wellbeing and the environment. This study aims to contribute to theory, practice, and public policies by providing a validated overview of the status, barriers, goals, and systematic activities for the implementation of CMA and S-LCA in TC value chains, and thereby for increased sustainability.

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