D4.3 – Circular Supply/Value Chains Training and Evaluation Report

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Abbreviation	*Explanation*
CSC	Circular Supply Chains
KPI	Key Performance Indicator
OEM	Original Equipment Manufacturer

Executive summary

The purpose of this deliverable is to sustainably embed developments of circular value/supply chains (WP4) by implementing trainings, seminars, workshops with key stakeholders of pilot demos in ReCiPSS.
This document enlists the stakeholder training activities held based on the key learnings from the work on circular value/ supply chains in WP4 as well as the general awareness of the circular economy. To disseminate the learnings from WP4, a circular supply chain workshop was held online with key partners. The significance of simulations in catering the complexity of circular manufacturing systems in general and supply chain, in particular, were shared in a panel discussion format. To share the learnings and key findings from the simulations developed in D4.1, three webinars were pre-recorded and shared online consisting of a webinar on simulation techniques, circular supply chains in the automotive and white goods industry respectively.

For comprehensive training on circular manufacturing systems, a board game developed by CirBES team was offered in an interactive training format to the automotive demonstrator.

The evaluation of supply chain activities requires input data from the demonstrators. Since the pilot is delayed due to COVID, at the time of submission of the deliverable it was not possible to report the quantitative data; nevertheless, D4.3 compiles a list of potential circular supply chain KPIs from peer-reviewed literature, reports and ReCiPSS proposal into an excel document that can be used for the evaluation of the supply chain.

1. Introduction

Deliverable D4.3 Circular Supply/Value Chains Training and Evaluation Report describes the activities held as part of WP4 key learnings and training on circular value/supply chains. The task focusses on implementing trainings, seminars, workshops with key stakeholders of pilot demos in ReCiPSS. The purpose of the task was:

- To sustainably embed developments of circular value/supply chains,
- Develop different training formats
- Gather feedback on trainings, seminars, workshops
- Evaluate the supply chain performance of the demonstrators.

The outcome of this task is a report on educational activities held and a discussion on of the supply chain performance targets.

1.1. **Scope**

The objective of D4.3 was to develop training formats, conduct workshops and trainings on circular value/ supply chains both to disseminate the learnings and key developments in WP4 as well as to gather feedback in order to improve the training formats. The initial plan as described in the proposal was to run the trainings primarily onsite with the partners. Due to COVID we have adapted the training formats to online workshops and webinars; however, CirBES game has been offered to academics and automotive demonstrators onsite.

This document enlists the stakeholder training activities held based on the key learnings from the work on circular value/ supply chains in WP4 as well as the general awareness of the circular economy. To disseminate the results from D4.1 and D4.2, circular supply chain workshop was held online with key partners participating from the C-ECO, Bosch, Gorenje, Masaryk University, TU Delft, Fraunhofer, and KTH. The significance of simulations in catering the complexity of circular manufacturing systems in general and supply chain, in particular, were shared in a panel discussion format. To share the learnings and key findings from the simulations developed in D4.1, three webinars were pre-recorded and shared online consisting of a webinar on simulation techniques, circular supply chains in the automotive and white goods industry respectively.

For comprehensive training on circular manufacturing systems, a board game developed by CirBES team was offered in an interactive training format to the automotive demonstrator.

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2. Circular Supply Chain Workshop

2.1. Introduction

The Circular Supply Chain workshop was held as a part of dissemination activity in ReCiPSS project on 15th April 2021. It was an online workshop conducted by CirBES AB in Stockholm. The workshop was attended by 15 participants representing KTH, TU Delft, Gorenje, Bosch, CECO, Fraunhofer IPA and Masaryk University. The workshop was designed to present the proposed Circular Supply Chain (CSC) framework and discuss its different elements.

This report also includes a summary of the feedback collected from the participants based on a semi-structured questionnaire (attached in the Appendix). Taking the feedback as the foundation, the report also identifies the strengths and the weaknesses of the workshop as well as pinpoints the development priorities for the future.

2.2. Workshop design

The workshop was designed with the following key objectives:

- To introduce the proposed circular supply chain framework and discuss the different elements of the circular supply chain framework
- To develop a suitable workshop format for training and disseminate the circular value/ supply chain work package (WP4) activities.

The workshop was conducted in two stages. In the first stage, the participants were introduced to the proposed circular supply chain framework and its different elements like drivers, mechanisms and influencing factors. The second stage was a creative session that involved interaction among the participants. Here, the participants were divided into 2 groups. Each group was given a circular business model and had to propose supply chain configurations to close the loop. The participants had to think about different elements such as drivers, mechanisms and influencing factors of their proposed supply chain configurations. Each group had a discussion lead to navigate the discussion. At the end, both groups presented their solutions followed by a brief discussion where some participants shared their reflections on the workshop. Due to COVID-19 pandemic restrictions, the workshop was conducted online using ZOOM application. The creative session was conducted in an online platform called MURAL, where a digital workspace was provided to the participants to fill in their answers. Some pictures from the workshop session are shown in Figure 1.

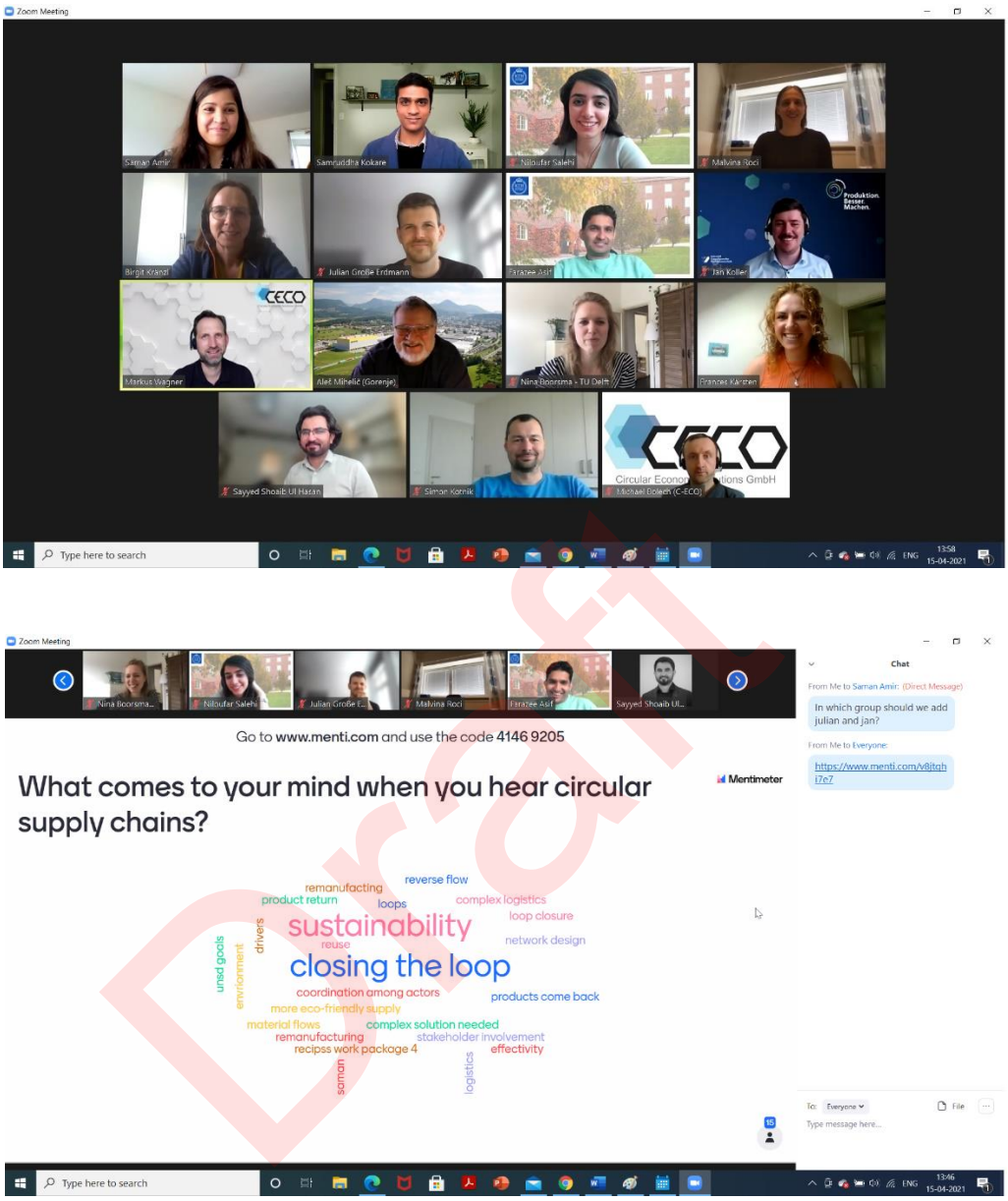


Figure 1: Pictures from the CSC Workshop held on April 15th 2021

2.3. **Feedback**

At the end of the workshop, feedback was collected using a semi structured questionnaire containing 2 Likert Scale Questions and 4 Open-Ended Questions. The first question of the questionnaire is to rate the overall experience of the workshop, where 5 means, great, I have learned a lot and 1 means opposite, i.e., this was a waste of time, I didn't learn anything. The response to this question is shown in Figure 2.

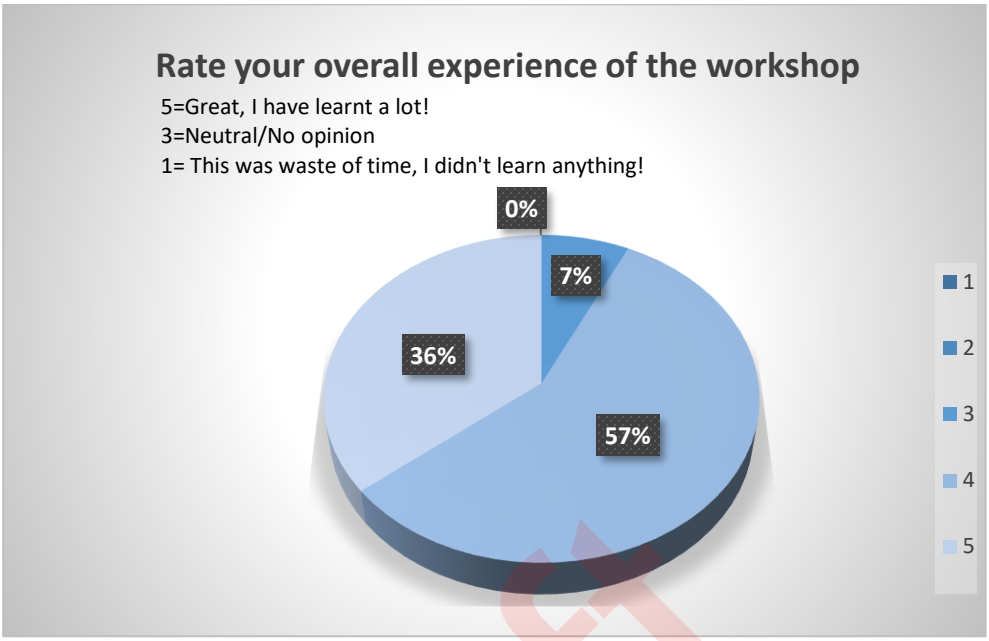


Figure 2: Response to the question rate the overall experience of the workshop

As the pie chart shows, 93% of the respondents had fair to great (i.e., 4 and 5 in the Likert Scale) learning experience. 7% of the respondents had a neutral opinion about the workshop. None of the participants thought that this workshop was not useful to them (i.e., 1 and 2 in a Likert Scale).

Developing a suitable workshop format for disseminating circular supply chain work package (WP4) was one of the key objectives of this workshop. The participants were also asked to rate the format of the workshop i.e., presentation followed by a creative session and plenary discussion. The response to this question is shown in Figure 3.

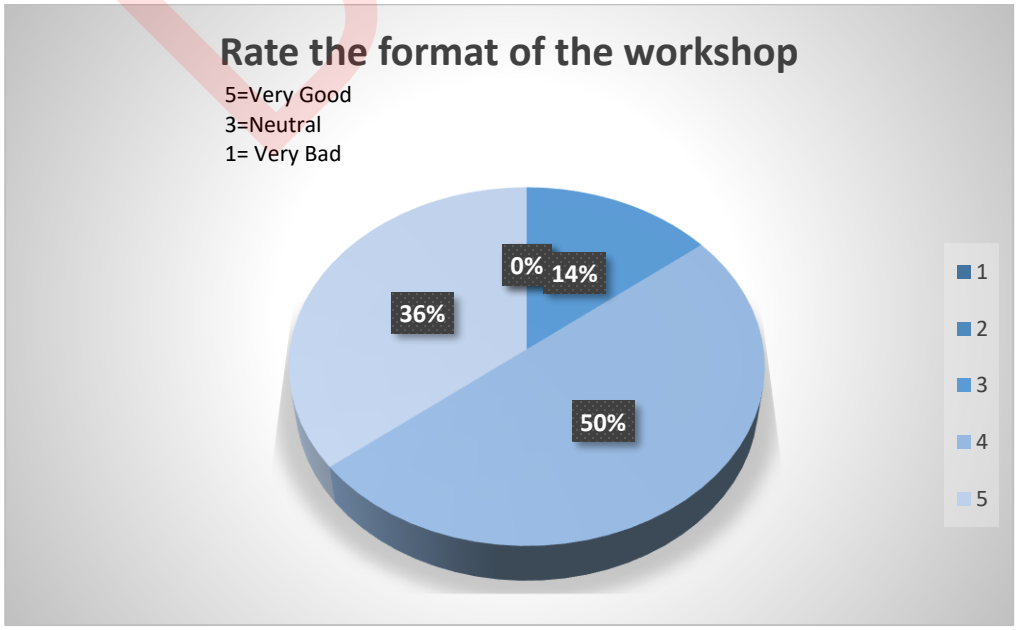


Figure 3: Figure 3: Response to the format of the workshop

As the pie chart shows, 86% of the respondents gave a higher rating of 4 or 5. 14% of the participants had a neutral opinion and no one rated the format as bad.

Apart from above mentioned 2 questions, 4 Open-Ended Questions were asked to collect feedback on the workshop, its contents and suggestions for improvement. The feedback has been categorized as the main take-aways from the workshop by participants and suggestions for improvements. Following sections present (in raw form without any editing) some key comments from the respondents.

2.3.1. Main take-aways from this workshop

"So far there is no systemic approach for CSC, drivers, mechanism, and influencing factors are critical for a systemic approach, feedback on practical implementation still needs to be added."

"It is complex, but manageable if we really want to close the loop."

"Closing the loop by intention and design; have the business model, product design and return management in place."

"Difference between closed loop supply chain and circular supply chain and getting to know the framework."

"Improved knowledge on circular supply chains."

"Complexity of Supply Chains."

2.3.2. Suggestions for improvements

"Simplify as much as possible and repeat instructions on mural."

"Better explanations on what do you mean by drivers, mechanisms, and influencing factors"

"Show lead questions/task also on mural page while the work is going on, maybe provide some definition."

2.4. **Conclusions**

This chapter summarizes the Circular Supply Chain workshop, its format and the feedback from the participants. The overall feedback is highly positive and most of the participants have mentioned that

they have learned the different elements of circular supply chain framework. The majority of the participants were satisfied with the digitalized format of this workshop. The instructions during the creative session should have been repeated on the MURAL platform as few participants were not familiar with its interface. Also, elaborate definitions of drivers, mechanisms and influencing factors of a circular supply chain framework could have been given to avoid confusion caused to some participants.

3. Panel Discussion

3.1. Introduction

The panel discussion on the topic "Role of simulation modelling for enhanced decision-making in circular manufacturing systems" was held as a part of the dissemination activity in ReCiPSS project on 23rd March 2021. It was an online discussion conducted by CirBES AB in Stockholm. The workshop was attended by 10 participants representing KTH, TU Delft, CirBES, Gorenje, Signifikant Svenska, CECO, Fraunhofer IPA and Masaryk University.

We discussed the significance of working with simulations, backed up by the partners to strengthen the argument by sharing thoughts on the work in ReCiPSS in combination with the future outlook on individual themes such Product Design, Supply Chains, Business Models and Information and Communication Technology (ICT). This chapter provides an overview of the current state of the supply chains of the two demonstrators. It summarizes the supply chain operations of Gorenje and Bosch. This creates a baseline for analysis that eventually will be used to develop models to design and optimize circular supply networks. Before going into further details, it is useful to get an overview of the two demonstrators in ReCiPSS.

The overall goal of ReCiPSS is to explore key success factors for circular manufacturing systems in two cases where OEMs have different control levels over their value chains: one case with full control, and one case with partial control.

3.2. Panel discussion design

The panel discussion was designed as a means to build awareness with the following key objectives:

- To discuss the importance of simulation models to understand the interactions between different aspects of a circular manufacturing system and make informed decisions based on these interactions.
- To develop a suitable training format for dissemination of circular value/ supply chain work package (WP4) activities.

Due to COVID-19 pandemic restrictions, the panel discussion was conducted online using ZOOM application. However, it is important to highlight the fact that the plan was to record the panel discussion in order to make it available online, thus, reaching a wider audience. The panel discussion was conducted in four segments, where each segment was dedicated to an element of a circular manufacturing system. These elements were product design, business models, supply chains and ICT. In each segment, the moderator interacted with individual experts on the importance of simulations in decision-making in their field of expertise, motivation for using simulation models, challenges and opportunities in using simulation models, etc. Additionally, the experts from our industrial partners namely Gorenje and CECO also shared their opinions about implementing simulations in their Circular Economy (CE) initiatives. In the end, a Question and Answer (Q&A) session was held where participants asked questions to the experts. For the list of panelists, please see Figure 4. The full recording of the panel discussion is available on YouTube at the following link: https://youtu.be/xt3RcYaFIy4

Figure 4: Participants in Panel Discussion held on 23rd March 2021

3.3. **Conclusions**

Based on the discourse of the panel discussion, the following conclusions can be made:

- Modelling and simulation is an effective tool to understand complex interactions between different elements of Circular Manufacturing Systems.
- It can also aid in decision-making by simulating different scenarios and estimating their consequences in the form of cost, performance, delivery times, environmental impacts, etc.
- Unfortunately, not everything can be simulated. However, identifying and incorporating critical parameters in simulation can certainly enhance the decision-making in circular manufacturing systems.

4. Webinars on supply chain simulations

4.1. Introduction

As part of the work package dissemination activity, a series of webinars to share the work related to circular value/ supply chains in the project. A webinar series was recorded and shared on social media platforms. The focus of the webinars is to present the simulation models developed for the ReCiPSS demonstrators.

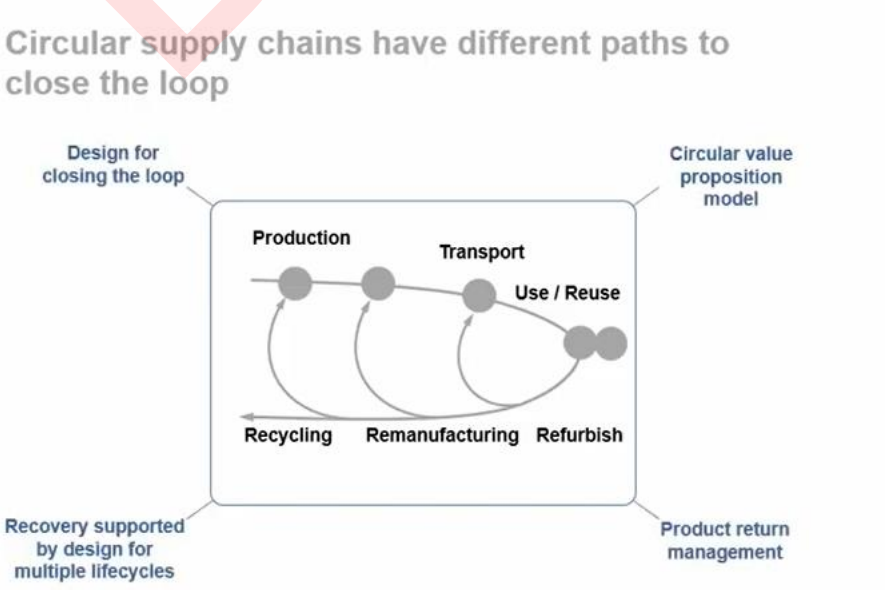
The following webinars were prepared and disseminated through the social media:

1. Webinar on the basics of simulations: https://youtu.be/ACAO4N7ZjKE
2. Webinar on circular supply chains in the automotive industry discussed the circular supply chain model, the assumptions.The webinar can be viewed here: https://youtu.be/6hQSvnLtCeI
3. Webinar on the simulation of circular supply chains in the white goods industry can be viewed at : https://youtu.be/wX0OfW2SRQI

4.1.1. Webinar 1: Basics of simulations

The purpose of this webinar was to highlight how simulations are different from other analysis methods. How randomness or uncertainty can be handled more effectively in simulation environment. The webinars also explained different modeling approaches and why and how such tools can serve as decision support both in the design phase of the system as well as the improvement of a circular system. The screenshots from the webinar are show in Figure 5

The webinars discussed how simulations can support decision-making in the transformation towards circular value propositions. This webinar can be viewed here : https://youtu.be/ACAO4N7ZjKE



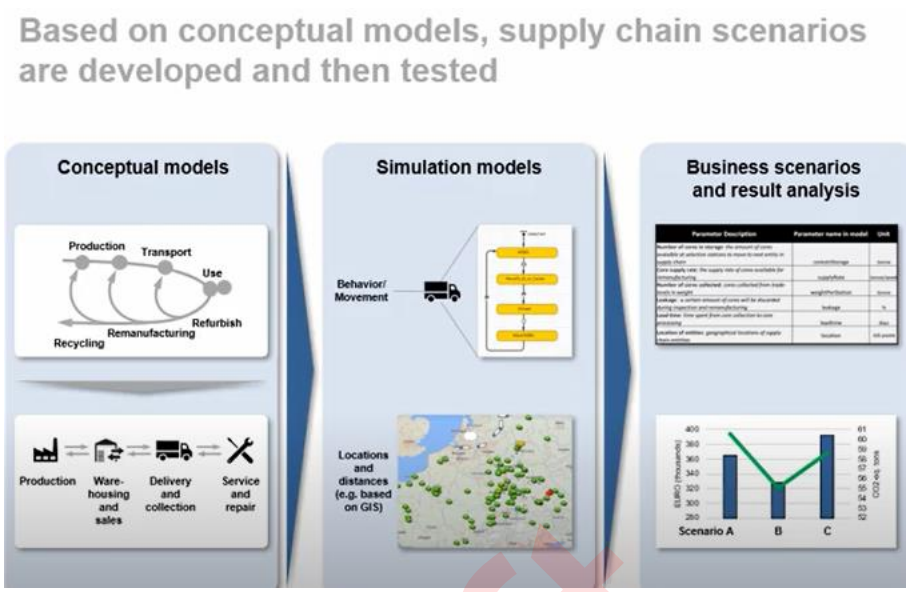


Figure 5: Screenshot from webinar on simulation techniques

4.1.2. Webinar 2: CSC in automotive industry

Webinar on circular supply chains in the automotive industry discussed the circular supply chain model, the assumptions. The main objective of the simulation model was finding hot-spots to make the reverse logistics efficient and transparent, see (Figure 6). The webinar can be viewed here: https://youtu.be/6hQSvnLtCeI

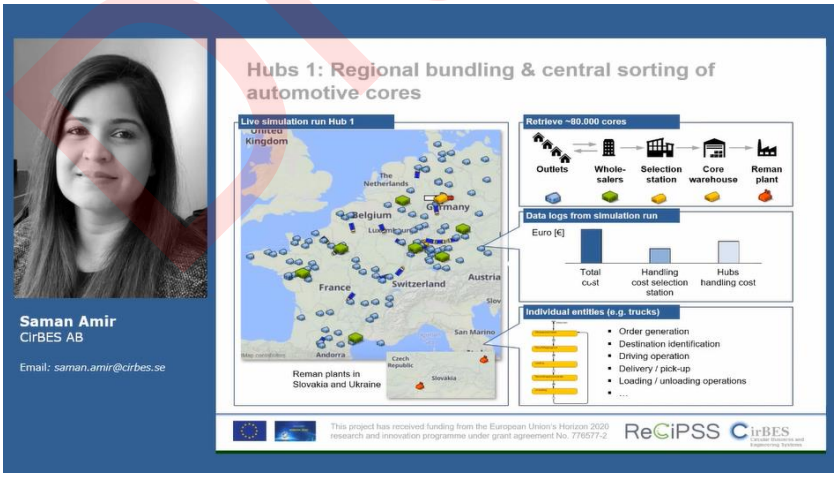


Figure 6: Screenshot from the webinar on circular supply chains in the automotive industry

4.1.3. Webinar 3: CSC in white goods industry

Webinar on the simulation of circular supply chains in the white goods industry can be viewed at : https://youtu.be/wX0OfW2SRQI.

This webinar discussed the transformational challenges when moving from a sales model to selling washes as a service (pay-per-wash), additionally discussing the centralization and decentralization

scenarios for the white goods demonstator. Figure 7 showing a screenshot from the webinar recording.

Figure 7: Screenshot from the webinar on circular supply chains in the whitegoods industry

5. Circle Scope – Workshop based on circular manufacturing systems board game

4.2. Introduction

This chapter reports the CircleScope board game workshop that was held with the automotive demonstrator on June 1st 2022 at Bosch office, Karlsruhe. The workshop was designed and conducted to provide a hands-on learning experience of circular manufacturing systems to the participants. In total, 8 participants from Bosch (2), CECO (3), FHG (2) and, KTH (1) attended the workshop.

This report includes a summary of the feedback collected from 8 (response rate is 100%) participants based on a semi-structured questionnaire (attached in the Appendix A). Taking the feedback as the foundation, the report also identifies the strengths and the weaknesses of the workshop as well as pinpoints the development priorities for the future.

4.3. Workshop design

The workshop was designed with the following main intended learning outcomes (ILOs):

- Understand the challenges and opportunities of linear, conventional closed-loop and circular systems
- Describe possible scenarios and take actions to turn these challenges to opportunities

The ILOs are ensured through a combination of conventional presentation, a series of activities in the form of a board game of running a manufacturing company and discussions. It is a 3-scenario game that was played by 4-5 participants in each team on three different fixed layouts (Figure 8).

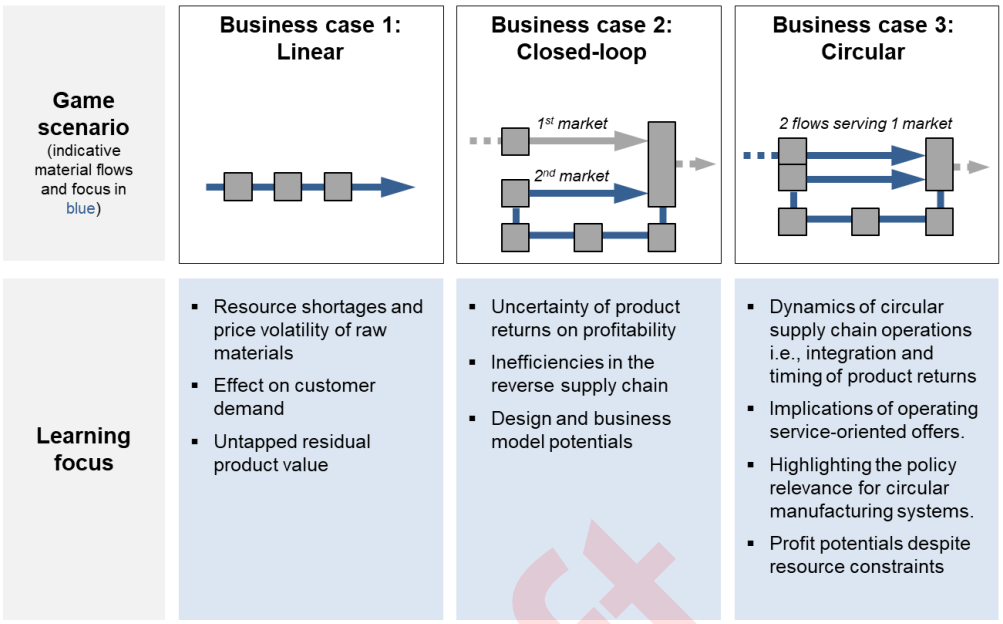


Figure 8: CircleScope game scenarios and learning objectives

Each participant in the team had a specific role either called as Manager, Operator, Accountant, Cashier or Environmental specialist. Each scenario started with a brief presentation of the game layout, instructions and ILOs of that particular scenario. At the end of the scenario the participants presented their reflections and a brief discussion was held. The pedagogical approach is shown in Figure 9

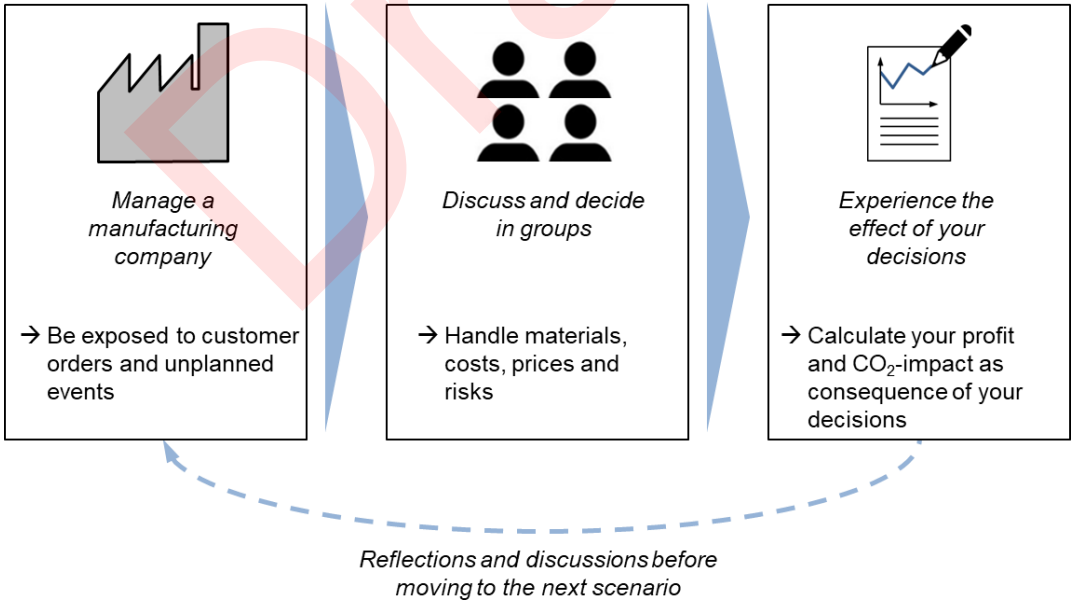


Figure 9: CircleScope pedagocial apporach to ensure learning outcomes

At the end of all scenarios, a longer discussion was held to combine the reflections gained from all three scenarios. Some pictures from the workshop session are shown in Figure 10.

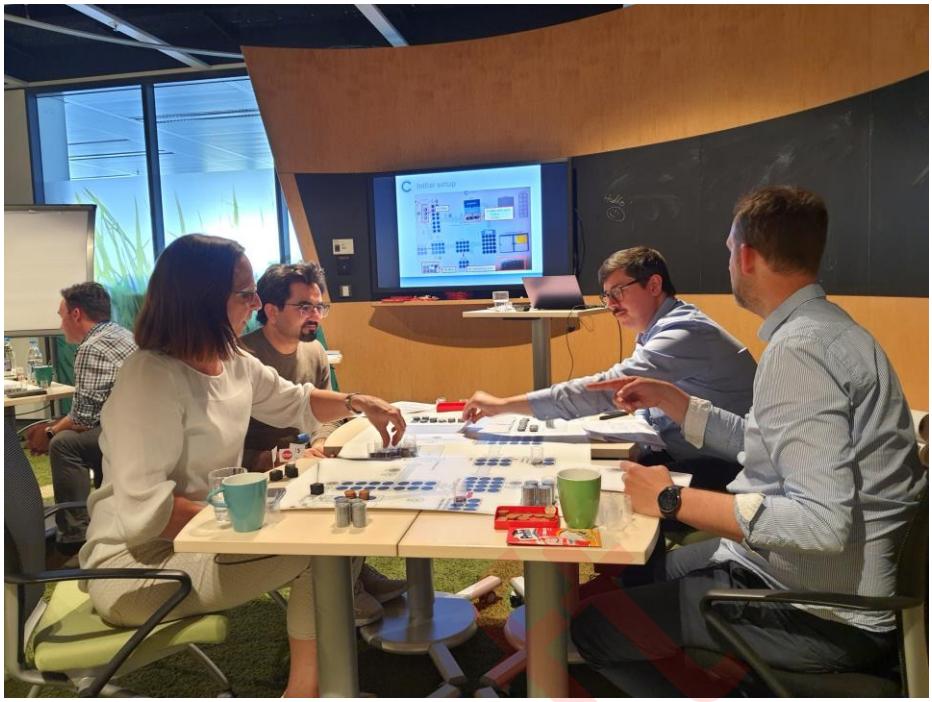


Figure 10: Pictures from the CircleScope Board Game Workshop at Bosch on 1st of June, 2022

4.4. **Feedback**

At the end of the workshop, feedback was collected using a semi-structured questionnaire containing 2 Likert Scale Questions and 4 Open-Ended Questions. The first question of the questionnaire is to rate the overall experience of the workshop, where 5 means, great, I have learned a lot and 1 means opposite, i.e. this was a waste of time, I didn't learn anything. The response of this question is shown in Figure 11

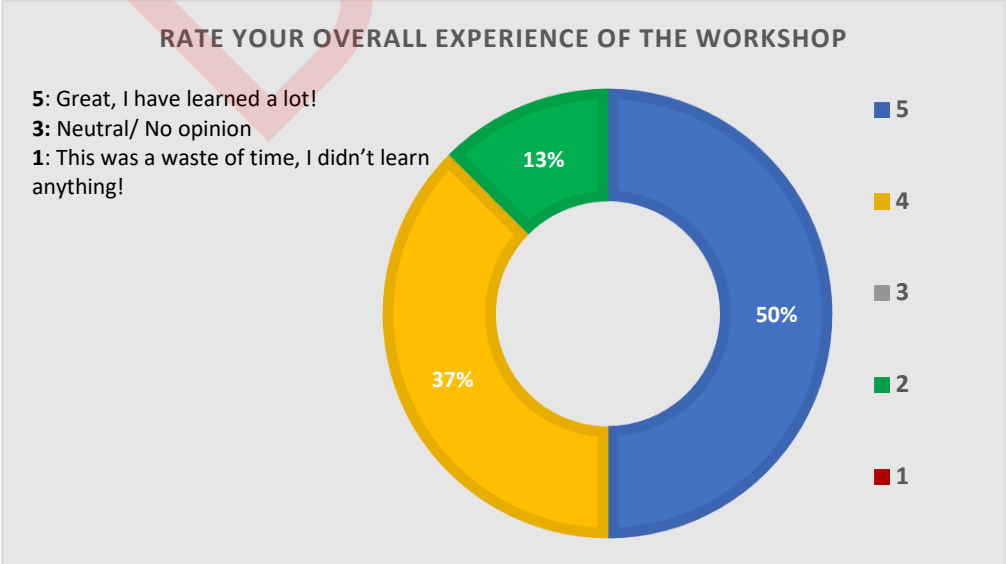


Figure 11: Response to the question rate the overall experience of the workshop

As the pie chart shows, 87% of the respondents had fair to great (i.e. 4 and 5 on a Likert Scale) learning experience. 1 respondent rated the workshop lower (i.e. 2 on a Likert Scale) and the person motivated his/her response as, " As our company is already very experienced, it is too vague it stays on too abstract level."

Apart from above mentioned 2 questions, 4 Open-Ended Questions were asked to collect feedback on the workshop, its contents and suggestions for improvement. The feedback have been categorised as positive, critical and suggestion for improvements. Following sections present (in raw form without any editing) some key comments from the respondents.

4.4.1. Positive feedback

"I would recommend this session to all those who want to explore circular business model approaches also because the session involves colleagues from different departments of the company, bringing in valuable insights."

" Yes. I would recommend to (1) colleagues/ teams that are not experienced in remanufacturing, (2) experienced colleagues as a starting point for future discussions for the second group, it can even be more complex"

"Yes. it clearly gives insights in circular business models. it makes it very transparent that circular economy is a sustainable and profitable business (and in a very entertaining way)"

"Great a lot more than watching PowerPoint and listening. Learning and remembering is better in this setting."

"The game mechanics are quite nice and the competition between different teams motivate's furthermore"

"In my opinion you have to play all scenarios to get out the most of it. scenario three showed that market uncertainties are less important for leasing business models."

"For me scenario three was most interesting because one could directly see the impacts of the decisions. Furthermore, it leads us to discuss advantages/disadvantages when making our decisions."

"I like gamification as it involves you emotionally it is great to have more than one team."

" This is somehow learning by doing. Like this, a lot more will stick than in another way e.g. presentation.."

"This type of training provides a hands-on experience in circular business model where you learn different market dynamics and how they might affect business. One learns about the impact of their decisions on costs and revenues. When playing the game you feel as if you are running an actual business and your decisions are going to have consequences. This is helpful when you compare the output of different scenarios."

4.4.2. Critical feedback

"The customer reaction was very digital when it came to delivery problems this could be softened.."

" Revenue for recycling products (materials)"

"Maybe go through the instruction once to prevent people from proceeding too fast."

"More event cards as X stated concerning high core costs."

"For non CE-experienced I would recommend but for specialists not."

4.4.3. Suggestions for improvements

"Distinguish what was the effect of the leasing business model versus what was the effect of the production variance? it would also be interesting to check effects on competitors/market"

" I suggest to make a clear differentiation between the environmental and economic impacts /consequences of linear versus circular decisions. the more diverse the group the more diverse the discussions -> outcomes -> so diversified team is of advantage."

" More deeper explanation on dependencies after the scenarios, more sophisticated background and realistic examples"

" A little preparatory session on the mechanics of game will help with a good start. In addition, the instructor should have a kind of checklist with them to make sure the participants are on right track. "

4.4.4. Analysis of the feedback

The analysis of the responses of the open-ended questions have identified some critical points, which can be summarised as:

- Deeper explanation of dependencies and concepts used such as remanufacturing and the effects of different business models in terms of revenue versus CO_2 tax.
- Adding aspects such as revenue for recycling the products, varying customer demand that are currently not covered in the game.
- A detailed walk-through of the scenarios instruction sheet.

The most repeated concern was the discussion on dependendices such as effect of price and raw material fluctioaons on the overall market especially the competitors. The were also comments about adding other related aspects such as warehousing and detailed inventory management.

Currently, the game considers the inventory costs as fixed costs. In our view, the extent of events and triggers considered in the scenarios serves the purpose of understanding the whole system in one go that is meaningful and an effective learning process. Consdiering that circular economy is inherently complex, adding too many details such as more "decision points" throughout the game might cause the "players/ participants" to lose focus on the systems view of circular economy and may result in lack of motivation by the participations and as a result less interaction. We are aware that gamification requires a compromise on rules/abstraction so that the participants can act more creatively on events and compare/analyze the scenarios by interaction and discussing with other participants in the group.

Finally, a lot of good suggestions are provided by the participants which will make the game even more interesting and rich in terms of learning and further development of the game mechanics.

4.4.5. Improvement priorities

Based on the feedback and analysis following short-term improvement initiatives have been prioritised (1 means highest priority):

1) Make the CO_2 aspect of the game more influential in decision making process.
2) Start each scenario with a briefing of the instructions.
3) Create a digital version of the game to engage a wider audience.

4.5. **Conclusions**

The chapter presents a short summary of the feedback collected from the participants, analysis of the feedback and further actions that will be taken in near future.

The overall feedback is highly positive and most of the participants have mentioned that they appreciated the gamified learing approach as constructive and hands-on as compared to lectures with Powerpoint slides. Many participants reinforced that playing with diverse multifunctional teams can indeed help in breaking the silo thinking in organizations especially for the circular economy implementation. Furthermore, playing against other teams promotes both creativity and interaction among the participations. It also enhances the learning as the participants retain the concepts and discussions for a long period of time. Although there are some critical remarks, we consider them trivial as we believe that gamification is an effective tool to convey the complexity of circular economy. There are obviously trade-offs to be considered to transfer the necessary knowledge in terms of abstraction of the concepts and time restrictions. Overall, training about the circular economy concepts through a board-game was highly valued by the participants.

5. Evaluation of circular value and supply chains

5.1. Background

Circular economy indicators are becoming increasingly popular in many public and private organizations. Developing and implementing circular key performance indicators in an organization will assist in the transition towards the circular economy. Circular key performance indicators can be used as a tool to progressively measure the progress which can lead to a better understanding of the organization's performance.

An analysis was made by referring to literature from journals, business reports and empirical data gathered from the demonstrators. The availability of circular economy related indicators in the context of supply chain is very limited and both the demonstrators are not fully aware of the value these indicators can generate for both environment and the economy. This is mostly because of the complex nature of circular economy and information transparency within the companies. It is also important that we know what to measure and how measuring a particular KPI can help improve the performance of an organization. Also, it is crucial to include both standardized circular performance indicators and organization-specific circular performance indicators for the OEMs.

We conducted a study to develop a comprehensive understanding of the most relevant circular key performance indicators. This is done by including a simple description of the selected KPIs, the purpose of measuring the KPIs and the methodology/ formulae used to measure the KPIs while considering all the required parameters. Although, many researchers have included what a particular circular KPI measures, many have failed to explain how measuring them could benefit the organization or society. It is crucial for the organization to know the purpose of measuring a specific circular KPI to ensure their full involvement in developing the KPIs.

Circular performance indicators need to be specific and simple to understand yet easy to implement. However, a few circular performance indicators found in the existing literature are extremely complex and needs many parameters to be considered for measuring the performance. The circular key performance indicators are first screened from the literature study and then relevant indicators are selected based on results from weak market test that was carried out by collecting responses to the email query sent to the ReCiPSS demonstrators. The purpose of the weak market test was to guage the willinness of the demonstrators to implement circular performance indicators. Rautiainen et al classified market test into three different levels: weak, semi-strong and strong [1]. The weak market test is passed when the manager or group responsible for the project in the case company is willing to implement the developed construction[2].

5.2. Evaluation of Circular Supply Chain

For the evaluation of the circular supply chain, firstly, an overview of circular key performance indicators from the perspective of the demonstrators' supply chain and business model is presented. Secondly, the existing literature are extensively researched, and relevant circular key performance indicators are identified. Then semi-structured interviews and discussions are conducted with the two demonstrators to understand each of their critical success factors related to their supply chain operations and circular business models. Lastly, the data collected from the demonstrators are analyzed and a set of circular key performance indicators along with the simple framework of measuring them is established.

The KPIs focus on the product and component level of the material flow and exclude the product design aspects of material usage. The study elucidates only the key performance indicators in the downstream

supply chain. The upstream part of supply chain is not taken into consideration as it is not covered in the scope of this study.

5.3. Research perspective on performance measurement and Circular supply chains

Performance indicators are used to understand what needs to be changed in a value chain. The goal of using a performance indicator is to see how an organization performs and moves towards its achieved targets. Organizations select performance indicators depending on their business operations and objectives. Many organizations do not monitor their actual KPIs, but instead, incorrectly measure the wrong indicators [3].

Parmenter classified performance measures into four types [4]:

1. Key result indicators (KRIs): Gives an outline of the organization's previous performance. Does not discuss how to improve the results.
2. Result indicators (RIs): Gives an outline of efforts of different departments or teams in a particular area.
3. Performance indicators (PIs): Informs the team members and management on what they should do to get better results.
4. Key performance indicators (KPIs): Inform the team members and management on what they should do to improve their performance in specific areas.

5.3.1. Definition and characteristics of key performance indicators

Parmenter defined KPIs as 'indicators that focus on the aspects of organizational performance that are the most critical for the current and future success of the organization'[4]. In other words, KPIs are metrics that focus on assessing the organization's critical factors and improving the performance to achieve the targets and goals of the organization.

Eckerson has classified KPIs into three types [5]:

1. Leading indicator: This type of KPI measures actions that are critical to achieve the targets and goals of the organization in the future.
2. Lagging indicator: This type of KPI measures the results of the past actions of the organization.
3. Diagnostic measure: A KPI that is neither leading nor lagging but communicates the state of activities in an organization.

Various researchers have defined the characteristics of a KPI and there are still discussions going on about constructing an effective KPI. To ensure that the management of an organization meets its objectives, Doran has introduced the acronym S.M.A.R.T, which many researchers have agreed on. SMART criteria are often used to bring clarity and structure the measurability of the performance indicators in an organization. Although there are many alternate objectives and goals of this criteria, the acronym SMART stands for:

1. Specific: Target a specific area for improvement
2. Measurable: Quantify or at least suggest an indicator of progress.
3. Assignable: Specify who will do it.

4. Realistic: State what results can realistically be achieved, given available resources.
5. Time-related: Specify when the result(s) can be achieved.

Doran highlights that the objectives need not fulfill all the five criteria but emphasizes that the objectives will be smarter when they are closer to the SMART criteria guidelines [6].

Another description of the characteristics of effective performance indicators was suggested by Wayne Eckerson [5]. Wayne has listed the following ten characteristics of an effective KPIs:

1. Sparse: The fewer KPIs, the better.
2. Drillable: Users can drill into detail.
3. Simple: Users understand the KPIs.
4. Actionable: Users know how to affect outcomes
5. Owned: KPIs have an owner.
6. Referenced: Users can view origins and context.
7. Correlated: KPIs drive desired outcomes.
8. Balanced: KPIs consist of both financial and non-financial metrics.
9. Aligned: KPIs do not undermine each other
10. Validated: Workers cannot circumvent the KPIs.

5.3.2. KPIs for circular supply chain and circular business models

Nowadays, many organizations focus on supply chain performance evaluation and monitor them regularly to improve the efficiency and effectiveness of operations. Supply chain management deals with the management of flow of materials and information at different levels and thus a bigger opportunity lies in this topic to integrate circular economy concepts. By integrating circular economy concepts and strategies into the supply chain, numerous benefits can be obtained [7], [8].

The term circular supply chain was established when circular economy is integrated into supply chain management [7]–[10]. Due to the unavailability of a definition of circular supply chain management in a broad perspective, Farooque et al [11] have proposed their own definition. The proposed definition of circular supply chain states that 'Circular supply chain is the integration of circular thinking into the management of the supply chain and its surrounding industrial and natural ecosystems. It systematically restores technical materials and regenerates biological materials toward a zero-waste vision through system-wide innovation in business models and supply chain functions from product/service design to end-of-life and waste management, involving all stakeholders in a product/service lifecycle including parts/product manufacturers, service providers, consumers, and users'. Farooque et al have also mentioned that circular supply chain management includes a systematic application of circular economy concepts in different supply chain levels and tasks from a sustainability perspective. Generally, a circular supply chain produces no waste due to its design to restore and regenerate resources to keep the resource flows within the ecosystem. In practice, circular supply chain management is designed to generate zero waste as the value is often recovered by activities such as recycling, reusing, repairing, remanufacturing, recovery, and refurbishment.

In a circular supply chain, there are two types of resource flows: Primary resource flows and circular resource flows [11]. The primary resource flows have two types of forward flow of resources: Linear supply chain and closed loop supply chain. The linear supply chain illustrates a tradition flow of resources and disposal the end-of-life products, waste in the end stage of supply chain. Whereas a closed loop supply chain focuses on recovering resources by delivering back recovered values to the producer, thus

reducing the overall environment impact. But the recovery rate capacity by a closed loop supply chain is limited and does not account for the secondary supply chains. It is also not realistic to recovery all the types of wastes within the same supply chain. This is where a circular supply chain has a huge advantage. A circular supply chain aims to recover values from waste by working together with organization in similar or different industrial sectors [12].

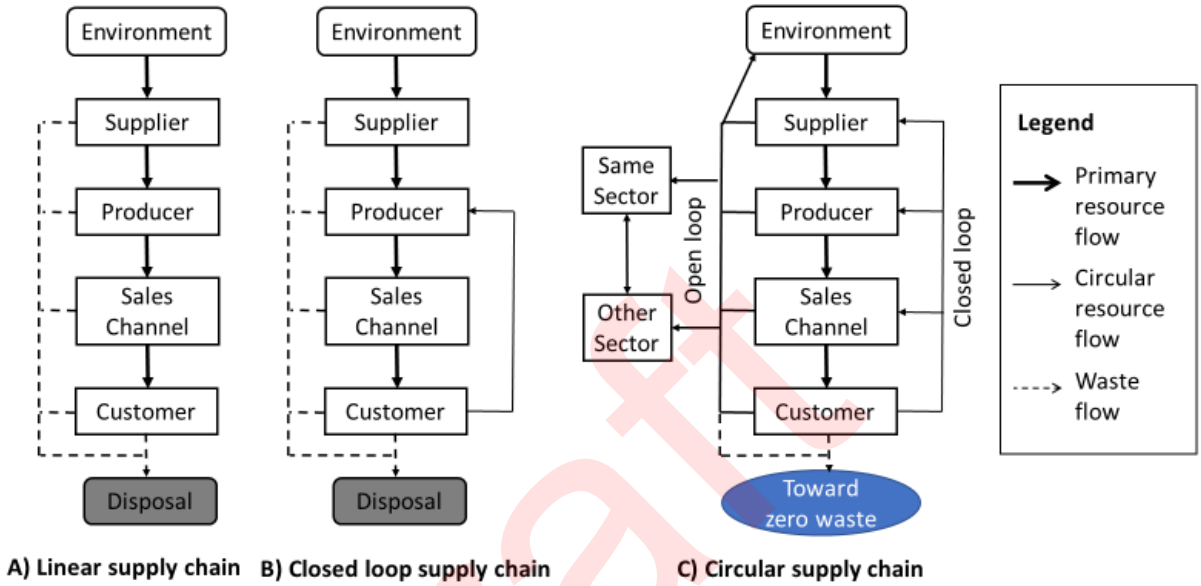


Figure 12: Linear, closed loop and circular supply chains [11]

With regards to measuring performance of circular supply chain management, Jain et al. established a strategic framework to measure circular supply chain management by using supply chain operations reference model (SCOR model) [13]. This developed strategic framework did not focus on the social and economic factors by instead focused mainly on the environmental dimensions. Most of the key performance indicators from the literature focused on product and material level circularity instead of the technical process as the processes vary even within the same industry sector. With abundant existing circular economy indicators, it has become a challenge to make decisions for top management in organizations. This is often due to the complexity of the indicators to completely understand its meaning and relevance and then translate them to measurable values [14]. One example of a complex element to measure is the environmental footprint, which needs to calculate multiple impacts of an activity and needs numerous parameters to be accurate.

5.4. Framework for measuring environmental, economic, technical and social KPIs

A set of relevant circular key performance indicators were carefully selected for the business model of the case companies. The information on circular key performance indicators were gathered from different literatures including scientific journals, business reports and then correlated with the empirical finding obtained from the case companies to construct an indicator pool. This indicator

pool consists of indicators that are both generic and company specific. The constructed indicators focus on different themes such as: gas emissions, material waste recovery, customer retention, repairability, revenue generation and other economic benefits. The KPIs are categorized in Table 1 as environmental, economic, technical, and social based on what each one of them addresses. Next, the description of each KPIs along with its purpose and methodology/calculation formulas are mentioned.

Table 1: List of KPIs from literature review and ReCiPSS proposal

Category	Demonstrator	Name of KPI	Description	Purpose	Formula / Methodology used to measure	References
Environmental	Automotive	Annual green house gas emissions	Company's green house gas emissions converted into CO2 equivalents	Used to reduce the company's energy consumption and carbon footprint	Excel sheet- GHG emissions	[15]
Environmental	Whitegoods	Logistics performance (Freight transport)	Performance of logistics considering a particular type of freight transport	Evaluates vehicle energy efficiency by relating distance to weight transported. Can be used evaluate the performance of both truck and train transport.	Annual total weight of goods transported by all the units/ Annual distance travelled by all the units	[16]
Environmental	Both	Emissions from transport (Forward and reverse logistics)	Emissions from transporting goods in both forward and reverse logistics (kg CO2 e/tonne-km)	Lower CO2 emissions from transport to save cost and reduce environmental impact	Emissions from road transport = ∑ (Weight of good transported (tonnes) * Distance travelled * Emission factor of transport mode)	[17]
Environmental	Automotive	Energy consumption for disassembly	Energy used to disassemble one product	Reducing the energy consumption could reduce the cost spent on electricity	Energy consumed to dismantle one part (kWh) * Total number of parts	[18], [19]
Environmental	Whitegoods	Old scrap collection rate	Measure of how much End-of-life metal is collected and enters the recycle facility	Reduces landfill and reduces the possibility of unsafe waste disposal	End-of-life metal collected for recycling/ End-of-life products (metal content)	[20]
Environmental	Automotive	Core disposal rate	The percentage weight of cores which do not get remanufactured or whose components are not recovered or sold on	Could help reduce landfill and the possibility of unsafe waste disposal	CDR= Waste/ (Weight of Incoming cores + Weight of new components) Waste = Weight of incoming cores - Weight of invoiced goods Weight of invoiced goods includes:remanufactured products and components, components sold unprocessed and for recycling)	[21]
Environmental	Automotive	Net energy savings	Net energy savings generated over 2 reuse cycles (both production and use phase)	Could help understand and compare the improvements of energy saved	Total energy a washing machine consumes over the period of two reuse cycles	ReCiPSS proposal
Economic	Both	Cost of transportation in reverse supply chain	The cost of transportation in reverse supply chain. This cost depends on the total distances traveled in reverse supply chain (can include collection of products at the customer, delivery to the dissassembly/remanufacturing	Helps reduce and assess the reverse supply chain cost	([Transported distance (km) / fuel consumption (km/l)] * cost of fuel (EUR/litre)/ Total quantity of used products transported) * information sharing cost and ordering cost (IT cost)	[19], [22]

			site to either another supplier or original manufacturer)			
Economic	Automotive	Revenue from remanufactured products	The total amount of income generated by the sale of remanufactured products	Helps assess and compare the improvements	Number of remanufactured products sold * Unit sale price for remanufactured product	[19]
Economic	Both	Take back cost	The costs incurred by a company that are associated with a procedure of product take back option	Ensures if the manufacturer or producer offers to responsibly collect products at the end of its life cycle at a reasonable price	Number of products ordered to be taken back* Cost of collecting each product	[19], [22]
Economic	Automotive	A. Actual cost savings due to direct return (80,000 cores @ €5 logistics cost) B. Potential cost savings due to the direct return (if applied to all 35M cores in EU-28)	Cost savings due to direct return A. Actual cost savings due to direct return (80,000 cores @ €5 logistics cost) B. Potential cost savings due to the direct return (if applied to all 35M cores in EU-28)	Assess the revenue generation and cost savings	Simulation Model A: Determine the cost of one selection transport per part. Compare 3 time selection (i.e. going through several trade levels: WhSa outlet, WhSa central, Reman) with direct return. [1st step: Two selections @WhSa & Service provider. 2nd step: One selection @Service provider] B: Calculate for all 35M cores.	ReCiPSS proposal
Economic	Whitegoods	Revenue from refurbished products	Total income generated by the sale of refurbished products	Extend product's use cycles by offering refurbished products and goods for sale.	Number of refurbished products sold * Unit sale price for refurbished product	[19]
Economic	Whitegoods	Revenue from upgrade, repair and maintenance services of products	Total income generated by providing options for upgrading, maintenance and service of products	Assess the revenue generation from maintenance and repair. Can help create new service-related opportunities for the company if required.	Total revenue from upgrading the product + Revenue from maintenance and other related services	[19]
Technical	Automotive	Core/Product ratio	The average number of cores used to produce one remanufactured product	Less usage of virgin resources helps in resource efficiency.	Cores processed/ (products shipped+ stocked midbuild products+ work in progress)	[21]
Technical	Automotive	Core return ratio	Number of cores that are returned (only the cores registered in the pilot)	Could help analyze when there is a decrease or increase in core returns.	Number of returned cores / Total number of registered cores	ReCiPSS proposal

Technical	Automotive	Number of active and potential users of platform (* potential users refer to the capability of the software)	Measure of total number of registered customers and capability of the sotfware for future customers	Helps view the number of customers joining the eXchange program and can help increase the current capacity of the software to add more customers.	Number of active customers registered on the platform and current capacity limit of the platform	ReCiPSS proposal
Technical	Automotive	Component salvage rate (Cores)	The percentage of components and/or subassemblies salvaged	Higher this percentage, normally the lower the total cost of remanufacturing, due to minimizing purchasing cost.	Number of reused cores / total number of cores entering the plant	[21]
Technical	Both	On time delivery to customer	Sales unit delivered on time to customer	Helps decide if route needs to be more optimized and assess other options	Sales units delivered on time / Total sales unit	[23]
Technical	Whitegoods	Maintainable period after sales	Maintainable time of the product after it reaches the customer.	Helps extend the maintenance and service period of a product. Generates more revenue. Can compare with products in similar business sector.	Time of maintainable service (months, years)	[19]
Technical	Whitegoods	Mean time between failures	Average time passed between a machine failures	Helps anticipate how likely a machine is to fail within a certain time period or how often a certain type of failure may occur. Helps reduce breakdown cost when measured and analyzed.	Number of operational hours / Number of failures	[24]
	Whitegoods	Mean time to repair	The average time taken to repair a machine	Can improve maintenance planning and decide if preventive maintenance scheduling and better tools are required for maintenance.	Total maintenance time / Total number of repairs	[24]
Technical	Whitegoods	Repairability index	Measures the repairability of the products sold	Soon, EU might introduce stricter laws for manufacturers to be more responsible in extending the life of products to ensure better resource efficiency and safer disposal. France has already introduced repairability index.	Excel sheet- Repairability index for washing machine	[25]
Technical	Whitegoods	Scale of pay-per-wash model	Number of washing machines (WM) deployed in a pay-per-wash model	Helps evaluate the business model and evaluate customer acceptance	Total number of washing machines (WM) deployed in a pay-per-wash model during the pilot period	ReCiPSS proposal
Social	Both	Total customer complaints	Total number of complaints compared to the washing machines sold	Helps understand customer needs.	Number of complaints / Total sales units	[23]
Social	Both	Purchase of locally produced and offered goods and service	Measures the amount of goods and services that a company has purchased locally	Higher value indicates larger extent to which the company or facility contributes to local economy from buying local materials and products	Number of locally purchased products(goods)/ Total output number of products produced (or) Weight of locally purchased products(goods)/ Total weight of products produced	[18], [19]

Social	Both	Totally number of hours of capacity and skill development training per employee	Measures the time spent on employee's education and professional and personal development per employee	Introducing policy and initiatives to expand workers' capabilities and skills, thus increasing their capacity and employability. Capacity development is important as it contributes to the growth of human capital within the organisation.	Total number of hours of training aimed at capacity and skill development per employee per year	[19]
Social	Both	Job creation per unit of product	The extent to which the company or facility creates new jobs in circular business sector	Measures the increase in opportunities for circular business job. Higher value indicates a larger community employment.	Total number of workers working on a specific product type / Total number of products produced or serviced	[19]

Although, these identified KPIs are relevant to demonstrators, there is always a need to prioritize these indicators based on separate weights that can be set each demonstrator. Separate weightage can be assigned to the KPIs and more parameters of each KPI can be reviewed. More teams from the case companies from other departments can be involved in the study to finalize and provide feedbacks for the identified KPIs. A systematic management system to implement the identified KPIs could be set up at the case companies to ensure the effectiveness of measuring them. For a company to progress towards their targets, it is important that KPIs are evaluated regularly, and individuals accountable for them should be assigned to achieve the required target levels.

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6. Conclusion

Circular value/ supply chains are getting increasingly crucial for enabling the development of circular business models. To this end, it is equally important to share the learnings and knowledge that is produced during the project as well as develop innovative methods to share those learnings with the stakeholders.

The main impact of this deliverable is to develop different formats to train the stakeholders, and gather their feedback. This has been achieved in the form of circular supply chain workshops, panel discussion and webinars. Firstly, the circular supply chain workshop was designed to present the proposed Circular Supply Chain (CSC) framework and discuss its different elements. The participants rated the workshop positively and were satified with the design and content of the workshop. Next to that, a panel discussion was conducted online with ReCiPSS partners to discuss the significance of working with simulations, reinforced by the partners as they shared their thoughts on the work in ReCiPSS in combination with the future outlook on individual themes such Product Design, Supply Chains, Business Models and Information and Communication Technology (ICT). Furthermore, a webinar series comprising simulation basics, circular supply chains in the automotive industry focusing on the scenarios to make the reverse logistics efficient and transparent for the automotive demonstrator was recorded and shared on social media platforms as well as a simulation webinar on whitegoods demonstrator focusing on the circular supply chain scenarios in transforming from sales to selling washing machines as-a-service in different markets. The webinars were targeted both at the stakeholders within the ReCiPSS consortium as well as wider audience reached through the social media platforms. Moreover, a board-game workshop with a game about circular manufacturing systems called CircleScope was held with the automotive demonstrators. The participants liked the gamified approach with hands-on learning on circular business models and key concepts such as leasing, remanufacturing etc. The participants acknowledged that playing with a diverse group of participants sparks more insightful discussions around the topic of the circular economy.

Another goal of this deliverable was to evaluate the circular value/ supply chains and this aim has not been fulfilled due to Covid limitations. The pilot was delayed and it was not possible to evaluate the circular supply chain with key metrics. However, in this report we have included an overview of circular supply chain KPIs to measure the progress towards circular supply chain implementation.

Nonetheless, the identified set of circular supply chain KPIs may serve as a reference for the demonstrators when their organizations would systematically introduce circular KPIs to measure and evaluate the progress towards the circular economy.

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7. References

[1] A. Rautiainen, K. Sippola, and T. Mättö, “Perspectives on relevance: The relevance test in the constructive research approach,” *Manag. Account. Res.*, vol. 34, pp. 19–29, 2017.

[2] E. Kasanen and K. Lukka, “The constructive approach in management accounting research,” *J. Manag. Account. Res.*, vol. 5, no. 5, pp. 243–264, 1993.

[3] M. Badawy, A. A. A. El-Aziz, A. M. Idress, H. Hefny, and S. Hossam, “A survey on exploring key performance indicators,” *Futur. Comput. Informatics J.*, vol. 1, no. 1–2, pp. 47–52, 2016.

[4] David Parmenter, *Developing, Implementing, and using winning KPIs*. 2015.

[5] W. W. Eckerson, “Performance management strategies How to Create and Deploy Effective Metrics Research Sponsors Business Objects , an SAP company IBM Corporation,” *Data Warehous. InstituteTM*, p. 36, 2009.

[6] G. Doran, “S.M.A.R.T-Way-Management-Review.pdf,” *Management Review*, vol. 70, no. 11. pp. 35–36, 1981.

[7] A. Genovese, A. A. Acquaye, A. Figueroa, and S. C. L. Koh, “Sustainable supply chain management and the transition towards a circular economy : Evidence and some applications $,” *Omega*, vol. 66, pp. 344–357, 2017.

[8] M. Haneef, A. Nasir, A. Genovese, A. A. Acquaye, S. C. L. Koh, and F. Yamoah, “Int . J . Production Economics Comparing linear and circular supply chains : A case study from the construction industry,” *Intern. J. Prod. Econ.*, vol. 183, pp. 443–457, 2017.

[9] L. Canning and L. Canning, “Rethinking market connections : mobile phone recovery , reuse and recycling in the UK,” 2013.

[10] L. Du, L. Yu, and R. Cheng, “The construction Research on Rapid-Response Eco-Supply Chain of the Textile Industry Based on the Circular Economy,” no. 1, pp. 248–251, 2010.

[11] M. Farooque, A. Zhang, M. Thürer, T. Qu, and D. Huisingh, “Circular supply chain management: A definition and structured literature review,” *J. Clean. Prod.*, vol. 228, pp. 882–900, 2019.

[12] C. Weetman, *A circular economy handbook for business and supply chains*. Kogan Page, 2016.

[13] S. Jain, N. K. Jain, and B. Metri, “Strategic framework towards measuring a circular supply chain management,” *Benchmarking An Int. J.*, 2018.

[14] J. Sánchez-Ortiz, V. Rodríguez-Cornejo, R. Del Río-Sánchez, and T. García-Valderrama, “Indicators to measure efficiency in circular economies,” *Sustain.*, vol. 12, no. 11, 2020.

[15] “GHG Emissions Calculation Tool,” *Greenhouse Gas Protocol*, 2021. [Online]. Available: https://ghgprotocol.org/ghg-emissions-calculation-tool. [Accessed: 08-Aug-2021].

[16] “Methodology benchmarking for energy efficiency and carbon footprint.”

[17] P. Jofred and P. Oster, “CO2 Emissions from Freight Transport and the Impact of Supply Chain Management,” 2011.

[18] L. C. Roca and C. Searcy, “An analysis of indicators disclosed in corporate sustainability reports,” *J. Clean. Prod.*, vol. 20, no. 1, pp. 103–118, 2012.

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[19] M. Kravchenko, D. C. A. Pigosso, and T. C. McAloone, “Leading sustainability indicators for circular economy,” 2019. [Online]. Available: https://data.dtu.dk/articles/dataset/Leading_sustainability_indicators_for_circular_economy/8034188/1. [Accessed: 08-Aug-2021].

[20] G. Moraga *et al.*, “Circular economy indicators: What do they measure?,” *Resour. Conserv. Recycl.*, vol. 146, no. November 2018, pp. 452–461, 2019.

[21] I. Graham *et al.*, “Performance measurement and KPIs for remanufacturing,” *J. Remanufacturing*, vol. 5, no. 1, 2015.

[22] E. Kongar and S. M. Gupta, “A multi-criteria decision making approach for disassembly-to-order systems,” *J. Electron. Manuf.*, vol. 11, no. 2, pp. 171–183, 2002.

[23] N. Gamme and M. Johansson, “Measuring supply chain performance through KPI identification and evaluation,” *Master’s thesis “Supply Chain Manag. "Quality Oper. Manag. CHALMERS Univ. Technol.*, pp. 1–87, 2015.

[24] E. Saari, “KPI framework for maintenance management through eMaintenance,” 2019.

[25] “Repairability index worksheet of washing machines,” *Ministère de la Transition écologique*, 2021. [Online]. Available: https://www.europarl.europa.eu/RegData/etudes/BRIE/2016/573899/EPRS_BRI(2016)573899_EN.pdf. [Accessed: 08-Aug-2021].

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Appendix A

Feedback Sheet

Rate your overall experience with the seminar:	☐	☐	☐	☐	☐
5: Great, I have learned a lot!	1	2	3	4	5
3: Neutral / No opinion					
1: This was a waste of time, I didn't learn anything!					

Would you recommend this workshop to a colleague or another team? **(Yes/No? Please also state why/why not)**
Please openly describe what you think about this type of training. How do you rate your experience with this "gamified" learning approach?

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What did you miss while you were playing? What would you improve?
Which of the 3 scenarios was most interesting? and Why?

Thank you for your feedback!

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