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Roadmap development in the circular economy context; achieving circular inflow and outflow in passenger trains according to the CTI framework

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A shift from the current linear economy to a circular economy could slow down climate change. This research explores the field of the of the circular economy, for the main passenger railway operator in the Netherlands, through the development of a roadmap using the CTI framework. It translates general principles of roadmapping into the context of the circular economy for a tailor-made roadmap.

Roadmap development; circular economy; passenger trains; CTI framework

1. Introduction

The current 'take-make-waste' linear economy, powered by fossil fuels and a short term vision on resource management, is seen as one of the causes behind climate change. Adapting principles of the circular economy (CE) concept can decrease the effects of climate change [1]. The client company, the Nederlandse Spoorwegen (NS), takes responsibility for this and sets the goal of having 100% circular trains by 2030 and wishes to achieve this using the Circular Transition Indicator (CTI) framework. This results in a master thesis exploring the field of the circular economy through the development of a roadmap for the realisation of circular economy principles. The main research question is: how can NS realise circular inflow and outflow for their current trains by 2030, using the CTI framework?

According to the Design Science Research approach, and through literature research and semi structured interviews, a tailor-made roadmap is developed for NS to answer the research question. Section 2 forms the basis for the understanding of the roadmap and provides the theory behind the circular economy concept and the CTI framework. Subsequently, section 3 describes the circular roadmap development process. Section 4 and 5 elaborate on the roadmap and its implementation. Finally, section 6 concludes the research and is followed by a discussion and recommendations in section 7 and 8.

2. Theory

2.1. Circular economy

The circular economy (CE) concept has a long history, multiple definitions, and different developments in various global contexts [2]. According to [3], the CE can be seen as an umbrella concept that underlines and connects certain aspects of circular concepts. Therefore, each CE concept has its own fundamental principles. In essence, the CE of the Ellen MacArthur Foundation (EMF) focuses on transforming the linear take-make-dispose economy to an economy that is restorative by design [4].

This research uses a similar definition of the CE, but according to the World Business Counsel for Sustainable Development (WBCSD). It implies that the CE is an economic model that is regenerative by design and aims to preserve the value of the circulating resources, products, parts and materials through the creation of a system with innovative business models that enable long life, optimal (re)use, renewability, refurbishment, remanufacturing and recycling. By applying these principles, organisations can collaborate to design out waste, increase resource productivity and maintain resource use within planetary boundaries [5]. This definition is also in line with the CTI framework and NS.

2.2. CTI framework

the CTI framework determines the total circularity of a company by assessing the circularity and thus also the linearity of material flows that circulate throughout a company. It provides insights in ways to optimise the resource efficiency and efficacy. Moreover, the CTI framework is in line with the CE concept of the EMF and the corresponding circular principles: 1) design out waste and pollution, 2) keep products and materials in use, 3) regenerate natural systems. Therefore, the CTI also differentiates between the technological and biological cycles, like the butterfly model of the EMF.

In order to calculate the percentage of the total circularity, the material flows are assessed at three key indicators; the inflow and the outflow which consists of a multiplication of the outflow-recovery potential and the outflow-actual recovery. The weighted average between the percentage of the circular inflow and the percentage of the circular outflow is then the percentage of the total circularity. Figure 1 illustrates the total circularity in relation with the material flows. Moreover, only the material flows within the company boundaries are incorporated in the calculation. So what other companies have done or are going to do with the material flows is excluded [5].

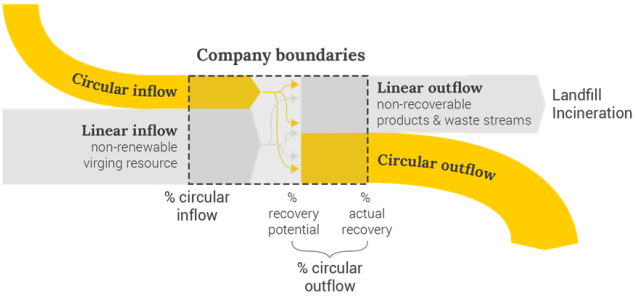

Figure 1.; The total circularity in relation with the material flows retrieved from [5].

General roadmap development	CIPS roadmap development process	*Circular* CIPS Roadmap development process
1) Context		
2) Architecture		
3) Process	1) Defining the current state	1) Establishing a Circular Indicator (CI) framework
	2) Identifying the gaps	2) Creating a total overview of the circularity and the (linear) gaps
	3) Prioritising the gaps	3) Analysing the indicator impact
		4) Analysing the viability of the proposed strategies to prioritise the linear gaps
	4) Define the roadmap strategy	5) Linking the gaps to the impact categories, to interpret the impact and to create a roadmap strategy: a) the mountains, high indicator impact and low viability b) the low hanging fruits, high indicator impact and high viability c) the flies, low indicator impact and low viability d) the harmless, low indicator impact and high viability.

Table 1.; The principles and activity groups of the roadmap development and process.

3. Circular roadmap development

3.1. Roadmap development in the CE context using a Circular Indicator framework

In order to integrate circular economy principles into a roadmap, the general roadmap development principles; context, process and architecture, are customised to the specific context of the circular economy. For that, this research proposed to first generalise the roadmap development process by combining the top 'why' layer activities, the middle 'what' layer activities, the bottom 'how' layer activities with the activity processes (ideation, divergence, convergence and synthesis) to the CIPS roadmap development process. Subsequently, the CIPS process is customised based on existing literature, and a circular CIPS process is proposed. Table 1 shows the principles and activity groups of the roadmap development and processes.

3.2. The roadmap development for NS

Subsequently, the NS case study demonstrates the roadmap development with the CIPS process. In which the roadmap context included the objective to guide NS in achieving their circular goal using the CTI framework in an understandable way. The scope included mapping out and prioritising the relevant projects and stakeholders and excluding the required resources regarding people, finances, technology. Additionally, the CIPS process is made specifically for NS, as shown in figure 2. The proposed NS roadmap architecture development consists of the activity groups related to the layers, time and graphics. In which each activity group incorporated corresponding criteria. In addition, within each activity group the roadmap strategy is reinforced and feedback from participants is processed.

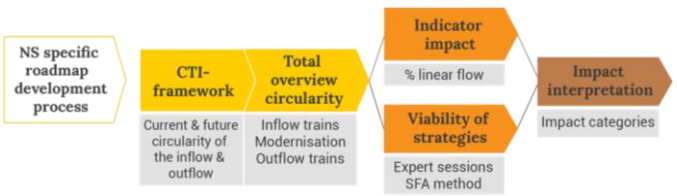

Figure 2.; The NS specific roadmap development process.

4. The NS CT'30 roadmap

The proposed circular CIPS process is demonstrated through the NS case study, resulting in a three-layered NS CT'30 roadmap that corresponds with the NS lifecycle phases:

1. inflow of new trains, with the sublayers material inflow, material outflow and material data management,
2. modernisation, with material inflow and material outflow as sublayers and
3. outflow of trains, with the sublayer material outflow.

In which, each main layer has designated sublayers, impact categories, stakeholders, and a strategy to support the interpretation of the overall impact of the linear material flows.

The corresponding timeframes are a timeline from 2020 till 2050, the timeline of the trains, and the short term, mid-term and long term projects timeline to achieve the milestones for acquiring the best possible solutions on the market by 2025 and obtaining 100% circular inflow and outflow by 2030. Figure 3 illustrates a simplification of the characteristics of the roadmap.

5. Recommendation for the implementation of the roadmap

For implementing the circular roadmap, three recommendations for NS are put forward. The first recommendation entails determining the available resources in terms of time, people and budget, however this only concerns the implementation and not the realisation of the roadmap yet. For this, it is essential to create a champion team with members who have deep knowledge and are (heavily) involved in the operations of the NS lifecycle phase of the trains.

Secondly, building a tailor-made implementation plan for the operations of NS is recommended. The champion team preferably does this by combining a suitable change management approach with the three stages of the roadmap implementation; initiation, development and integration.

The third recommendation addresses a full integration between the circularity, the roadmap and the business objectives, thus aligning the CTI framework, the roadmap, the organisational performance matrices and the corporate governance of NS with each in order to measure, report and act according to the progress made.

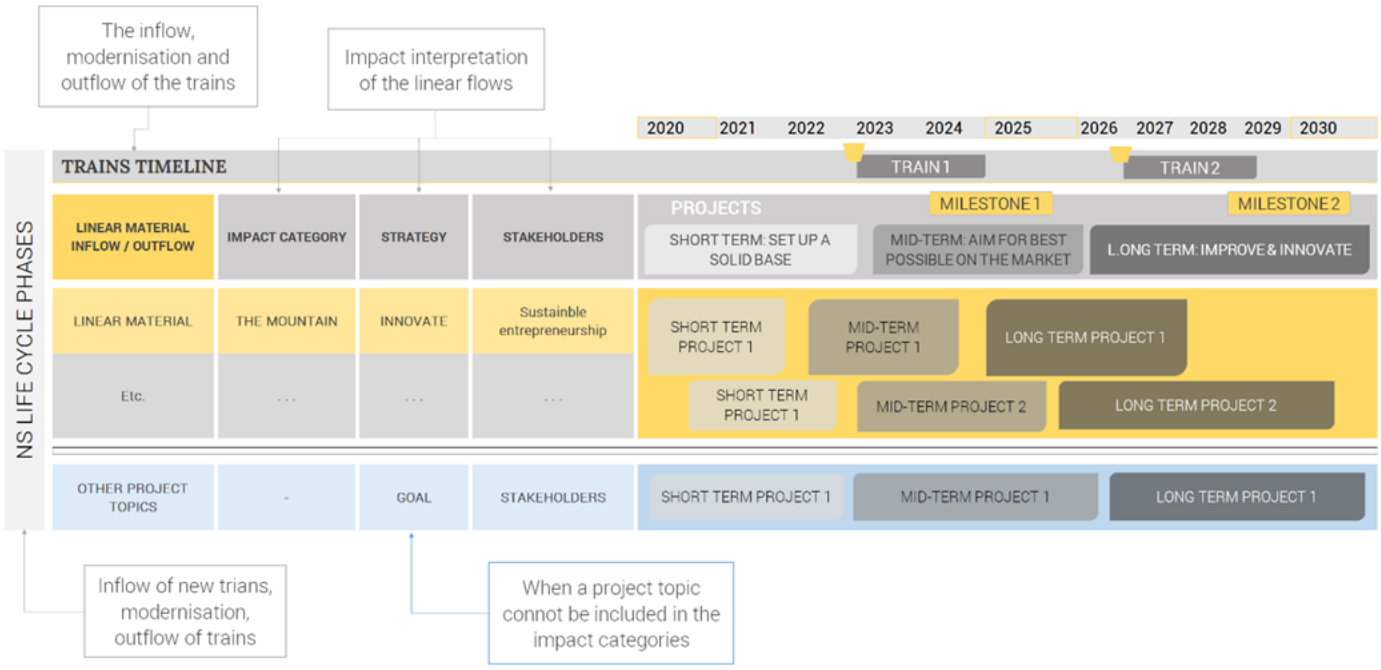

Figure 3.; Simplification of the characteristics of the roadmap.

6. Conclusion

Finally, circular inflow and outflow for the current trains of NS by 2030 using the CTI framework can be realised through developing and implementing the tailor-made circular roadmap and the corresponding roadmap strategy.

The combined strategies of each main layer form the roadmap strategy, which implied in the short term for the inflow setting up specifications with the other train operators and researching the use of non-virgin content, the circular design, the actual recovery and the certification of renewable materials and implementation of material passports, for the inflow of new trains. For the modernisation phase, to put the obtained knowledge from the researches into practice and set up circular requirements for the modernisation. Finally, for the outflow phase, research the most circular ways to deal with the linear outflows and the highest actual recovery rates, then collaborate with the most suitable partners.

Based on the results of the short term projects, in the mid-term the roadmap strategy implied to research which parts have the most potential for a modernisation and how to make the modernisation process more circular, consequently to partner up with the most circular manufacturers with the best circular capabilities.

In the long term, the roadmap strategy implied collaborating with the sector to innovate the percentages of non-virgin content, circular design, percentage of the actual recovery, the implementation of material passports, the modernisation of trains and the actual recovery in order to reach the highest rate possible.

7. Discussion

Based on the insights derived from this research various discussion points for further thought are highlighted.

First of all, the CIPS and the Circular CIPS roadmap development processes are only demonstrated in the case study of NS. It would be interesting to demonstrate them in various similar case studies and different contexts, with other CI frameworks and other definitions of the circular economy. In addition to this, from the railway sector perspective, the comparison between the European railway companies showed that not all of them use the exact CE definition and CI framework. For them, using the proposed processes could result in different roadmaps with other interests, while sector collaboration is required and all of them have similar (final) circular goals.

Another thought-provoking point would be the availability of the required datasets to calculate the inflow (percentage non-virgin content) and actual recovery for the CTI framework. This raises the question of whether that information is even available and, when obtained (from the manufacturer after a purchase, for example), how to assure that this information is reliable.

Lastly, a complication between the theory and practice was evoked due to the fact that the circularity changes regular basis and that it should be tracked in real-time, in which the percentage of non-virgin content and the actual recovery should be known of the changing components.

8. Recommendations

The roadmap is developed according to its specific focus and scope, however it can be further enhanced and complemented beyond this given scope.

Improvements for the continuation of the roadmap could be achieved by using more railway specific datasets for the percentage of non-virgin content and actual recovery. Where preferably the obtained material data from the manufacturer is confirmed through a legitimate process for its reliability and the data sets are more specified to the railway sector.

It is also recommended to develop strategic collaborations further and create or opt for an industry roadmap with the relevant external stakeholders, such as the other European railway companies, governments, research institutions, overarching organisations, main train manufacturers or even suppliers of the train manufacturers. This way, all the relevant stakeholders throughout the supply chain will head in the same direction hence the required innovations can be pushed faster.

Lastly, research in ways for adapting digital innovations such as the digital twin and block chain technologies could enhance accessing and processing real-time reliable data to calculate and keep track of the circularity in combination with business objectives.

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