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Data in sustainable production chain management

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Abstract: The aim of this paper is to innovate the role of data in sustainable production chain management by identifying drivers, challenges and future solutions related to sustainability and data utilisation. The research data was collected from a literature review, a sustainability seminar entitled "Strong Stronger Responsible" and interviews with company representatives. The interviewees represented operators in the renewable forest and chemical industries and the companies serving them. This study examines sustainability data on the wood fibre-based production chain, from the forest to the consumer. The results show that for sustainability data, production chains have challenges and development needs in terms of indicators, data collection, quality and sharing. Sustainability data should guide decision making in processes at all levels of the organisation, as well as in the production chain.

Keywords: sustainability, production chain, manufacturing companies, sustainability data, data utilisation

1 Background

Digitalisation and sustainable development are the long-term megatrends of our time. These two enduring megatrends will be coloured by nature, people, forms of power, technology and the economy. In addition to climate change, biodiversity loss has emerged as a key societal challenge that must be considered in industrial activities. The challenges to people's well-being are manifested in industrial activities as human rights issues and in the changing forms of tasks in the work environment shaped by digitalisation. Data and its ownership create power, a new kind of economy and business. However, digitalisation and sustainability are challenging in the production chain because these trends affect several actors, and the value created varies for different parties. All these future drivers create an operating environment for the issues examined in this study. *In this paper, our main goal*

is to innovate the role of data in sustainable production chain management by identifying drivers, challenges and future solutions related to sustainability and data utilisation.

Sustainability in wood fibre-based production chain

In the twenty-first century, the global forest-based sector has undergone many changes that have had an impact on the concept that describes the sector itself. Traditionally, the concept of the forest sector has been explained by the forest industry, including the pulp and paper industry, the wood products industry and forestry (Näyhä et al., 2015). In the twenty-first century, a broader concept of the forest-based sector has become popular. This reflects the fact that forest-based companies, as well as companies in other industrial sectors, are increasingly developing new products and services based on forest biomass, such as bioenergy, textile raw material, nanopulp and microfibrillated cellulose, which are usable in a wide range of sectors. In fact, forest biomass and forests are exploited for different purposes and in many different sectors of the economy, so it is no longer justified to talk about the 'forest industry' in the sense in which we are accustomed (Näyhä et al., 2015). In this paper, the *wood fibre-based production chain refers to the production of goods based on wood fibre raw material, from forest to consumer products.* The production chain's key operations include harvesting, pulping, paper/board making and converting.

The sustainability approach originates from United Nations (UN) processes, which started already in the 1980s. The Brundtland report in 1987 brought the sustainable development concept into global decision-making processes. The development of sustainability received a boost in the June 1992 Earth Summit in Rio de Janeiro, Brazil, where more than 178 countries adopted Agenda 21, which was a plan of action to build a global partnership for sustainable development to improve human lives and protect the environment. The process continued in other conferences and meetings, arriving at the adoption of the 2030 Agenda for Sustainable Development, with 17 Sustainable Development Goals (SDGs), in September 2015.

Feil et al. (2019) studied industrial sustainability indicators. Based on their literature review results, environmental aspects of sustainability are related to energy, water, waste, emissions, products, resources, effluents, labels and certificates, logistics, environmental investments, impacts and environmental degradation, as well as soil. In turn, social aspects involve employees, work, clients/consumers, communities, stakeholders and ethics. Economic aspects consider costs, profits, investments and so on. A recent regulative boost in European markets towards corporate sustainability is the Corporate Sustainability Reporting EU Directive (CSRD), which entered into force in the beginning of 2023. However, in the corporate world, the so-called environment, society, governance (ESG) approach has guided sustainability development without legislative coercion too.

For instance, the global forest industry company MetsäGroup (2023) recently announced its new ESG targets, which reflect the current sustainability indicator and data needs in the forest industry. The environmental targets deal with biodiversity, climate change and resource use. The social targets promote employee career and safety. Governance focuses on innovation and open-minded cooperation, as well as address the importance of a bio-based economy for society. *In this paper, we focus on innovating data utilisation perspectives of sustainability in the wood fibre-based production chain.*

Sustainability data in production chain

Our literature review shows that data utilisation and sustainability are widely studied. However, the relation between these two topics has not been extensively examined

(Garrigós-Simón et al., 2021). Academic research mainly tackles approaches to specific technological and general management aspects. Some articles on data utilisation and sustainability address sustainable supply chains (see, e.g., Zhang et al., 2020; Gupta et al., 2020; Chalmeta & Santos-deLeon, 2020) or supplier selection based on sustainability innovations (Ahmadi et al., 2020). It has been established that the understanding of how data is used in operations also needs to be expanded. Data should be utilised, not only to meet policy and regulatory requirements, but also to guide planning, procurement, manufacturing and financing decisions (see, e.g., Walden et al., 2021; Sharma et al., 2020). Rantala et al. (2022, p.2) defined sustainability data as "any data that enables sustainable innovations, increased sustainability performance or indication of sustainability in companies". Furthermore, sustainability data can be both "active", that is, can enable sustainable innovations and increased sustainability performance, and "static", that is, can monitor or present sustainability performance in annual sustainability reporting.

Sustainable industrial activities can be viewed from the perspectives of monitoring, tracing and optimising. Monitoring involves measuring industrial activities, such as their emissions to air, land and water. In this case, data refers to measurement results. Traceability of data is important throughout a product's production chain so that the state of the production chain in different situations can be traced all the way to the source of the raw materials. From the sustainability standpoint, a significant aspect is that production can be optimised with the help of data aligned with sustainability.

The existing literature does not focus on innovating sustainability capabilities and measures, especially through the utilisation of data in the manufacturing production chain (Malacina & Teplov, 2022). Innovating sustainability data utilisation in the production chain is challenging. The keys to a company's success are strategic cooperation and networked innovation with other organisations and actors that affect the production chain. The necessary information and resources are shared among several independent but interconnected network actors (Valkokari et al., 2012). However, sharing sustainability data in the production chain is problematic. Some technologies are already available, but companies may be unwilling to share any data, and they hold on to their intellectual property (Luoma et al., 2010). *In this paper, we focus on innovating the role of data, drivers, challenges and future solutions in sustainable production chain management.*

2 Research question and methodology

In this paper, we focus on innovating the combination of data, sustainability and manufacturing production chain with our study's main research question: *How can data support a sustainable production chain?* We also address this sub-question: *What kinds of drivers, challenges and future solutions have actors in the wood fibre-based production chain related to sustainability and data utilisation?*

The research methodology employed in this paper is a qualitative case study because of its suitability for situations that include complex and multiple variables and processes (Yin, 2014). From September to November 2022, the qualitative data was collected from interviews with a total of 16 executives from 10 companies representing the management of sustainability, research and digital solutions (Table 1). The interviewees represented operators and actors in the renewable forest and chemical industry's production chain, up to the retail trade and the companies serving the entire chain.

The interviews were recorded, and comprehensive notes were taken. A typical interview had a duration of 1 to 1.5 hours, and each involved 1–2 interviewers. Because the research was partially exploratory in character, and the definitions of the concepts needed to be discussed with the respondents, semi-structured topic interviews were selected as the primary sources of observational materials. The interviews went beyond sustainability and the role of data to gain a comprehensive understanding of the case companies' businesses and sustainability perspectives. The results have been elaborated, based on several discussions with researchers and a workshop (held on 24 November 2022) with company and researcher representatives for the purpose of analysing the research results. Additionally, qualitative materials were obtained from the discussions in the responsibility seminar "Strong Stronger Responsible" organised by VTT Technical Research Centre of Finland, which was held in Tampere, Finland on 19 October 2022. This seminar included several company representatives' panel discussion about sustainability and the related data utilisation. The qualitative research data included interview recordings and notes, as well as workshop and seminar discussion notes.

Table 1. Interviewed companies, their main products and services, number of interviewees and interview dates.

Company	*Main products and services*	*Number of interviewees*	*Interview date*
A	Machinery, lifting business	2	September–October 2022
B	Machinery, paper making and automation systems	1	September 2022
C	Machinery, valves	2	September 2022
D	Retailer	1	October 2022
E	Software	1	October 2022
F	Chemical industry	2	September 2022
G	Forest industry	2	September 2022
H	Forest industry, bio-based materials	1	September 2022
I	Forest industry, harvesting machinery	2	November 2022
J	Digital consulting	2	November 2022

3 Results

In the following three sections, we present our results. First, the complexity of a networked production chain is discussed. Second, the key findings of sustainability data sharing are provided. Finally, we summarise future areas of research to address the challenges.

Networked production chain

Based on the interviews, complex production chains affect sustainability awareness and coherence. The interviewees reported that the partners' and the subcontractors' levels of

awareness varied from company to company and within different countries. In complex production chains, different actors may also have their own goals that guide their actions. This makes it difficult to achieve consistency and transparency throughout the lifecycle of a product, the production process or the lifecycle services. For example, several different stages and actors are linked to a product lifecycle. Furthermore, each stage may have several subcontractors working for the primary subcontractor (Figure 1). The interviewees believed that this arrangement could affect transparency, traceability and the verification of social perspectives (e.g., human rights and security). One interviewee clarified the data sharing in the production chain:**Error! Reference source not found.**

> "Some of the partners and subcontractors are aware and able to provide sustainability data, and some are not. Even within different countries, there is a dispersion here."

Production chains have not yet been optimised; instead, economic profitability guides the operation more than the sustainability goals. The SDGs decrease in uniformity farther along the production chain. According to the closest actors, the goals common to Tier 1 are more consistent but become less aligned as the production chain moves on to the next levels (cf. Tier n).

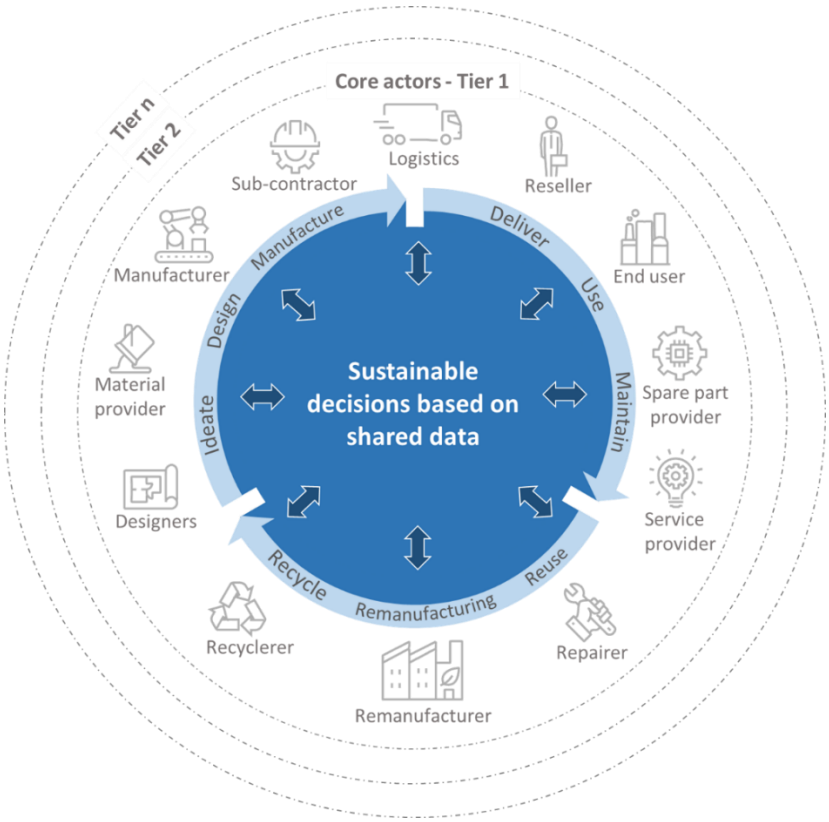

Figure 1. Multiple actors in the product lifecycle and shared data as an enabler of sustainability decisions1.

Emissions in the production chain may vary, e.g., emissions from manufacturing can be significantly lower than those from supply chains or during use. When considering ways to reduce emissions in the production chain, it would be advisable to pay attention to those production stages, where emissions could be more clearly reduced and thus optimise the environmental benefits of the whole production chain. It is challenging to obtain sustainability data from the production chain, where there is no complete transparency to do so, and the ability to provide sustainability information varies. Some of the interviewees mentioned a few measures that they had already taken to address the sustainability challenges of networked operations: mandatory self-inspections of subcontractors, several different training programmes and integration of subcontractors into target settings.

Sustainability data sharing

A common result from the interviews is that the efficiency of data sharing is defined by the capability and cooperation of the whole network. Bottlenecks are possible if all partners cannot respond to the set requirements for data collection and sharing. In addition to general capabilities of single companies, technical barriers are also identified. One of the main questions is how data management and sharing should be implemented in practice as the information is often heterogeneous, contains confidential matters and needs to be collected from multiple sources. Especially, smaller companies tend to have problems with accommodating these changes due to their lack of resources and know-how. As an interviewee stated:

> "All kinds of knowledge and capabilities are needed: knowledge about regulation, improvement of reporting, data management, skills for usage and development of technical systems. Companies are willing to change, but they have to struggle with developing systems and data collection too often by themselves. There is too much overlap, and we should work more together."

Regulations constitute a clear driver of data collection and sharing, but the primary actors in the network may also have a great effect on the requirements as they define what data needs to be reported. These actors may also define the used operating models and technical systems to which the supporting actors in their network must respond. Promoting changes in the network therefore needs each actor's cooperation and participation.

Future areas of research to address the challenges

According to our analysis based on the interviews, the literature and seminar discussions, our findings call for sustainability key performance indicator (KPI) identification and KPI data reliability verification and real-time data collection. To be able to share the data in the networks and ecosystems, we need commonly agreed rules and operating methods. Finally, we have to acquire an in-depth understanding of the meaning of sustainability data in organisational culture and decision making. These main results are also described in Figure 2.

Figure 2. Sustainability data-related challenges and future research areas.

The key to the first challenge, identifying sustainability indicators, that is, ultimately identifying the data needed, is the analysis of materiality. It is used to identify the activities' impacts on the sustainability of the organisation, the formation of business and the surrounding society. It should also be noted that sustainability does not only entail environmental protection and conservation, but social and economic factors are equally important in achieving sustainability. For this reason, data related to employee well-being and data related to customers and consumers, as well as other stakeholders, are relevant. Business success and financial performance guide industrial operations; at the same time, these are important factors and sources of data for promoting sustainable development.

The second challenge underscores the fact that companies find it problematic to obtain data specifically from the perspective of sustainability. However, it may be that suitable data is already being collected in practice, but we just do not understand that it is related to sustainability. We may also lack an understanding of data needs and do not recognise all data needs. Additionally, the data quality is often a problem or at least, ensuring quality.

The third challenge would require data sharing platforms and tools as solutions. Among other things, based on our study's findings, we propose a supplier pool that would assess and verify the sustainability of the operations of the actors in the production chain. The second proposal is a national data platform that could be used to share, for example, material flow data with network members, which could then be used to enhance circular economy solutions, among others.

The fourth challenge prompts an organisation to transfer the ideas of sustainability and responsibility from the strategic level of the organisation to its operating culture. This means that every employee at different levels of the organisation understands the importance of sustainability, as well as the connection of one's own work to sustainability. Special attention should be paid to the fact that sustainability data is used to steer operations towards sustainability, not only for reporting, which is required, for example, through legislation and permit conditions.

All four presented challenges are interconnected, forming a data system as a whole. Through the definition of sustainability indicators, we understand what data we need, what data we need to collect with high quality and how it could be shared in a way that promotes networking and sustainability, as well as how it is used in decision making at different levels of the organisation to implement and achieve sustainability. In this case, decision making is based on facts, not on assumptions.

5 Discussion and Conclusions

The key drivers, challenges and solutions identified in our study are summarised in Figure 3. The main drivers are EU-level legislation and programmes, as well as environmental and responsibility-related trends. The strategic programme EU Green Deal (EU, 2019) strives for "Europe to be the first climate-neutral continent". Sustainability reporting, including double materiality and science-based targets, are the main key approaches used to implement this strategy.

Double materiality forces a company to report not only on how sustainability issues might create financial risks for the company (financial materiality) but also on the company's own impacts on people and the environment (impact materiality) (EU, 2022). Hence, science-based targets are required to avoid green washing in business; therefore, data and its analysis are necessary.

Climate change is no longer the only reason to achieve green deal solutions. Biodiversity aspects, including nature loss, are emerging issues to be considered in industrial operations. Sustainability also covers an increasing number of ethical issues, including human rights and inclusion questions.

All these drivers create challenges to industry, which are listed in the middle of Figure 3. A key challenge is to identify the most effective KPIs to measure and show the performance of the processes, and especially to develop the processes towards a more sustainable and responsible mode. Key solutions for achieving these targets can be found in developing the company culture, data-based decision making, and data sharing across the value chain.

Sharing the right and impactful sustainability data is key to developing sustainability. Data transparency and reliability are the most important characteristics needed for success in the sustainability data-sharing process. Our findings also clearly indicate that the drivers of sustainability are not just prerequisites of the development actions, but they boost new business creation and competitiveness in the whole value chain as well.

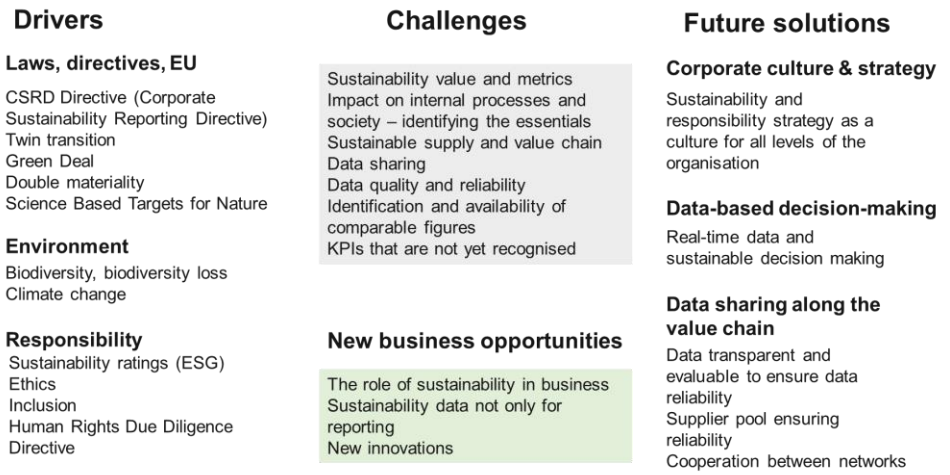

Figure 3. Sustainability data drivers, challenges and future solutions.

Sustainability data-sharing challenges and future needs – concluding remarks

To sum up our key results and analysis, we suggest the following four key themes as the main development areas for industrial value chains to succeed in sharing and using sustainability data effectively:

1. *Identifying sustainability indicators and defining their content to understand what sustainability data means*. In this context, relevant data related to operations and their optimisation shall be identified.
2. *Collecting sustainability-related data*. Identify what data is already being collected, what more data is needed, and how to ensure the quality of the data collected and more real-time collection.
3. *Sharing sustainability data within the ecosystem's network to promote sustainable business actions*. This requires mutually agreed rules of the game and operating models.
4. *Obtaining sustainability data to guide decision making in operational processes at all levels of the organisation*. The goal must be to incorporate data on sustainability from the strategy level into the operating culture of the entire organisation. Sustainability data is not only for reporting but also for guiding the entire operation.

Decision making, with the help of efficiently utilised and high-quality data, is based on facts, not assumptions. This requires the meaning and the benefits of the data to be understood at all levels of the organisation and the data to be utilised in such a way that the operations become sustainable. Relevant real-time data must be identified and connected to decision-making processes from management to employee levels. Additionally, reliability and ways of sharing must be established by common rules and processes that go beyond organisations. Cooperation across ecosystems is needed to optimise the sustainability of the entire production chain. Our findings are in line with findings of Malacina and Teplov (2022), who report that innovating sustainability capabilities and measures in the manufacturing production chain, especially from the data utilisation perspective, requires more research, new models and methods.

In conclusion, we propose that the creation of a culture of sustainability in organisations and businesses, the integration of online data into decision-making processes at all organisational levels, and the creation of data reliability and sharing practices through common rules and processes are the main solutions for the future, which will achieve the sustainability targets in industrial value chains.

As reported in the previous literature (see e.g. Rantala, 2022), empirical findings on innovation related to sustainability and data utilisation are mainly focused on technical aspects, models and frameworks rather than on practical aspects. There are not many papers that combine innovation, sustainability data and the manufacturing supply chain. Several companies struggle with innovating sustainability in practical actions. Our paper provides practical points of view for the utilisation of sustainability data in the manufacturing production chain.

This paper is intended to help practitioners benchmark practices in other companies and to provide managers with feedback on how to develop their sustainability function successfully in practice. This article also helps researchers innovate the use of data in a broader context, including sustainability and the manufacturing supply chain.

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