

MASTER THESIS

DENISE HUIZING

TOWARDS CIRCULAR ECONOMY BY INCORPORATING PRODUCT-SERVICE SYSTEM IN INFRASTRUCTURE PROJECTS

Developing a model that provides insight into the application of PSS characteristics in the project lifecycle of infrastructure projects to support a circular economy


TU Delft



DURA VERMEER



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TOWARDS CIRCULAR ECONOMY BY INCORPORATING PRODUCT-SERVICE SYSTEM IN INFRASTRUCTURE PROJECTS

Developing a model that provides insight into the application of PSS characteristics in the project lifecycle of infrastructure projects to support a circular economy

by Denise Huizing

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ost of my days in the last seven months were filled with reading articles, writing texts, designing a model and talking about this thesis. Six years ago, I made the decision to study Architecture at the Technical University in Delft. A conscious choice to develop myself in an area where I might have an impact on the daily life of people. During the bachelor, I gained broad knowledge and skills in the various fields of the construction industry. After completing my bachelor, I decided to focus more on the process level, whereby the master

construction management and engineering was perfectly matching my interests. From the beginning of my study time, I have always seen sustainability as important, because I think there is no reason to don't see the importance. However, over the years it became clear to me that there are many people that think, but also act differently, also in the construction sector. After finishing my courses, the time of graduation had arrived. Finding a topic for my graduation thesis was not difficult for me. My interest in sustainability has led to the realisation that the construction sector has to change drastically. After reading articles and seeing a documentary about the circular economy, it became clear that a radical transformation of the system is necessary. In the meantime, I saw a movement in which ownership of a product is becoming less important, and that it mainly concerns about the functionality of products (e.g. shared cars, Netflix, Spotify and the coupling of bicycles to the Dutch public transport pass). The question arises whether this could also be applied to the infrastructure sector, as it has been identified as a way to realise efficiency and sustainability. And there, my research topic was born!

Now, after months of research, I believe I have found an interesting way to implement circularity in the infrastructure sector, which hopefully can act as input to practice to set steps forward to circular economy. Writing my thesis has been an instructive process in which I have been able to apply the knowledge and the skills that I have gained during my study period. Besides that, I also developed a lot of new skills and knowledge. Before presenting the results of this thesis, I would like to thank the people that have supported me during this thesis.

To begin, I would like to thank my graduation committee of the TU Delft with their help throughout the process. You made it possible to let me reach a higher academic level. A special thanks to my first supervisor, Daan Schraven, for his helpful and supportive comments on my research. Additionally, to my second supervisor, Joyce Kooijman, for her useful legal knowledge and guidance. My professor, Hans Bakker, for his critical comments and trust throughout the research. Finally, thanks to my company supervisor, Karlijn Mol, who supported me on a daily basis at Dura Vermeer. I have really appreciated your availability and time to have a chat, and your constructive feedback.

Second, I would like to thank all colleagues at Dura Vermeer for the open attitude towards my research. Also, a special thanks to the members of the development group of 'De Circulaire Weg' who provided me with substantive information. Participating in this development program was a great experience for me to develop knowledge and skills regarding the application of research insights in practice. Furthermore, I would like to thank the people who opened their network for me, especially all colleagues at Dura Vermeer. You have made it possible for me to conduct interviews and to participate in useful meetings. Additionally, a thank you to all interviewees and participants of this research who made time for me available and to be open about their experiences, as well as providing me with a lot of great insights into their organisations.

In addition, a special thanks to all the people that helped me with the execution of this research, as well as supporting me throughout my time as a student. These people include my parents, and boyfriend Jim, who supported me mentally, substantively and financially throughout my time in Delft. Furthermore, my friends and family who were always there to cheer me up when struggling in the graduation process. Additionally, special thanks to my fellow graduate students who made time available to discuss and reflect on my research. Finally, I would like to thank Marloes and Martijn for revising my English, and Fred for helping me with the design of my report. Thanks to everyone's contribution, this graduation process was a lot more fun!

Enjoy reading!

Denise Huizing
Amsterdam, January 2019

EXECUTIVE SUMMARY

INTRODUCTION

On a global scale, a transition is proceeding towards a new economic model. The current linear economic model of ‘take, make and dispose’, which is applied in the construction sector as well, depends on raw materials that are easily accessible (The Ellen MacArthur Foundation, 2015). This economic model has been applied for centuries, placing a large amount of stress on the earth as a resource provider. Therefore, this economic model is not future-proof and a change towards a new economic model is required. Mentink (2014, p.14) defined circular economy as “an economic system with cyclical material loops based on a financial incentive”. To change in the infrastructure sector from the linear model into a circular model requires a crucial transformation. Both contractors and clients do not sufficiently know how the principles of circular economy can be implemented in infrastructure projects. In the infrastructure sector, project delivery methods are used as a system to organise and finance a project in front of the lifecycle to facilitate the delivery of a good or service (Miller et al., 2000). Academics noticed that one of the tools in the transition towards circular economy is the concept of product-service systems (PSS) (Adrodegari, Saccani, & Kowalkowski, 2016; Bastein, Roelofs, Rietveld, & Hoogendoorn, 2013b; Michelini, Moraes, Cunha, Costa, & Ometto, 2017). Research in other sectors has shown that the more a product is delivered as a service, the more it fits with the principles of a circular economy (Michelini et al., 2017). An important question is whether, and under which conditions, the shift from paying for ownership to paying for use will take place. Further, it has to be identified in what way this change is contributing to incorporate economic, as well as environmental benefits, and the transition to a circular economy. The objective of this research is to gain a deeper understanding of financial, legal, organisational and technical considerations regarding the application of a product-service system on a project level. Besides that, this research aims to find out how these characteristics could be implemented in project delivery methods to contribute to a circular economy. To achieve the objective, the main research question is formulated as follows:

“How can product-service system characteristics be implemented in project delivery methods to support a circular economy in infrastructure projects?”

METHODOLOGY

To answer the main research question a qualitative design-based research is conducted by using several methods. First, a literature study is done in which the concept of a product-service system is defined as central definition of service delivery. In addition, it is identified that product-service systems do have legal, financial, organisational and technical characteristics. After defining the theoretical framework, the Double Diamond methodology was chosen to compile and analyse the application of service characteristics in project delivery methods and to come up with a solution that could be applied in practice. To collect data, it was decided to participate in the development program ‘De Circulaire Weg’ as a single case study to observe and gain insight in the perspective of the contractor regarding the application of PSS characteristics. This program aims to develop the concept of applying service aspects in infrastructure projects from a multidisciplinary perspective. Furthermore, to gain insight into the perspective of the client and supplier, in relation to the application of the PSS characteristics, semi-structured interviews were conducted. In total, interviews were conducted with six public client organisations, and three supplier organisations.

RESULTS

During analysis, it became clear that for the application of PSS in infrastructure projects five conditional state-of-affairs should be fulfilled to include PSS characteristics in projects. In addition, throughout the project lifecycle, some required changes are identified as being important as shown in figure 1.

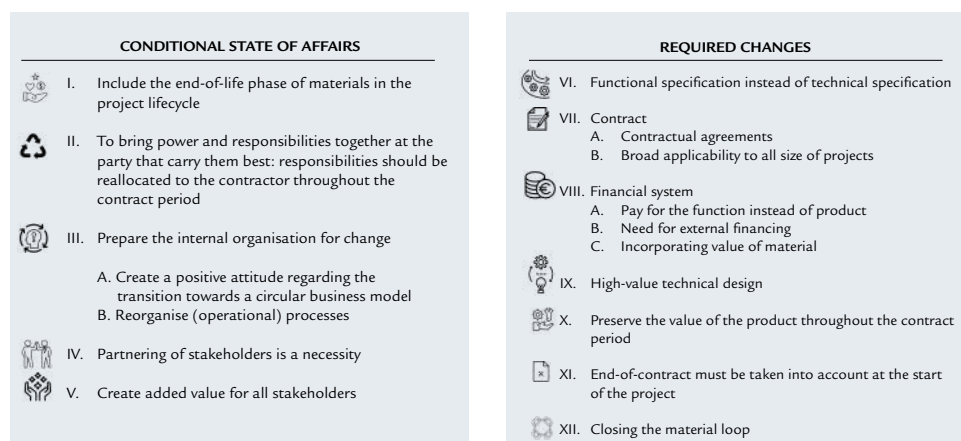


FIGURE 1. PREREQUISITE CHANGES FOR THE APPLICATION OF PSS IN AN INFRASTRUCTURE PROJECT

To develop a project delivery method suited to circular economy and incorporating PSS characteristics it is identified that certain steps should be taken. The concept of product-service system consists of three categories: product-oriented services, use-oriented services and result-oriented services (Tukker, 2015). The distinction between the various categories are based on the ration whether the value is by the product component or by the service component (Tukker, 2015, pp. 80–81). Additionally, from literature it was adopted that product-service offers a better fit within the opportunities of the infrastructure market compared to a competing product offer. Therefore, an agenda for change is developed to clarify what steps need to be taken to make the transition to application of product-service in the infrastructure sector.

After analysis, these prerequisite changes for application in infrastructure projects were plotted in the project lifecycle in order to clarify their position and point out their influence on other activities or processes in the lifecycle. During the research, a model has been created based on the application of PSS characteristics during the different stages of a project.

The outcome of this model leads to the most optimal situation in relation to circular economy for application to the infrastructure sector. The model indicates that the identified prerequisite changes need to take place up front and during the lifecycle of the infrastructure project to transform towards a service-oriented project delivery (see

figure 2.). This model creates insight for stakeholders in the infrastructure sector to indicate what characteristics need to be included when developing a suitable project delivery method for infrastructure projects complying with the principles of circular economy. Most important change in relation to the existing project lifecycle is the inclusion of the end-of life phase, which should be standard incorporated in project delivery of infrastructure projects to support the closing of the material cycle.

DISCUSSION AND RECOMMENDATIONS

From the agenda for change it is concluded that there are two conditional state-of-affairs that influence the transition from product delivery towards service delivery the most. First, the reallocation of power and responsibility to one entity is seen as an important prerequisite to change towards service delivery in infrastructure projects. Due to the distribution of responsibilities throughout the lifecycle to the contractor, an incentive will be created to preserve the value of the product throughout the product lifecycle. Especially when incorporating the (residual) value of materials in the financial model, an economic incentive is created. The second state-of-affair that influences the transition towards a more circular model is the extension of the project lifecycle with the inclusion of an end-of-life phase. Hereby, opportunities for closing the loop are generated which supports the application of PSS characteristics in relation to circular economy. However, in all cases it is important that the client changes the specification of projects from technical towards functional.

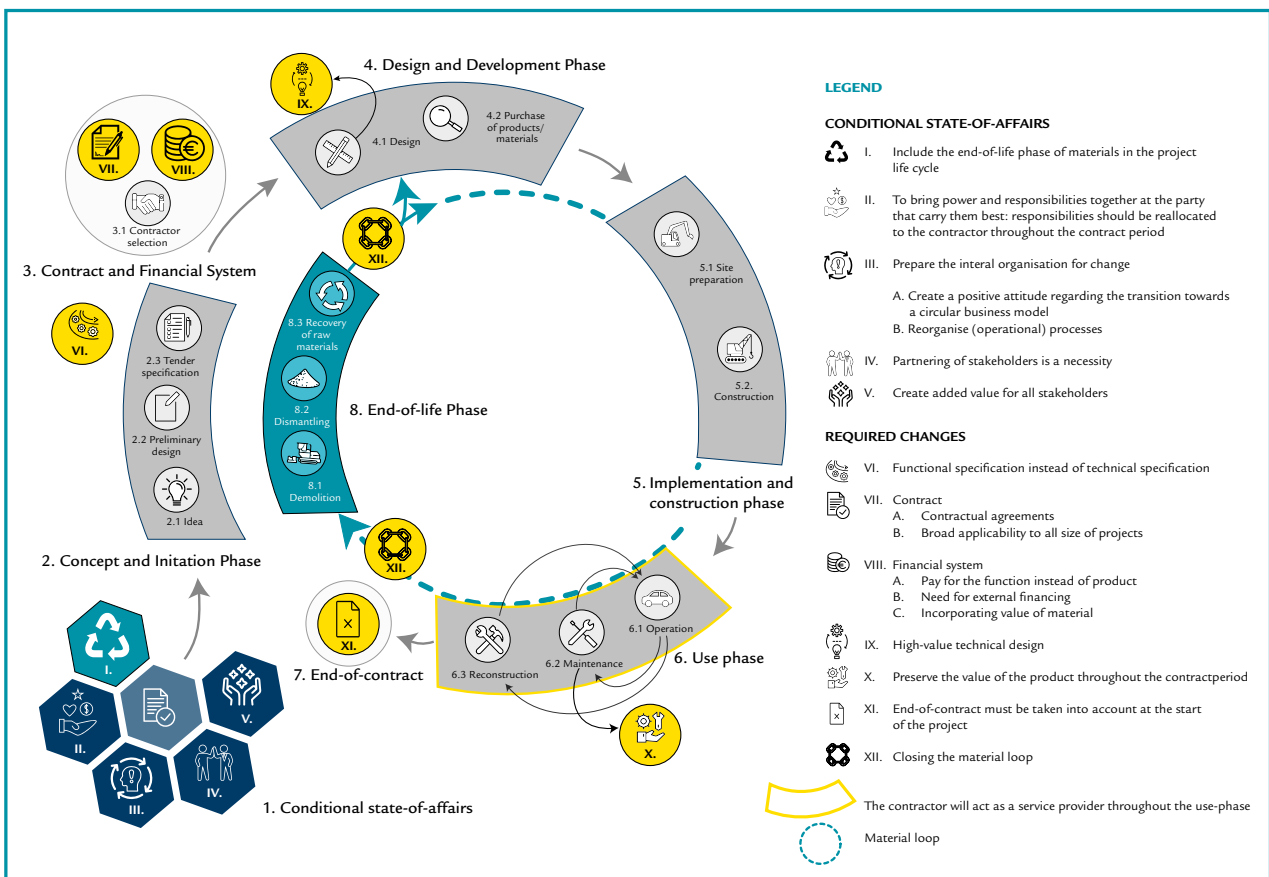


FIGURE 2. FINAL MODEL INCORPORATING PSS CHARACTERISTICS IN INFRASTRUCTURE PROJECTS



The developed agenda for change indicates what steps need to be taken to transform from product-oriented projects towards service-oriented projects. The model that has been created can be used beforehand, when project teams are defining how the project must be organised through the different lifecycle phases. In addition, it also clarifies what contractual agreements and financial system need to be developed on project level. During analysis, it appears that it is currently not possible to achieve the third category of PSS.

In the result-oriented service category the business model is geared towards selling a result instead of a product, a pure-service, where no predetermined product is involved. This is currently not possible for the infrastructure sector, whereby the road (the product) is still prerequisite for transport. Therefore, in infrastructure projects it will be only possible to achieve the use-oriented product-service system category by following the model as developed in this research.



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LIST OF ABBREVIATIONS

CE	Circular Economy
CM	Construction Management
BIM	Building Information Model
BOT	Build Operate Transfer
BOOT	Build Own Operate Transfer
DB	Design Build
DBB	Design Bid Build
DBFM	Design Build Finance Maintain
DBFMO	Design Build Finance Maintain Operate
DC	Dutch Civilcode
DCW	De Circulaire Weg
DNR 2011	De Nieuwe Regels 2011
E&C	Engineer & Construct
PDM	Project Delivery Method
PSS	Product-Service System
UAV	Uniforme Administratieve Voorwaarden
UAV-GC	Uniforme Administratieve Voorwaarde Geïntegreerde Contracten
VAT	Value Added Tax

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CHAPTER

1

INTRODUCTION

1. INTRODUCTION

The world is on the verge of a substantial change in behaviour. The production model, in which people work to buy things, is coming to an end (VPRO, 2015). More often it appears that people do not want to own the product, but want to have access to it and use it (Bastein, Roelofs, Rietveld, & Hoogendoorn, 2013a; Remmerswaal, Kishna, & Hanemaaijer, 2017; VPRO, 2015). On a global scale a transition is proceeding towards a new economic model. The current linear economic model of 'take, make and dispose', which is applied in the construction sector as well, is dependent on raw materials which are easily accessible (The Ellen MacArthur Foundation, 2015). This economic model has been applied for centuries, placing a large amount of stress on the Earth as a resource provider. Circular economy is a crucial transformation factor for the construction industry. Yet, both clients and contractors struggle on a daily basis with the integration of circular economy aspects in projects. Something which requires crucial changes in order to make the transition possible is the transformation from product to service. Therefore, there is a need to prepare the infrastructure sector for change. An important question is whether, and under which conditions, the shift from paying for ownership to paying for use will take place. Further, it has to be identified in what way this change is contributing to incorporate economic, as well as environmental benefits, and the transition to a circular economy.

The Dutch government has identified three important reasons to switch to a circular economy: 1) Dutch industries are asking for large amounts of raw materials, 2) the industries are depending on foreign countries and 3) the current impact on earth's climate is not future proof (Ministry of infrastructure and the environment & Ministry of economic affairs, 2016). The concept of a circular economy (CE) describes an economy in which material loops must be closed. The CE concept could be a solution to economic and environmental problems that are caused by the extraction of raw materials from nature (Mentink, 2014; MVO Nederland, 2018; The Ellen MacArthur Foundation, 2015).

The construction sector is also subject to these changing circumstances, since this industry has an important share in the extraction of raw materials by using these materials on large scale. Transformation towards a circular economy in the construction industry is necessary to make the construction sector future proof. Since there will be a scarcity of raw materials in the nearby future it is essential to gain more insight into what this transition entails for the delivery of construction projects. The Dutch government has developed a transition plan in order to change from the current linear economy towards a circular economy by setting the goal that the Netherlands must achieve a 100% circularity in 2050 (Ministry of infrastructure and the environment & Ministry of economic affairs, 2016). The concept of a product-service system (PSS) is defined by Baines et al. (2007, p.1) as "a market proposition whereby

the traditional functionality of a product will be extended by incorporating additional services which implies the relocation of the emphasis on the sale of use rather than the sale of product". When applying product-service system characteristics the customer is going to pay for the use of the asset and no longer for its purchase (Baines et al., 2007). The customer will benefit from changing circumstances, like the restructuring of risks and having less responsibilities, but also the costs that are associated with having the asset in property (Baines et al., 2007). One of the principles of circular economy is comparable to the concept of PSS, since it indicates that producers preserve the ownership of user products, whereby the customers pay for the use and not for possession (MVO Nederland, 2018; The Ellen MacArthur Foundation, 2015). Therefore, in contrast to the current economic system, a change must be made from traditional design and supply of large products on project basis towards service provision throughout the lifecycle of products (Alderman & Ivory, 2010).

Existing research on circular economy in the construction industry shows the relevance to change, also in projects preparing for the future of project delivery (Alderman, Ivory, McLoughlin, & Vaughan, 2005; The Ellen MacArthur Foundation, 2015). Backes (2017) notified that these researches have prioritized asking the why question. The how question is becoming increasingly important, but remains unanswered (Backes, 2017). Research in other sectors, based on literature regarding product-service systems, has shown that the more a product is service-oriented, the more it fits with the principles of a circular economy (Michellini et al., 2017). However, in relation to the infrastructure sector, this research is still limited.

To make the transition and use a more circular approach it is necessary to transform the current product-oriented infrastructure sector towards a service-oriented sector. An important aspect of the construction industry is the fact that this sector is driven by projects (Vrijhoef & Koskela, 2005). A construction project is often subject to a cooperation between client and contractor, which is mostly done on the basis of an agreement between both parties. This agreement is described as a project delivery method, which is defined by Miller, Garvin, Ibbs and Mahoney (2000, p.59) as "a system for organizing and financing the project for the design, construction, operation and maintenance phase". Current project delivery methods are all in line with the principles of a linear economy, which emphasizes the need to come up with a circular method. This method should consider the entire lifecycle of an asset, including the fact that all assets have an expiration date. Implementing service aspects in infrastructure projects requires changes to current project delivery methods, which incorporates the entire lifecycle of a project, as well as the financial feasibility of the model.

1.1. PROBLEM STATEMENT

To reach the Dutch goals of circular economy change is required (Nelissen et al., 2018). Current project delivery methods describe a linear process. Given that the infrastructure sector has to change towards a

circular economy there is a need for a project delivery method that stimulates circularity. This method should consider what happens to the materials before, during and after the lifetime of an infrastructure asset. There are integrated project delivery methods that already have some characteristics of circularity (Hoezen et al., 2010; Lenferink, Tillema, & Arts, 2013). For example, increasing the value of the product for the owner and maximizing efficiency by integrating diverse phases. However, in these project delivery methods the infrastructure projects are still focused on delivering a product against the lowest price (Leiringer & Bröchner, 2010).

In the current contracts, ownership of infrastructure will be handed over to the client, after completion of the project. Sometimes, besides the infrastructure work itself, a maintenance contract is added. This is also indicated as a service from the contractor to the client (Hoezen et al., 2010). The transition from product-oriented towards service-oriented is something that requires changes in contracts and collaboration between actors in the construction industry. To make the change from a linear business model towards a circular business model, diverse strategies are identified as possible solutions.

However, stakeholders in the infrastructure sector have a lack of knowledge regarding the application of certain circular strategies. In literature it is indicated that the transition from product delivery to the delivery of a long-term service could possibly be a solution to support the transition from a linear economy to a circular economy. A change from product delivery to the delivery of a service requires changes in the organisation of projects. Therefore, the infrastructure sector needs insights in which aspects have to be incorporated in project delivery methods to support the transition towards CE. The application of the service characteristics on project level must also fit within the existing legal framework, since all projects are subject to contractual obligations.

Currently, infrastructure as a service, where ownership ratios have shifted from client to producer, is not yet applied in Dutch infrastructure (Lenferink et al., 2013). As a result, the infrastructure sector deals with a lack of knowledge about what the application of a product-service system entails (consultation meeting DCW, personal communication, October 30, 2018). It is important to carry out research to find out what changes in project delivery methods must take place to make the transformation from product to service applicable for Dutch infrastructure projects.

Therefore, there is a need to develop a model in which it becomes clear how service aspects could be implemented and to find out if incorporating service aspects can stimulate the transition towards circular economy in infrastructure projects.

This is summarized in the following problem statement:

“Both contractors as well as clients do not sufficiently know how service aspects can be implemented in project delivery methods in order to find a structure in which circular principles could be integrated in the delivery of infrastructure projects.”

1.2. RESEARCH GOAL AND OBJECTIVE

Based on the introduction and the problem statement, this research attempts to design a systematically developed model intended to implement service characteristics in project delivery of infrastructure projects.

The aim of this research is to gain a deeper understanding on the financial, legal, organisational and technical considerations regarding the application of product-service systems and how these characteristics could be implemented in project delivery methods to contribute to a circular economy.

1.3. RESEARCH QUESTION(S)

To achieve the above-mentioned research objective, this research aims to answer the following research question:

“How can product-service system characteristics be implemented in project delivery methods to support a circular economy in infrastructure projects?”

The main question is divided into several sub-questions, which correspond to the steps that have to be taken to answer the main research question.

- 1) What are the characteristics of a product-service system when applied to the infrastructure sector?
- 2) How to compile and analyse the product-service systems characteristics for application in a project delivery method for infrastructure?
- 3) What changes are required for the application of product-service systems characteristics as part of the project delivery method for infrastructure projects?
- 4) How can the identified changes be incorporated in the project lifecycle to achieve a higher level of product-service system in infrastructure projects?

1.4. SCOPE OF RESEARCH

This thesis is conducted in cooperation with Dura Vermeer, which is one of the largest contractors in the Netherlands. The development program ‘De Circulaire Weg’ was carried out by the department ‘Participaties’ (English: Participations). This department is part of the division of Infrastructure and focuses on new businesses in the construction sector. In addition, this department is responsible for specialised companies that are (partially) owned by Dura Vermeer.

Delivering construction projects as a service, by following the principles of a circular economy, is a big comprehensive topic in research. Due to the broadness of this topic, the following scoping decisions are made to define a framework in which this graduation thesis will be conducted. The first decision is to focus on the infrastructure sector, because (1) Dura Vermeer started a development program in relation to CE which aims to discover how a road (infrastructure) can be delivered as a service, (2) the majority of projects are between the contractor and public client which reduces complexity, and (3) the infrastructure sector is most in line with the courses I took during my studies and therefore within my field of knowledge. Furthermore, since the contractor is normally the party that should come up with a proper



plan for execution in the tender phase (shaping the project delivery method throughout the lifecycle of a project), this research is conducted from the contractor point of view, in this case specifically from the perspective of Dura Vermeer.

1.5. RESEARCH RELEVANCE

The research process is motivated by a problem observed in practice, as well as the gap in literature on the application of service aspects in the construction industry. This serves as the starting point for this study.

1.5.1. SCIENTIFIC RELEVANCE

Research within the theme of circular economy is growing. Existing literature on circular economy often stays at an abstract level. This makes it difficult to understand how the principles of a circular economy can be adopted by companies and applied in projects and processes (Ellen MacArthur Foundation, 2013; Mentink, 2014; van den

Brink, 2015). It implies that there is a gap between the theoretical principles and the practical implementation of the circular economy principles. Currently, there is an increasing amount of research done on the implementation of circular economy at Delft University of Technology to close this gap. However, none of these studies focus on the circular principle in which ownership remains with the producer, which implicates a research gap regarding the transition towards a more service-oriented industry. Earlier research already focused on circular business models and circular contract forms (Castelein, 2018; Mentink, 2014; van den Brink, 2015). However, this research is unique in that (1) it investigates how service aspects can be implemented in project delivery methods, (2) it is set up in a way that it will be applicable for infrastructure projects in practice and (3) it indicates which changes are needed in current project delivery methods to make the transition towards a more circular approach in infrastructure projects. In general,

this research aims to close the literature gap by developing a model that incorporates service characteristics and can be applied to the construction industry with a focus on the infrastructure sector.

1.5.2. PRACTICAL RELEVANCE

In recent years, a movement has arisen to achieve circular economy in the construction sector (Nelissen et al., 2018; Wientjes et al., 2016). This was recognised in vision documents such as the transition agenda and ‘de Bouwagenda’ (in English: the construction agenda). In practice there are currently many initiatives to enhance circularity on a project level. For example, the contractor Dura Vermeer is working on the development of a concept implying a circular road (called “De Circulaire Weg” in Dutch). Many steps have been taken in this development program to create a business model that is in line with the principles of a circular economy. The existing concept of the circular road consists of a design that aims to use as little material as possible. Developments are taking place to design the road in such a way that it is possible to separate materials after expiration of the function of the road. This requires close collaboration with partners who also pursue a circular economy in their products. The increased attention for circular economy in the construction industry stresses the (growing) need for applying other business models, since currently the focus of linear business models is not in line with the principles of a circular economy. As indicated in the introduction, changing from product delivery towards service delivery in the infrastructure could possibly change the current linear business model into a circular business model. Therefore, more insights about implementing service characteristics are needed to help the construction industry to make the step towards the delivery of circular infrastructure projects. Especially tender managers want to get more insight in how to organize projects in a way that they comply with the principles of circular economy. Therefore, this research aims to find a solution for the implementation of service aspects in project delivery methods to come up with new project initiatives that are in line with the principles of circular economy.

1.5.3. SOCIETAL RELEVANCE

As indicated in Dutch government documents, changing the construction sector will have a significant impact on the transition to a circular economy (Wientjes et al., 2016). For example, the Dutch construction and demolition sector represents an important share within the Dutch economy, with building production worth 72 billion Euros (Van Odijk & van Bovene, 2014). In the Dutch circular program it was noticed that the construction sector is responsible for 40% of the total energy consumption and

30% of the total water consumption in the Netherlands (Ministry of infrastructure and the environment & Ministry of economic affairs, 2016, p.60). In addition, the biggest negative impact of the construction sector in relation to circularity is caused by the dependency on fossil fuels, which is indicated to be more than 90% (Van Odijk & van Bovene, 2014, p.8). The fuel consumption totalled about 260 million tons in 2010 (Van Odijk & van Bovene, 2014, p.8).

Besides the dependency on materials and fuels, the construction sector is also responsible for approximately 35% of the CO₂ emissions (Ministry of infrastructure and the environment & Ministry of economic affairs, 2016, p.60). A large proportion of all waste in the Netherlands (around 40%) relates to construction and demolition waste (Ministry of infrastructure and the environment & Ministry of economic affairs, 2016, p.60). The negative impacts of the construction sector affect the society in the change towards a better economic model. Therefore, the construction sector is indicated as one of the priority sectors that have to change to transform towards a circular economy (European Commission, 2015).

1.6. RESEARCH DESIGN AND THESIS OUTLINE

To answer the research questions, as developed in this chapter, the following research design is formulated (see figure 3). In the first place, there is a need for a further exploration of the concept of service in relation to the infrastructure sector. In addition, service characteristics should be determined to clarify which changes are necessary in the transition from product delivery towards service delivery. Therefore, the second chapter represents the theoretical framework focussing on the definition of service and service characteristics, providing an answer to the first sub-question. Second, to enable further research, a methodology is chosen which will help to gather and investigate data, in relation to the application of service characteristics to project delivery methods. This will be further elaborated in chapter 3 and will give an answer to the second research question. Chapter 4 postulates the results and analysis with the application of the methodology. First, the required changes for applying service delivery in project delivery method are identified, which answers the third research question. Subsequently an agenda for change is set up, providing an answer to the fourth sub-question. In addition, the validation of the developed model will be described. In chapter 5 a discussion is carried out to critically analyse the outcome of the research. Lastly, chapter 6 draws conclusions on the application of service characteristics in project delivery methods by answering the main research question.

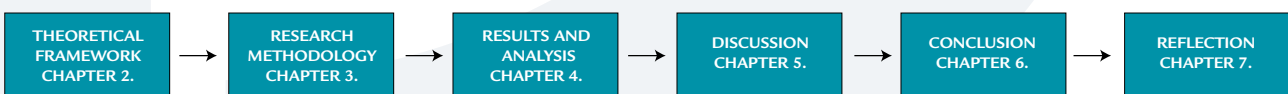


FIGURE 3. THESIS OUTLINE





CHAPTER

2

**THEORETICAL FRAMEWORK:
CIRCULAR ECONOMY AND
PRODUCT-SERVICE SYSTEM**

2. THEORETICAL FRAMEWORK: CIRCULAR ECONOMY AND PRODUCT-SERVICE SYSTEM

This chapter provides an answer to the first research sub-question which is formulated as: “*What are the characteristics of a product-service system when applied to the infrastructure sector?*”. Before elaborating on product-service systems and its opportunities for application in the infrastructure sector, the need for change is introduced in paragraph 2.1. In paragraph 2.2. the concept of a product-service system in general is defined. Then, the definition and exploration of project delivery methods in the infrastructure sector are postulated in paragraph 2.3. After this, in paragraph 2.4. a short explanation is given regarding the current organisation of Dutch infrastructure to clarify the system in which this research takes place. In addition, section 2.5. discusses the characteristics of product-service systems when applied in the context of infrastructure projects. Followed by paragraph 2.6., in which an exploration of strategies is given that are important to consider when applying PSS to the infrastructure sector in order to support circular economy. Lastly, in paragraph 2.7. a conclusion is drawn in relation to the theoretical framework.

2.1. THE NEED FOR CHANGE

The world is on the verge of a substantial change in behaviour. The production model, in which people work to buy things, is coming to an end (VPRO, 2015). More often it appears that people do not want to own the product, but want to have access to it and use it (Remmerswaal et al., 2017; Rijksoverheid, n.d.; VPRO, 2015). On a global scale, a transition is proceeding towards a new economic model. This new economic model is notified in literature as the transition from a traditional business model geared to sell products, towards a business model that is focused on the sale of the function rather than the product (Adrodegari et al., 2016). This combination of product and services is an alternative economic model to link sustainability goals to profitability (United Nations Environment Programme, 2015).

2.1.1. CIRCULAR ECONOMY

THE DEFINITION OF CIRCULAR ECONOMY

A circular economy (CE) is defined by The Ellen MacArthur Foundation (2013, 2015) as an economic system that supplies a framework and possibilities for economic growth, whereby the focus is to downsize the impact on the environment. In addition, it aims to reduce the use of raw materials by focussing on quality, and preserve the value of the materials and product by extending their lifecycle. Mentink (2014, p.14) defined circular economy as “*an economic system with cyclical material loops based on a financial incentive*”. In addition, Kjaer, Pigosso, Niero, Bech, & McAlone (2018) have defined a circular economy as an economic system having the aim to preserve the value of products, materials and resources as high as possible, and as long as possible in the economy while minimizing the production of waste.

According to the Ellen MacArthur Foundation (2015, p.3) the current linear economic model of ‘take, make and dispose’, which is applied in the construction sector as well, is not future proof. This economic model has been applied for centuries, placing a large amount of stress on the Earth as a resource provider (The Ellen MacArthur Foundation, 2015). The biggest problem of the current economy is that profit is a private gain, while the pollution created by making products is a public problem (Sauvé, Bernard, & Sloan, 2016). Price volatility, supply chain risks and growing pressure on resources are incentives that the current economic model has to change towards a circular economic model (The Ellen MacArthur Foundation, 2015).

The Ellen MacArthur Foundation (2013, p. 26-28) identified the following five principles to change towards a circular economy:

PRINCIPLES OF CIRCULAR ECONOMY

1. Design out waste / design for reuse
2. Build resilience through diversity
3. Rely on energy from renewable sources
4. Think in systems
5. Waste is food

Research of Mentink (2014) shows that achieving a circular economy in the business chain is more complex than applying just the principles of circular economy provided by the Ellen MacArthur Foundation. In Appendix A, the visual overview of Mentink (2014) regarding CE is adopted to show how this research matches to the principles of CE. In this visual overview it becomes clear that especially thinking in systems is a concept that can be broadly adopted through

increasing collaboration, increasing exchange, and understanding systems and system dynamics. Further, it is identified that circular economy refers to the idea of lifecycle thinking. Hereby, the focus is no longer on the production, but also includes environmental, social and economic impacts throughout the entire lifecycle (Amati, 2017).

PUBLIC AMBITIONS REGARDING CIRCULAR ECONOMY

More and more international, national and regional authorities have set high ambitions regarding circular economy. For example, in 2015, the European Commission set up an action plan for the circular economy. The aim of this plan is to adjust the regulatory framework in such a way that it will support the development of a circular economy (European Commission, 2015). This plan at European level has the purpose to drive investments in sustainability. In addition it aims to reduce barriers stemming from European legislation to ensure favourable conditions for innovation (European Commission, 2015). Besides that, the Dutch government started a nationwide program which focuses on the development towards a 100 percent circular economy to be realized by 2050. This shows that, also on governmental level, ambitions are set in order to change towards a circular economy (Ministry of infrastructure and the environment & Ministry of economic affairs, 2016). The Dutch government and business community work together on a circular economy with the aim to reuse products and raw materials.

The vision of the Dutch government regarding a circular economy in the construction sector is as followed:

“In 2050 design, development, use, management and disassembly will be organised in a way that objects will be built, (re) used, maintained and dismantled in a sustainable manner. During construction sustainable materials are used and the dynamic wishes of the users and clients are considered. The aim is to create an energy-neutral built environment in 2050 in accordance with European agreements.” (Ministry of infrastructure and the environment & Ministry of economic affairs, 2016, p. 61). Out of this research and these vision documents can be concluded that there is broad attention at policy level towards a circular economy in the construction sector.

Rijkswaterstaat (Directorate-General for Public Works and Water) and ProRail are the biggest public clients in the civil and hydraulic engineering industries, whereby each of these parties set their own goals regarding circular economy. Rijkswaterstaat aims to work a 100 percent circular by 2030 (Rijkswaterstaat, 2018). Currently, Rijkswaterstaat already uses a large amount of recycled material, because building waste is used for foundations in the construction of new roads or in renovation projects. Since this is not in line with the purposes of circular economy, Rijkswaterstaat strives for high-quality reuse in the future.

Waste becomes a fully-fledged raw material, resulting in a closed flow of materials (Rijkswaterstaat, 2018). In the program ‘Nederland circulair in 2050’ it is noticed that property must be replaced by the provision of services (Ministry of infrastructure and the environment & Ministry of economic affairs, 2016). This is substantiated with the example of lighting provided by the manufacturer as a service, whereby the ownership of the lamps remains with the manufacturer. The trend regarding development of the sharing economy is the shift from ownerships of goods to the possibility of using these goods (Ministry of infrastructure and the environment & Ministry of economic affairs, 2016), but this is not concretely substantiated in the document (Chao-Duivis, 2017). However, it becomes clear that a circular economy is broader than just the reuse of waste products (Ministry of infrastructure and the environment & Ministry of economic affairs, 2016; Wientjes et al., 2016)

2.1.2. NEED FOR A CIRCULAR BUSINESS MODEL IN THE CONSTRUCTION INDUSTRY

According to the authors of the Bouwagenda (2016) the complicating factor in the Netherlands is the current relationship between clients and contractors and the other parties in the construction chain. As identified by Mentink (2014), one of the principles of circular economy is that thinking in systems requires an increasing collaboration. Wientjes et al. (2016) argued that the obstruction of innovation occurs due to the current way of cooperating and the presence of distrust between parties. Furthermore, it is stated that competition is mostly on price, which leads to legalization of contract forms, little room for innovation and limitations in cooperation (Wientjes et al., 2016). In comparison to the current linear economy, the use of materials in a circular economy is at a minimum level and reuse of materials is done as much as possible. For the construction sector, there is a need to use products that are more economical, and people are looking for new, smart ways to produce them aiming to reduce the ecological impact.

On the other hand, companies should still generate sale, and therefore there is high need for the construction industry to look critically at their current business model in order to achieve circularity in construction projects. A business model gives an overview of what value the company creates with its product or service, how the value is created, who the customers are and what the financial model comprises of (Frankenberger, Weiblen, Csik, & Gassmann, 2013; Osterwalder & Pigneur, 2010). Mentink (2014) argued that the change of the construction industry towards circular economy is asking for a circular business model. In his research a circular business model is defined as *“a circular business model is the rationale of how an organisation creates, delivers and captures value with and within closed material loops”* (Mentink, 2014, p. 24).

2.2. FROM PRODUCT TO SERVICE DELIVERY

2.2.1. TRANSITION FROM THE SUPPLY OF PRODUCTS TOWARDS A SERVICE

In other sectors manufacturers have been working on strategies to deliver products that are more sustainable. The aim of these strategies was mostly driven by reducing costs of manufacturing and stimulating technical innovation, as well as the quality of the product. However, pressure from changes in the business environment has led to a decline of this transitional focus. Reasons for this diminishing focus are trends as globalisation, increasing competitiveness, but also an increasing customer demand and the accession of outsourcing of secondary activities (Lay, Copani, Jäger, & Biege, 2010). In response to changing circumstances companies started to transform their business to be more service-oriented, which resulted in profitability growth and the capturing of new revenue streams.

2.2.2. DEFINITIONS OF SERVICE DELIVERY

Several terms are used in literature to describe the delivery of a service. Studies in product-service system literature show that this is a rising theme in papers since 2003 and that there are several definitions of this term (Boehm & Thomas, 2013; Tukker, 2015). To find a definition for service delivery in the infrastructure sector the definition of product-service systems, and related concepts in general are shown in Appendix B. According to Robinson & Chan (2014, p.908) product-service systems and servitization are comparable concepts. However, the main difference is that the focus in product-service system literature is more on the environmental benefits, which will be achieved by combining the delivery of products and services.

Tukker & Tischner (2006) noticed that servitization creates an opportunity for suppliers to change the behaviour of their customers in a more sustainable direction by transforming their way of consumption. Hereby, servitization is argued to be a business model which supports transitions on an organisational level towards service-delivery (Robinson & Chan, 2014). A more sector specific term that is used in literature for the construction industry is service-led construction or integrated solution. The most important aspects of these service delivery definitions (see Appendix B) are integration of a bundle of products and services, satisfying the customer needs, lower environmental impact and the consideration of the entire life cycle of an asset. In practice, at the contractor, the term infrastructure as-a-service is often used to indicate the transition from product to service. Several researches underlined that the concept of product-service systems could be one of the tools to use in the transition towards circular economy (Adrodegari et al., 2016; Bastein et al., 2013a; Tukker, 2015; Van Ostaeyen, Van Horenbeek, Pintelon, & Duflou, 2013). Therefore, the model of product-service system was chosen to be the main concept in this thesis.

2.2.3. THE CONCEPT OF PRODUCT-SERVICE SYSTEM

A product-service system is characterised as a service-oriented business model that replaces selling products with selling services (United Nations Environment Programme, 2015). Michelini et al. (2017) implies that the concept of product-service systems is suited in the transition towards a circular economy. To comply with the governmental goals of a circular economy for the construction sector, there is a need for a strategy to deliver circular economy principles in infrastructure projects. Currently, there is a lack of clarity about the role of a product-service system within the circular economy concept and also about its potential to positively contribute to the transition (Blomsma, Kjaer, Pigosso, McAloone, & Lloyd, 2018). Bocken, de Pauw, Bakker, & van der Grinten (2016) stated that product life expansion is an example in which PSS is a means to facilitate CE. Blomsma et al. (2018) argued that product-service systems enhance a product's entire life cycle, but also includes the related activities. Such as, the manufacturing process and operations as well as activities regarding take-back, recycling and financial disposal. Therefore, a product-service system is defined as an opportunity to satisfy the customers' needs by delivering the combination of both product and service aspects to improve resource productivity, create value and reduce value destruction (Blomsma et al., 2018). This is in line with the construction industry, where there is always a combination of a product (the construction itself, based on the client demands) and the function it fulfils to which a certain service or performance is linked.

One of the principles of circular economy is comparable to the concept of product-service systems since it indicates that producers preserve the ownership of user products, whereby the customers pay for the use and not for possession (MVO Nederland, 2018; The Ellen MacArthur Foundation, 2015). Therefore, in contrast to the current economic system, a change must be made from traditional design and supply of large products on project basis towards service provision throughout the lifecycle of products (Alderman & Ivory, 2010).

The concept of PSS spans a wide range of activities since it is about a continuity between pure products (tangible products) and pure services (intangible acts or processes that exist in time). Figure 4. shows the division of the three categories, whereby product-oriented service is product related and the value is mainly in product content, while result-oriented service mainly delivers value through the service content (Tukker & Tischner, 2006). Tukker (2015, p. 80-81) noticed that distinctions of the different categories are based on the ratio, whether the value is by the product component or by the service component. Important aspects on which the categories differ are the distribution of product ownership, the extent to which the product is still involved and the value belonging to the service level (Tukker, 2015).

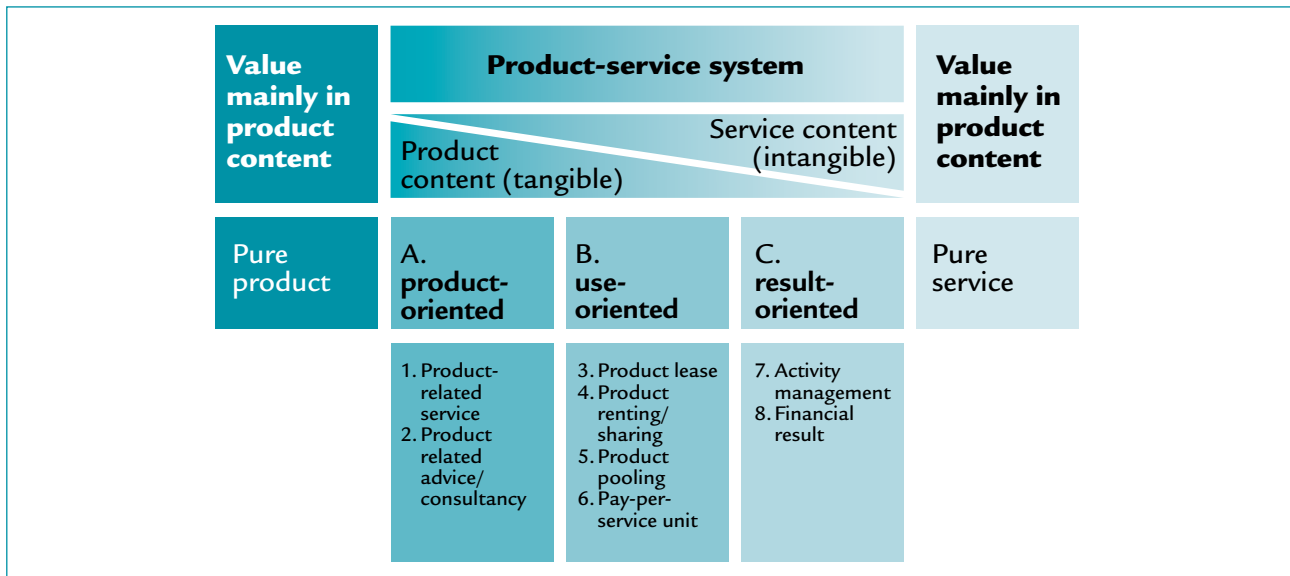


FIGURE 4. PRODUCT-SERVICE SYSTEM (ADOPTED FROM TUKKER, 2004, p.248)

Tukker (2015, 2006) divided the product-service system into three categories: product-oriented service (A.), use-oriented services (B.) and result-oriented services (C.). The more the focus shifts from product-oriented (A.) to result-oriented (C.) within the product-service system model (see figure 4.), the more ownership remains with the producer and the higher the theoretical potential for environmental improvements (Steger, O'Brien, Jordan, & Schepelmann, 2012). Table 1. provides an overview of the characteristics and the potential of each product-service system category.

TABLE 1. CATEGORIES OF PRODUCT-SERVICE SYSTEMS (TUKKER, 2015)

CATEGORIES:	CHARACTERISTICS	POTENTIAL
PRODUCT-ORIENTED SERVICE	This business model is aimed to sell products, with some additional services being added. This category includes product-related services, advices and consultancy. Examples are the application of take-back guarantees, maintenance contracts and financing contracts.	This system is comparable to the current integrated project delivery methods and therefore no major potentials are noticed. However, the application of the additional services can induce some environmental gains. Including a maintenance contract to the product can have an effect on the energy and resource use. However, the business incentive of this model is to sell the most as possible. There is full control over a product and there are simple agreements between parties and transactions often have a short duration.
USE-ORIENTED SERVICE	In this business model the product is still important, however the focus of business is no longer on selling as much as possible. This category is characterised by the changing position of ownership, since ownership of the product remains with the provider. Hereby, the product is made available for use (e.g. shared by a number of users).	Research concluded that when ownership is no longer transferred to the customer it often leads to less careful behaviour by the user. In contrast, also positive outcomes are identified, since product sharing and product renting leads to a higher use of the capital goods. The impacts of the use stage are also shared over the users of the product.
RESULT-ORIENTED SERVICE	This business model is characterised by the agreement between the client and service provider on a result, while there is no predetermined product involved. Result-oriented is focused on performance in which value is mainly in the service content and no longer in the product content.	A result-oriented service has the greatest effects on the environment, because the fact that there is no predetermined product involved. This creates freedom to come up with solutions that are different than the existing product concepts.

The potential of product-oriented services is more applicable to a linear economy, while in a circular economy long term transactions and efficiency in the use phase are more important. The use-oriented services and result-oriented services do ask for radical changes compared to the current situation. Therefore, the concept of product-service system is characterised by shifting the perspective from product ownership towards product utilisation (United Nations Environment Programme, 2015).

TABLE 2. COMPARISON OF PSS CATEGORIES IN TERMS OF VALUE CREATION, DELIVERY AND CAPTURING (REIM ET AL., 2015, P. 66)

	PRODUCT-ORIENTED	USE-ORIENTED	RESULT-ORIENTED
Value creation	Provider takes responsibility for the contracted services.	Provider is responsible for the usability of the product or service.	Provider is responsible for delivering results.
Value delivery	Provider sells and services the product sale and service sale (e.g. maintenance or recycling).	Provider assures the usability of the physical product along with service.	Provider actually delivers result.
Value capturing	Customer pays for physical product and for the performed services.	Customer can make continuous payment over time (e.g. leasing).	Customer payments are based on outcome units; meaning, they pay for the result.

This shift could lead to cost reductions and efficiency gains, and is therefore seen as possibility to be used for supporting the environmental objectives (United Nations Environment Programme, 2015). According to research of United National Environmental Programme (2015), sustainability benefits are not inherent in product-service systems. It is indicated that the right approach is necessary to achieve the preferable economic and environmental outcomes for the parties involved (United Nations Environment Programme, 2015). However, to put infrastructure on the scale of product-service systems it is important to first get more insight in the existing project delivery methods. Reim, Parida, & Örtqvist (2015) compared the different categories of PSS in terms of value creation, value delivery and value capturing (see table 2). This table shows that the more service-oriented a product is delivered, the more it meets the result as expected by the customer.

2.3. PROJECT DELIVERY METHODS IN INFRASTRUCTURE PROJECTS

2.3.1. THE DEFINITION OF PROJECT DELIVERY METHODS

Since the construction industry is dominated by a project-based approach (Vrijhoef & Koskela, 2005), it is valuable to find ways to implement service principles on project basis. To find a project delivery method that is suitable for the delivery of circularity in projects, it is necessary to find out what changes are required for application on a project level. A construction project is often subject to cooperation between client and contractor. This is mostly done on basis of an agreement between both parties. For every project, a project delivery method has been established. The definition of a project delivery method is as follows: “a project delivery method (PDM) is a system for organizing and financing the design, construction, operations and maintenance activities and facilitates the delivery of a good or service” (Miller, Garvin, Ibbs, & Mahoney, 2000, p. 59).

Literature shows that the project delivery method do have a great impact on the outcome of projects, since it affects project costs, schedule, efficiency and success (Hosseini et al., 2016). Using an appropriate project

delivery method is one of the key factors leading to project success (Hosseini et al., 2016). The three most commonly used project delivery methods are Design-Bid-Build, Construction Management and Design-Build (Hosseini et al., 2016):

- Design Bid Build (DBB) - known as the traditional method - is a project delivery method in which the client signs separate contracts for the design and construction phase of projects. Due to the way of specification by the client, the bid often consists of complete plans for each phase separately. In this project delivery method, the client retains a high level of control associated with risks. Traditionally it is a united priced contract.
- Construction management (CM) is a delivery method where the client hires a construction manager. Hereby, the construction manager has the role to advise the client during the pre-construction phase, sometimes also during the construction phase.
- Design-Build (DB) - known as integrated method - is a method where the client signs a contract with one entity. This entity is throughout the contract period contractually responsible for the design activities, but also for the execution of this design. Traditionally this delivery method is based on a lump sum contract.

These project delivery methods are comparable to building contract models. In construction law, there is a distinction between various contract models whereby the difference is mainly related to the level of control and influence the client has, and the distribution of liabilities (Chao-Duivis, Koning, & Ubink, 2013). With each project, clear agreements are made about the quality requirements, the division of roles, the time course and everything else that is of importance. The recording of these agreements is done by using contract forms, each contract is an agreement. The definition of an agreement according to art. 6:213 DC (Dutch Civilcode) as follows: “An agreement within the meaning of this title is a multilateral legal act, in which one or more parties undertake an obligation towards one or more other parties”.

Contracts are obligations between at least two parties. The contents of contracts pertain to contract law, this allows a party to try to resolve problems, when applicable, through legal remedies and a counterparty is obliged to comply with the established agreement.

2.3.2. CONTRACT FORMS

The project delivery methods mentioned above all have matching contract forms. Currently, there are a large amount of different contract forms available in the construction industry. More often, new types of project delivery methods or forms of cooperation have been applied in the construction industry. From traditional agreements towards framework agreements, alliances or integrated contracts, they have been used for years now. In the construction industry, every client is free to choose the form of a project delivery method and the associated contract. In practice, it appears that clients adhere to certain standards where the contract form is dependent on the choice of the building organisation model (Castelein, 2018). According to Chao-Duivis et al. (2013) there are four models: traditional model (comparable to DBB), the design team model, the integrated model (DB) and the alliance model. To get more insight on the diverse building contract models, a short description is given per method which can be found in Appendix C.

2.3.3. INTEGRATED PROJECT DELIVERY METHODS

This exploration of building contract models indicates that in integrated contracts like DBFM(O) the contractor already delivers the product, as well as delivering a service (i.e. availability of infrastructure) during a long term period indicated to last for 15 to 30 years (Lenferink et al., 2013). According to the The American Institute of Architects (2007, p.2), integrated project delivery is defined as follows: *“Integrated project delivery (IPD) is a project delivery approach that integrates people, systems, business structures into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication and construction.”*

This definition shows some characteristics that are comparable to the principles of a circular economy, since integrated project delivery increases value to the owner, reduces waste and maximizes efficiency during the lifecycle of an infrastructure asset. However, an important aspect of these contracts is that, specifically in the Netherlands, maintenance in the infrastructure sector is strictly divided from operation (Lenferink et al., 2013). Maintenance can be delivered through market parties, however operation of the infrastructure network remains a strict public responsibility in the Netherlands (Chao-Duivis et al., 2013; Lenferink et al., 2013). In current integrated contracts, ownership of infrastructure is still handed over to the client after construction. This method is already the most advanced with the aspects of service delivery compared to other project delivery methods and building contract models.

LIFECYCLE OF INTEGRATED PROJECT DELIVERY METHODS

For application of product-service systems in the infrastructure it is necessary to incorporate the required changes on project level in the phases of a project life cycle. A project is generally passing through four phases of the project management lifecycle, which are defined by Burke (2003) as follows:

I. Concept and Initiation Phase

In this first phase of the project lifecycle the need for a new project will be identified. During this phase the objective for the project, feasibility and identification of the major deliverables for the project will be defined (specification).

II. Design and Development Phase:

The purpose of this phase is to design a product, develop a build-method and set up detailed schedules and plans for the development and implementation of the product.

III. Implementation or Construction Phase:

In the third phase the project will be developed as defined in the previous phase.

IV. Commissioning and Handover Phase:

The fourth phase aims to implement the design in practice, resulting in the termination of the project. Hereby, products are handed over to the client.

INTEGRATED CONTRACTS IN THE DUTCH INFRASTRUCTURE SECTOR

In the field of construction, Leiringer & Bröchner (2010) argued that research agendas already encouraged academics to explore how the construction sector can change into a system that is based on added value, rather than cost efficiency. In their research, Leiringer & Bröchner (2010) recommend product manufactures to expand their product offerings by including services. Another research about service in construction industry is focused on innovation, which is according Bröchner (2010) less impressive in construction than in other sectors. This author argues that service industries can be used as an example for improving innovation performance in the construction sector (Bröchner, 2010). Alderman et al., (2005) mentioned that service-led contracts are linked to projects in which the implementation or construction phase is extended with an operation and maintenance phase, driven by the client's demand.

Service-led contracts are contracts that will increase the sector involvement from a technical and financial perspective, whereby the contract is extended with e.g. a maintenance phase or financing (Hoezen et al., 2010). Service-led contracts are characterised by giving contractors a greater freedom to make decisions throughout the diverse phases of the lifecycle while having the purpose to meet the client's service requirements (Hoezen et al., 2010). Research by Hoezen et al. (2010) shows the comparison between the different project delivery methods. As shown in the table 3, adopted from research of Hoezen et al. (2010, p. 1178), integrated contracts already have some characteristics that are applicable within the principles of a circular economy. Currently, in the Netherlands as well as in other European countries, integral project delivery methods are increasingly applied (Lenferink et al., 2013). In figure 5., adopted from Lenferink et al. (2013, p.617), an overview is shown of the development of integrated contracts in the construction sector over time. It is shown that traditionally each phase has a separate contract, which implies the high potential of implementation gaps. However, as shown in the figure, a transition is made

TABLE 3. CHARACTERISTICS OF THE THREE CONTRACTS (HOEZEN ET AL., 2010, P. 1178)

	TRADITIONAL	DB	DBFM
Specifications	Input: design-led	Output: product-led	Outcome: service-led
Scope	Construct	Design and construct	Design, construct, finance, maintain
Selection criterion	Price	Design creativity, constructability and price	Overall quality and price
Decision freedom for the contractor	None: has to follow the specifications	Little: can have some influence on the design	Much: can make decision as long as remaining within the scope
Natural incentive	Low bid, with compensation through extra work	Low bid by design efficiencies	Low bidding and cost reduction by design and process efficiencies
Effect on the contractor's behaviour after contract closure	Opportunistic, mistake-hiding, quality-shirking, extra work claiming	Opportunistic, mistake-hiding, quality-shirking	Opportunistic, mistake-hiding
Monitoring	Ongoing, by principal	Ongoing, by engineering firm	Ongoing, by contractor and by his financiers. Occasional, by the principal

towards an Engineering & Construct (E&C) contract in which contractors are responsible for the technical design specification and execution of projects. Followed by the development of Design and Construct (D&C) contract, in which the entire design phase is also assigned to a private party. The integration of phases already reduces the amount of potential implementation gaps. From 2008, design and construct contracts became the standard contract form within Rijkswaterstaat. Next, design and construction tasks were combined with activities regarding finance and maintenance over an extended period in order to deliver a certain performance to the client, which is the case with a Design-Build-Finance and Maintain (DBFM) contract.

Prolonging the lifecycle with the integration of different phases means that the contractor will be responsible over a longer period of time, in comparison to traditional contracts. In integrated contracts like DBFM the responsibilities are distributed throughout the lifecycle to one entity, which results in a growth of inclusiveness related to the dimension of actors, scope and time (Lenferink et al., 2013). The main idea of the reallocation of responsibilities, from other actors (e.g. consortia or private parties) than the government, is that the expertise of these actors can be applied throughout the lifecycle of an asset (Lenferink et al., 2013). According to Lenferink et al. (2013) the integration of the different phases of the project lifecycle will have efficiency gains, since it results in a higher project control. An increased project control will make it possible to deliver projects better in time and within budget. Although results are coming there is still a lack of knowledge about how

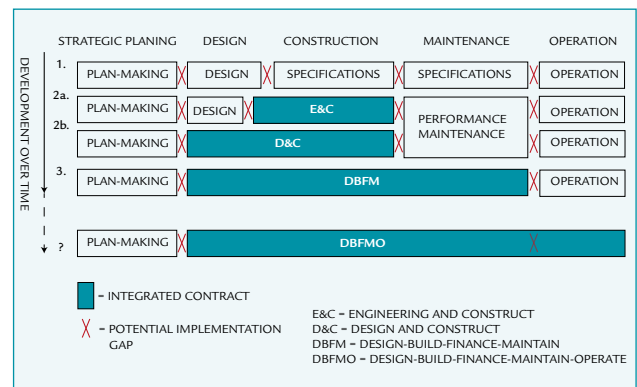


FIGURE 5. DEVELOPMENT OF INTEGRATED CONTRACTS IN THE INFRASTRUCTURE PROJECT LIFECYCLE (LENFERINK ET AL., 2013, P. 617)

involved public and private stakeholders experience the involvement in the application of integrated contracts, this in relation to interaction and cooperation (Lenferink et al., 2013). According to Lenferink et al. (2013), a study into the effects of integrated contracts on sustainability throughout the different lifecycle stages shows that there are positive effects, but also many negative effects (see Appendix C.).

2.4. ORGANISATION OF THE DUTCH INFRASTRUCTURE SECTOR

2.4.1. OPERATION AND FINANCE OF DUTCH INFRASTRUCTURE

In the Netherlands the Dutch authorities are designated as road operator by law, and therefore the DBFM contracts do not enable private parties to become operator and/or owner of the infrastructure (Lenferink et al., 2013).

The main motorways are part of the Dutch national Road system, which will be administered by the Rijkswaterstaat. The other roadways in the Netherlands are managed by authorities such as provinces, municipalities and water boards. In the Netherlands highways are funded through a national Infrastructure Fund, which is based on the type of vehicle you use and does not depend on how many kilometres you drive. Provinces, municipalities and water boards are authorized to apply toll on vehicles passing through certain tollgates on roads that are in their supervision (Acosta et al., 2014). In addition, the government applies taxes on fuel including a general VAT of 21% (Acosta et al., 2014). The Netherlands has a few toll roads, mostly tunnels. The Dutch government has considered charging a per-kilometre fee for use of motor vehicles, instead of letting users pay for the property. However, this has not been accepted yet by the majority of the governmental parties.

2.4.2. OPERATION PHASE AND FINANCING OF INFRASTRUCTURE IN FOREIGN COUNTRIES

In research on the organisation and funding practices of road infrastructure in foreign countries it is noticed that there are various approaches to this (Acosta et al., 2014). Several countries have fuel tax which is used to finance the construction and maintenance of infrastructure (e.g. Brazil, Canada, China, Israel, US). There are countries that have fuel or excise taxes to fund roads (e.g. Australia, England, Germany). However, many countries do apply a toll system, which obtains revenues to finance the construction and operation of roads. In France many highways are funded by a toll system in which private companies (mostly in the form of a concession system) manage the operation of the road (Acosta et al., 2014). In a French law (article L122-4) it is mentioned that the toll systems are used to finance construction, maintenance and operation. However, when a toll road is managed by a private party, the toll could also serve as profit (Acosta et al., 2014).

2.5. WHAT ARE THE CHARACTERISTICS OF PSS WHEN APPLIED TO INFRASTRUCTURE PROJECTS?

When PSS will be implemented parties include service or product elements to the development and delivery of products (Reim et al., 2015). The application of services instead of traditional project delivery requires a reorganisation of processes and structures. Further, the transition to a service-oriented project delivery is challenging and asks for fundamental changes in business organisation, as well as business culture and competencies of the parties in the construction chain. To be able to comply with the principles of a circular economy, the activities of the construction process should be reorganized. The existing definition of a project delivery method suggests a linear process. To design a project delivery method that is applicable for a circular economy it is important to identify which changes should be made to comply with the principles of CE. In relation to the application of PSS the following characteristics are identified to be necessary considering how PSS can be applied in the infrastructure sector.

2.5.1. LEGAL CHARACTERISTICS REALLOCATION OF OWNERSHIP

In service-oriented projects producers keep the ownership of their delivered products, whereby the client pays for the use and not for the possession (The Ellen MacArthur Foundation, 2015). In contrast to the current economic system, a change must be made from traditional design and supply of large products on project basis, towards service provision throughout the lifecycle of products (Alderman & Ivory, 2010). The reallocation of ownership associated with the change towards service delivery, transfers responsibilities for maintenance and disposal from the client to the producer. This transfer has a purpose to create incentives for a more resource-efficient and durable design and production of infrastructure projects (Steger et al., 2012). Next to this, it changes the value of products towards a higher level of circularity, since the products will be returned to the producer at the end of use, instead of other ways of disposal. According to Tukker & Tischner (2006), users currently prefer the possession of a product over renting or leasing, since there is a certain emotional attachment. As described earlier, the second category of PSS (use-oriented services) is characterised by the fact that the product in general is owned by the provider. The product will be made available for a user, for which the user pays a regular fee (Tukker & Tischner, 2006). Due to this organisational change, in relation to ownership, the producer keeps the responsibility for maintenance, repair and control. The challenge regarding the application of PSS is to compose a service contract which includes the right distribution of responsibilities to ensure sustainable outcomes, for both the client and the service provider (United Nations Environment Programme, 2015).

CONTRACTUAL AGREEMENTS

When applying product-service systems in the infrastructure sector there is always a combination of a product and a service. Therefore it is important, with regards to the principles of a circular economy, that it is contractually stated what happens with the product after the contract expires. According to Agrawal, Ferguson, Toktay, & Thomas (2011) a main factor which need to be considered to ensure that a PSS is more profitable is the entire lifecycle of a product, and the impact that a product has on the environment during the use-phase. In addition, as mentioned earlier, it is important that contractual agreements are made in relation to the distribution of responsibilities. The second category of PSS is characterised by the fact that the client no longer pays for the possession of the product, but for the use or service related to the product. This will also require a change in the contractual agreements, since this is connected with the distribution of responsibilities that need to be defined.

2.5.2. FINANCIAL CHARACTERISTICS

CHANGING VALUE PROPOSITION

The transition from product delivery towards a service delivery will change the value proposition from market parties, but also influences the value of infrastructure for the client. The most important benefit of the transition is that the client will gain the benefit by the usage of the product, while the function is guaranteed by the service provider (Adrodegari et al., 2016). In addition, value for the client is already generated by the reduction of the initial investment (Adrodegari et al., 2016). Reallocation of ownership will signify that another party will be responsible for the service throughout the lifecycle phases of a product, which also implies a reduction or minimalization of operational costs and risks for the client (Adrodegari et al., 2016). In addition, value creation becomes more important in a lot of industries, since there is a need for an economic system that lets parties compete on the basis of the added value, rather than the lowest price. This reflects a shift in which companies expand their current product delivery by providing a service throughout the lifecycle of a product (Oliva & Kallenberg, 2003). Added value can be created through customized solutions that comply with the needs of the client. However, achieving this level of added value is complicated since it requires companies to deliver an integrated solution, as the provided service needs to take over activities that were previously performed by clients or other organisations (Brady, Davies, & Gann, 2005). In addition, companies need to incorporate incentives to their business model to support a good technical design, which indirectly results in an added value for all parties involved (Dahmani, Boucher, & Peillon, 2013).

PAY FOR THE FUNCTION INSTEAD OF FOR THE PRODUCT

The change from product to service implies that contractors will get paid for the service they offer to the client, and no longer for the execution of the road construction. Hereby, an economic incentive will be created to prolong the service life (Tukker, 2015). It can generate a substantial revenue for contractor from the moment the product is in use (Oliva & Kallenberg, 2003). Oliva & Kallenberg (2003) argued that the delivery of a service does bring higher margins than product delivery. Hereby, the biggest change of the significant increasing revenue streams occur in the service component, rather than in the construction of the infrastructural product (Alderman et al., 2005). However, the contractor will have higher up-front investment costs, since the revenues will be spread over the service phase instead of one transaction early on. This can probably cause problems for the cashflow of contractor organisations (Mentink, 2014). For the determination of the financial model it is important that aspects such as price, risks, value of materials, the maturity of materials, reparability and the expected lifetime are taken into account (Poppelaars, 2014). It is seen as a necessity to identify which financial model is best applicable for infrastructure projects when driven by service delivery.



Within the various categories of product-service systems the following types of transactions can be distinguished for the business model (Fischer, Achterberg, & Ballester, 2018; Remmerswaal et al., 2017; Tukker & Tischner, 2006):

- Buy: ownership will be moved from the producer and/or supplier to the consumer (buyer) with a one-off payment.
- Lease-purchase (financial lease): during the lease or rent period, the consumer may use the product by doing a periodic payment and the consumer will own the product at the end of this period.
- Buy or hire purchase with buyback guarantee: the property shifts from the producer and/or supplier to the consumer with the guarantee that the product will be bought back after disposal.
- Rent (operational lease): product remains property of the producer and the consumer may use it against payment, which can be made in both one-off or periodic payments.
- Full service lease: operational lease that also provides services, such as maintenance and advice from the producer.
- Pay-per-use: a full-service lease in which the final costs for use are variable, and depend on the intensity and/or frequency of use and performance of the product.

2.5.3. ORGANISATIONAL CHARACTERISTICS

COLLABORATION OF PARTNERS IN THE INFRASTRUCTURE SECTOR

All stakeholders involved in the process need new capabilities, data and incentives, but also the project delivery method will change from transaction to relationship-based (Oliva & Kallenberg, 2003). Dutch infrastructure projects are mainly subject to public clients, which consists of central, as well as decentral governments. According to Mentink (2014) the change from product to service provision is mainly driven by performances. Especially the way of cooperation is hereby important, since the client becomes a partner compared to the traditional way of selling a product, which requires a limited role and influence of the client. Relationship-based services are comparable to current maintenance contracts, as there is an agreement in terms of operational availability and response time in case of failure (Oliva & Kallenberg, 2003, p. 168).

Further, it is identified that consideration of assumptions and expectations is necessary early on in the contract negotiations, due to the long-term duration of the client-contractor relationship (Leiringer & Bröchner, 2010). Additional project risks (e.g. unexpected extra costs) can be reduced by clarifying the project goals in an early stage of the project. This asks for close collaboration and different ways of distributing risks among the contracting parties. Due to the changes on process level when incorporating PSS, public clients need support related to the new ways of financing, contract management, asset management, but also risk management and tender procedures (Dahmani et al., 2013). In addition, Dahmani et al., (2013) noticed that the service provider should restructure its traditional sales approach and find a way that aligns the interest between parties. Good collaboration is, as identified in the research conducted by the United Nations Environment Programme (2015), seen as a prerequisite.

2.5.4. TECHNICAL CHARACTERISTICS

HIGH-VALUED TECHNICAL DESIGN OF THE PRODUCT

According to Dahmani et al. (2013) the technical design of a product is seen as a key element of the transition when implementing PSS characteristics. To come up with a good technical design it is important that the entire lifecycle of the product is assessed, as well as its use within the PSS model (Dahmani et al., 2013). To support sustainability in the design, it is necessary that the costs and benefits of applying PSS are considered in the design phase of the associated product.

PRESERVE VALUE OF PRODUCT THROUGHOUT LIFECYCLE

Service-oriented infrastructure should perform at an agreed service level (which is established in the contract with the client). However due to the lifespan of materials, at a certain point it is no longer possible to achieve the required level of performance. This means that the product needs to be taken out of the infrastructure or should be renewed at that moment. Therefore, it is important that the lifetime of infrastructure needs to be determined before realisation, this to achieve the highest efficiency and value.

2.6. PSS AS A STRATEGY FOR A CIRCULAR ECONOMY

Sustainability and a circular economy are elements which makes the construction world change. Stakeholders in the construction sector feel pressure and a need to approach a strategy development process to reach (sustained) a competitive advantage. As mentioned earlier, the construction sector is currently driven by competitive product offers, which means that the sector is driven by offering products at the lowest price. Combining a product with service should match the opportunities in the market better than the current competing product offering, since it should be easier to come up with a solution that fits the client needs (Tukker & Tischner, 2006). This is in relation to a circular economy and sustainability an

important factor. According to Tukker & Tischner (2006) it is important that the product-service combination serves the capabilities and resources of an organisation. Therefore, it is necessary to find out how the present stakeholders in the construction sector experience service related offers, as applied in the current infrastructure sector. In addition, it is also important to get insight on the differences between the result-oriented service category of PSS and the current way of project delivery in the construction sector.

Kjaer et al. (2018, p. 1) argued that “*absolute decoupling of economic growth from resource consumption only occurs when the resource use declines, irrespective of the growth rate of the economic driver*”. To achieve this, a two-step framework is developed proposing that certain steps must be taken to increase the likelihood of PSS leading to absolute resource decoupling through a circular economy. A more comprehensive explanation regarding the two-step framework is given in appendix G. To achieve the aim of a circular economy it is important that certain strategies for resource decoupling are taken into account.

2.7. CONCLUSION THEORETICAL FRAMEWORK

Due to the need for a transition towards a circular economy, PSS is chosen as central theoretical model in this research. A PSS combines a product with an associated service to comply with the clients' needs, but also has a lower environmental impact than the current business models. In relation to the PSS model it is noticed that, the more a product is delivered as a service, the higher the potential for a circular economy. Current integrated project delivery methods indicate a first step in the transition towards a service-oriented project delivery of infrastructure projects. However, to support a circular economy in the infrastructure radical changes are necessary, since there are a lot of principles that are still not covered. There is a lifecycle approach, but in integrated contracts the end of life cycle is not considered. Besides that, ownership is in the existing project delivery still transferred to the client, while principles of a circular economy, as well as the characteristics of PSS, noticed that it is best that the producer remains the owner of the product or materials (MVO Nederland, 2018; Tukker, 2015). However, to change from the current way of project delivering towards a project delivery that suits a circular economy, several steps need to be taken. The various categories of PSS are characterised by legal, financial, technical and organisational characteristics. Insight into the application to infrastructure projects is necessary in order to find out how the infrastructure sector can make the change towards a service-oriented project delivery.



CHAPTER

3

THE DOUBLE DIAMOND METHOD

3. THE DOUBLE DIAMOND METHOD

This chapter described the research method that will be used to find out what changes are required to apply service aspects in infrastructure and how these can be incorporated in the design of the project delivery methods. In paragraph 3.1. an introduction will be given in relation to the methodology that fits to the research goal. Paragraph 3.2. describes the theoretical information in relation to the applied methodology. In paragraph 3.3. it will be described how this methodology will be applied to this research. This chapter aims to answer the second sub-question of this research: *“How to compile and analyse the product-service systems characteristics for application in a project delivery method for infrastructure?”*.

3.1. DESIGN-BASED RESEARCH

A methodology that fits the research goal is design-based research or design science. According to Tschimmel (2012), design thinking has been identified as a method that changes the way of thinking, which leads to doing business in a different way by incorporating innovation and evolution. Since this exploratory research project had the objective to develop a product which helps the application of service aspects in project delivery methods for infrastructure projects, a qualitative research has been carried out. Qualitative research is more descriptive in nature and focuses on interpretations, experiences and opinions (Baarda et al., 2013). It was not the aim of this study to test theories (which is normally the case in quantitative research), but to reach the objective through gaining insight into the different interpretations and opinions people have on the service concept, and how this attributes to the application in project delivery methods.

The most important aspect of a design-based research is to reduce the gap between theory and practice by using theory to design the needed interventions, and to develop these for the application. To achieve an optimal result it is necessary that collaboration with participants from practice takes place (The Design-Based Research Collective, 2002; Van Der Sanden & Meijman, 2012). According to Wang & Hannafin (2005, p.2.) design-based research is defined as follows: *“design-based research is a research methodology aimed to improve educational practices through systematic, flexible and iterative review, analysis, design development and implementation, based upon collaboration among researchers and practitioners in real-world settings, and leading to design principles or theories”*.

Design science research is comparable to design-based research. Because, design science research is described as a research method to gather scientific knowledge which aims to help professionals design solutions with the intention to solve problems faced in practice (Dresch, Lacerda, & Antunes, 2015; van Aken, 2004). As mentioned earlier in the relevance of this study, there is a need for guidance to apply service aspects in infrastructure projects. In addition, insight into what this entails for projects in the construction industry is needed. This is in line with the purpose of design research, which is to produce scientific knowledge, as well as helping organisations to solve real problems (Dresch et al., 2015; Wang & Hannafin, 2005).

The research objective benefits from a result that can be used in practice, since the result will hopefully solve the problem of having a lack of knowledge on the application of service aspects in the delivery of infrastructure projects. This research is, however, not only practice- oriented. Besides supporting professionals in their work, it aims to improve scientific knowledge as well. Since this thesis aims to apply service aspects in practice, there is a need to combine findings from theory, in relation to findings from practice. Design-based research is characterised by doing an iterative the process.

3.2. THE DOUBLE DIAMOND METHOD

A design-based research methodology includes various research methods. In this thesis the ‘Double Diamond’ method, founded by the British Design Council, will be applied (Design Council, 2007). Although there are various methods, the double diamond method is the most complete one for this research, as it includes both the financial perspective, business’ focus and a designers’ perspective (Tschimmel, 2012). This method does not solely focus on designing solutions or interventions as an output, but it gets more into the actual problem definition prior to developing the solution as an output (Design Council, 2007). The double diamond model can be described as an overview of the design and research process, which is divided into four distinct stages: the discover stage, the define stage, the develop stage and the deliver stage. To discover which ideas are most important to incorporate into the design, it is necessary to go through an iterative process (Design Council, 2007).

An important aspect of the double diamond method is to take the problem as the central focus in the design process, and not the preliminary research. This will support the development of a solution, because it keeps the problem open to new insights. According to the Design Council (2007), every design process starts with a divergent phase of discovering new ideas, followed by going through a convergent phase of analysis, as well as synthesis, to find diverse areas of opportunity (see figure 6.).

in infrastructure projects. The aim of this first step is to define which changes are required to apply characteristics of product-service systems in the infrastructure sector. Diverse research methods will be used to collect data and analyse data, which will be further explored in the following section. The problem analysis starts with the selection of key people to identify which perspectives have to be included. The first discover phase asks for methods to retain the perspectives of research and practitioners open for ideas to the problem. The following perspectives in relation to the subject of this thesis are identified as most relevant for the infrastructure sector: the contractors' perspective, the clients' perspective, and the suppliers' perspective. This research is carried out in cooperation with the contractor Dura Vermeer. Dura Vermeer started a development program which is in line with the objective of this thesis. Therefore, it is chosen to take this development program as the central case study to collect data from the perspective of the contractor. The perspective of the client, as well as the supplier perspective, are identified by conducting semi-structured interviews. The PSS characteristics (legal, financial, organisational, technical) as identified in the theoretical framework are chosen as the core elements of the design research (see chapter 2.4).

Case study

To collect data from a broad perspective a case study was chosen to be the central research strategy. Because, it helps the researcher to understand the dynamics that are present within one casus (Eisenhardt, 1989). Due to the availability of a single case, it is chosen that numerous levels of analysis will be conducted. Central in this study is the case 'De Circulaire Weg (DCW)' (in English: the circular road). The aim of this development program is to explore how the contractor can deliver roads to public clients by applying service characteristics to the project delivery of infrastructure projects, while integrating the principles of a circular economy. The physical road is not important for the value proposition, but it is all about the associated service. A more in-depth description of the development program 'De Circulaire Weg' is given in Appendix D.

Observation is used a method to get insight into the perspective of the contractor regarding the application of PSS. Through observation it will be identified in what areas problems occur during the development of DCW, this in relation to the implementation of service



characteristics (Design Council, 2015). The purpose is to gain an understanding of the current situation, and what changes will need to take place to transform towards a more service-oriented project delivery method. Information is gathered through participating in multiple meetings of the development program of DCW. Hereby, it will be observed what different kind of barriers and opportunities are identified for the application of service aspects in the project delivery of a circular road. Data was collected by making observational notes during meetings, as well as having informal interviews with the representatives of the development group. Therefore, case-based reasoning is applied to the results, since the case tries to solve a new problem based on the experience that is associated with comparable problems that are already solved in earlier cases (Hüllermeier, 2007).

Semi-structured interviews

Theory shows that there are different methods for conducting interviews. In this research, it is decided to carry out semi-structured interviews, called topic interviews (Baarda et al., 2013). In this interview form, a structure is applied by establishing a predetermined list of topics that must be discussed during the interviews. The order of the topics, the formulation of the questions and the formulation of answers are not fixed (Baarda et al., 2013). To secure the reliability of the data all interviews will be audiotaped and fully transcribed. Afterwards, a summary of the conversation will be sent to the participants to confirm the content. The interviews will each last 45 to 60 minutes.

The interview starts with an introduction about the background of the interviewer and interviewee. In addition, the theory of product-service systems will shortly be introduced to ensure that there is a mutual understanding of the topic. To discuss the different characteristics of product-service systems in relation to the infrastructure sector, the interviews will be divided into four parts. The first and last part are separated from the other parts, the second and third part take place simultaneously. The final interview protocol is shown in Appendix E.

Introduction

- Introduction to the research topic and theoretical framework
- What is your organisation about?
- What is your perspective on the notion of circular economy?
- What activities organises your organisation regarding circular economy?

Topics

- Legal: procurement, (integrated) contracts, ownership, contractual arrangements, legislation
- Financial: payment model, financial risks, revenue streams
- Organisational: collaboration, lifecycle of project, internal organisation
- Technical: design, life cycle assessment

Plotting changes as an opportunity or threat on an A0-paper

To get insight in the consequences of certain changes the interviewees were asked to plot their identified changes on an A0-paper. This interactive part is applied to keep the interviewee involved during the discussion by letting them write down statements on post-its and to mark the statement as an opportunity or threat.

Future perspective regarding application of PSS in infrastructure

- What is your future perspective regarding the application of product-service systems in the infrastructure sector?
- Does the application of product-service systems in the infrastructure fit the need client/suppliers have in the field of circular economy?

Given that every project derives from the client’s request, it is important to evaluate what opportunities and threats exist of using service aspects in infrastructure from their perspective. To get broad insight in the underlying reasons regarding the implementation of service aspects in infrastructure projects, interviews should be carried out on different scales. Therefore, interviews have taken place with employees from Rijkswaterstaat and ProRail (national infrastructure), provinces and municipalities (see table 4).

On each level, two interviews will be conducted to get broad insight in the perspective of the client. The interviewees are chosen by expert sampling, which is a form of purposive sampling where participants will be selected knowing that they have certain expertise within the field of research (Hennink, Hutter, & Bailey, 2011). It is decided beforehand to only conduct interviews with people that have both knowledge of project delivery and circular economy. Sometimes two interviewees were therefore involved in one interview to get a broad view on the clients’ perspective. The sample of interviewees is not randomly chosen, but reflects the selection of specific interviewees to extend the theory to a broad range of organizations and perspectives.

Since the delivery of infrastructure has impact on all stakeholders in the lifecycle, the perspective of the supplier is also included in this research. It is chosen to take three different size suppliers to get sufficient insight into their perspective regarding the application of product-service systems in the infrastructure sector (see table 5).

TABLE 4. OVERVIEW CLIENT INTERVIEWEES

	CLIENT	FUNCTION
NATIONAL LEVEL	Rijkswaterstaat ProRail	Manager innovation for infrastructure and mobility Advisor sustainability
REGIONAL LEVEL	Provincie Noord Holland Provincie Overijssel	Program Manager Circular Economy Senior project engineer Program manager Circular Economy
MUNICIPAL LEVEL	Gemeente Rotterdam Gemeente Haarlemmermeer	Advisor professional commissioning and market approach Advisor project management & engineering and market approach Advisor sustainability, circularity and procurement

TABLE 5. OVERVIEW SUPPLIER INTERVIEWEES

	SUPPLIER	FUNCTION
BIG SIZED	Asphalt producer	Director
MIDDLE SIZED	Van den Bosch Beton	Head of sales
SMALL SIZED	Bio-based materials	Director

The qualitative data from the case study and the interviews will be structured by categorizing it in Excel. Since data will be collected from diverse stakeholder perspectives’ (client, contractor, and supplier), it is decided to keep information separated per stakeholder group by using separate sheets in excel. Categorizing the data will be done based upon the four different angles, as identified in the theoretical framework: legal, financial, organisational and technical.

Due to the application of semi-structured interviews, the topics are defined beforehand, however during interviews deviation of the topic could sometimes take place. This could result in more detailed information regarding a sub-topic within one perspective. Since each interview started with information regarding circular economy, it is chosen to apply one category in general.

This is followed by topic categories which will be divided following the sub-topics as defined in the interview design. Results will be analysed from the diverse perspectives after the categorisation. To analyse the clients’ perspective, it is necessary to identify similarities and differences between the various interviews. The division of national, regional and municipal public clients should here also be considered, in order to obtain a transparent insight into the required changes. This analysis method will also be applied to get insight into the suppliers’ perspective.

The next step in the process is to design a first conceptual model showing the connections, and combination of research findings and theoretical framework. Based on this analysis, a list of required changes will be established, which are indicated as necessary for the application of product-service systems in project delivery methods of infrastructure projects. Next, this list of required changes will be placed in their position in the different phases of the project life cycle. This functions as the basis on which a first design of the conceptual model will be made to clarify the position of the required changes in the project lifecycle.

3.3.2. PROBLEM SOLUTION: THE DEVELOP AND THE DELIVER STAGE

After identifying the required changes for the application of PSS in the infrastructure sector, it was decided to further develop this conceptual model by developing preconditions for an agenda for change. During literature review, a PSS-framework is created which gives an overview of the development of product-service systems. Based on the conceptual model, as defined at the end of the first diamond, an agenda for change will be developed. First, it is important that it will be defined what the characteristics in literature are, in relation to the research findings. Second, the preconditions for the agenda of change will be determined. This is all part of the process towards a conceptual model incorporating the required changes for the agenda of change. Next step in research is the validation of the conceptual model.

3.3.3. VALIDATION OF THE DEVELOPED MODEL

During research, several validation sessions were held in relation to the required changes regarding legal, financial, organisational and technical aspects. However, to guarantee the accuracy and applicability of the conceptual model, a validation session will take place with an independent focus group that consists of experts from diverse disciplines.

The aim of the focus group is to confirm the translation from results to a model. This model can then be used by the contractor to develop a suited project delivery method for infrastructure projects when incorporating service aspects. During a focus group session the conceptual model will be discussed. The participants will receive the conceptual model (figure 28, p.45), including a guidance text, one week before the meeting to prepare. The focus group session will be recorded and transcribed. A summary of these results will be sent back to the participants for validation.

The participants of the focus group all work for the contractor organisation. The intention is to have diversity of disciplines involved, this to enable a discussion between the experts in relation to the conceptual model. For the composition of the focus group, it is recommended to have at least 6 to 8 people present in order to get the best results (Wilkinson, 1998). Therefore, a group of 10 people will be invited to have a certain amount of people present for validation. The participants of the focus group will not be involved in the research beforehand, and therefore independence with respect to the research findings will be guaranteed.



CHAPTER

4

RESULTS AND ANALYSIS

4. RESULTS AND ANALYSIS

This chapter presents the results of the case study and interviews which have been conducted to gain insight into the application of PSS characteristics in project delivery methods. Since this research is conducted following the methodology of the double diamond, the results and analysis are combined in this chapter to work towards a final solution. In paragraph 4.1. an introduction will be given in relation to the partial design which will be used as a framework to present the results. Paragraph 4.2. answers the third sub-question of this research: *“What changes are required for the application of product-service systems characteristics as part of the project delivery method for infrastructure projects?”*. In this paragraph, the results from analysis regarding changes towards the application of PSS in the infrastructure will be described. Additionally, paragraph 4.3. will answer the fourth sub-question *“How can the identified changes be incorporated in the project lifecycle to achieve a higher level of product-service systems in infrastructure projects?”*. This will be done by translating the results of 4.2. into an agenda for change in relation to the different product-service system categories. Paragraph 4.4. postulates the outcome of the validation session resulting in the final validated model.

4.1. MAJOR INSIGHTS

The interviews, as well as the case study, indicate that most of the involved stakeholders (client, contractor, and supplier) do see possibilities regarding the application of product-service characteristics as a mean to integrate principles of a circular economy on a project level. However, to implement service characteristics on a project level it was noticed that some conditional changes must take place to make this happen. Further, it was identified that the stakeholders think that application on a short term is difficult, due to the complexity of change. A comprehensive analysis of the results is shown in Appendix F.

Throughout the interviews it became clear that in a traditional project delivery method parties have opposed interests. This is in line with insights from literature. The client has an interest in keeping the investment costs as low as possible. In contrast, the contractor wants to deliver a product with the aim to increase sales (mostly done by creating additional work). This is often associated with a bigger use of materials. Therefore, an alignment of incentives to reduce costs and benefiting the environment, should be created by incorporating PSS characteristics in the project delivery method of infrastructure projects (see figure 8.). The analysis of data has shown that due to the lack of integrating different phases of a project’s lifecycle will lead to additional costs arising from use, maintenance, repair, and end-of-life management. This is mainly due to the fact that these phases were not included in the initial decision-making process. Despite the use of integrated contracts, in which the integration of phases of a project already takes place, there is still no incentive to deal with the project in a more sustainable way (e.g. preserve value throughout lifecycle).

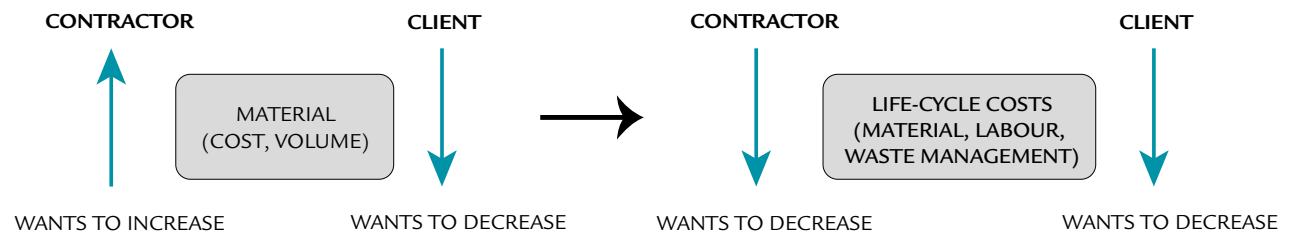


FIGURE 8. ALIGNMENT OF INCENTIVES (MODEL ADOPTED FROM THE CHEMICAL INDUSTRY OF UNEP, 2015)

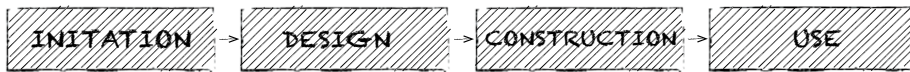
According to the participants, the interest of the client and contractor are still not aligned in these integrated contracts. The contractor is responsible for the design and construction phase in a project, but also handles the administration, and sometimes a maintenance contract is included. From literature, as well as from the collected data, it appears that reallocating responsibilities is essential for a change in the construction sector. The application of PSS characteristics in project delivery methods of infrastructure projects is seen as a potential for decoupling consumption from economic growth. A client noticed that *“the application of product-service system could be a solution to incorporate the value of materials in the financial system of project. This also creates an economic incentive to design and build differently.”* (Rijkswaterstaat, personal communication, September 14, 2018). The incentive will shift from maximising production and sales (high costs and additional work) to focus on quality and durability. Therefore, it is indicated that the major challenge for the transition towards a circular business model is to keep control over resources and preserve the value added to products throughout the project life cycle. To support a circular economy in projects, it is assumed based on the data, that it is necessary that power (knowledge and resources) and responsibilities are placed with the same party.

In the development of the partial design, resulting from analysis, the following design steps are taken:

- 1) As identified in the theoretical framework, the development of a project delivery method supports stakeholders to integrate all activities around a project into a process for collaboration throughout all phases of a project. From the data gathered, it turns out that there are a couple of conditional changes identified as necessary to create circumstances that first need to be fulfilled before application of PSS characteristics on a project level is possible. Additionally, it was identified that some changes require a structural change in the project lifecycle, since these changes must be incorporated into a specific phase, or between phases. The theoretical framework already clarified that in order to apply product-service systems, the distribution of ownership is seen as a critical point in the transition towards a service-oriented project delivery. Ownership requires fundamental changes in the organisation of projects, but also influences specification, distribution of responsibilities till the end of contract. Further, in the interviews it became clear that especially materials get more attention when changing to a circular business model. To achieve a circular economy in projects it is important to consider the entire lifecycle of materials. Since this research aims to clarify how service characteristics should be implemented in project delivery methods to contribute to a circular economy, it is chosen to develop the partial design following the project lifecycle of an infrastructure project. Therefore, the design is based on the project lifecycle as described in paragraph 2.3.



- 2) The application of product-service systems in the infrastructure will result in a prolonged contractual agreement between client and contractor as identified in the analysis. Whereby, after design and execution of the infrastructural product, the contractor will also act as a service provider till the end of the contract. The use phase will therefore be incorporated in the lifecycle of projects. As shown in the theoretical framework, these phases are already identified as standard project lifecycle phases. To emphasize the actual changes, it is decided to keep them grey-coloured.



- 3) From the analysis, it is observed that incorporating the material lifecycle is important. Therefore, it is decided to extend the project lifecycle with an end-of-life phase. Especially in the interviews with suppliers it became clear that there is a high potential for economic benefits when incorporating the end-of-life phase. Further, it is observed that especially the supplier and contractor find that the end-of-life phase of materials is important. A supplier argued this as follows *“We currently do not apply a take back guarantee on our supplied products, however when we do so we could reuse or recycle maximal. This reduces the need for resources resulting in lower investment costs. Collaboration with a recycling organisation could offer an economic benefit for both parties, while we also reduce the amount of waste and create efficiency.”* (Van den Bosch Beton, personal communication, October 17, 2018). This is a new phase for the project lifecycle and significant change in relation to the existing project delivery methods. Therefore, this phase is added and shown in blue.

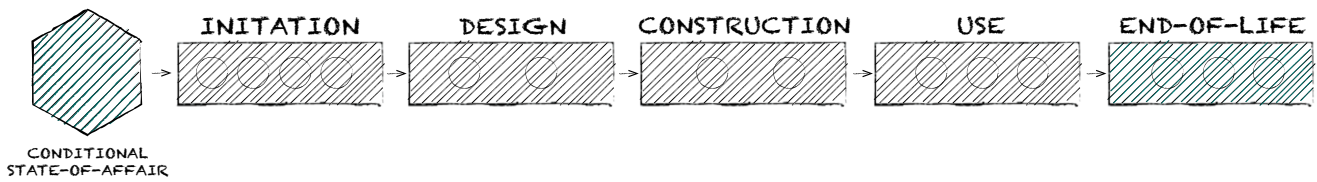


- 4) It became clear during the analysis that some required changes, that were previously identified, for the application of PSS are specific to subparts of a phase. Therefore, it was decided to divide each phase into relevant subparts. This facilitates the ability to specify the required changes into defined sub-phases of the project lifecycle. Some sub-phases are not subject to change but are indicated to provide readability and structure to the life cycle model.

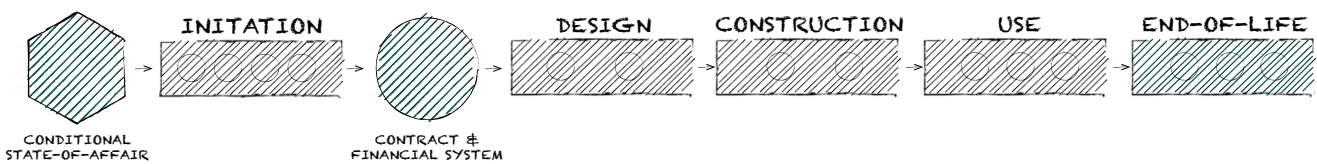
1. **Initiation phase:** idea, preliminary design, tender specification, contractor selection
2. **Design phase:** design, purchase of materials
3. **Construction phase:** deconstruction and preparation of the building site, construction
4. **Use phase:** operation, maintenance, reconstruction
5. **End-of-life phase:** demolition, dismantling, recovery of raw materials



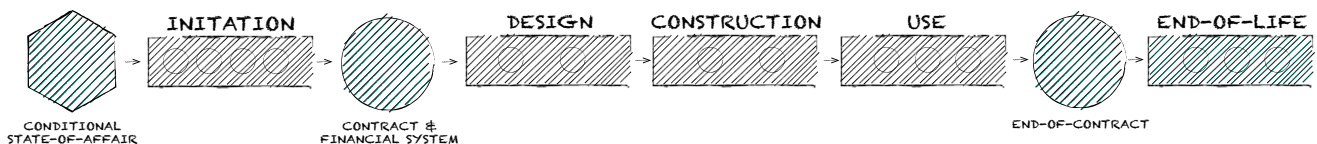
- 5) As identified in the research, some conditional state-of-affair should be fulfilled in front of the project life cycle. These conditional state-of-affairs are not specific changes to a process, but are necessary conditions that must be fulfilled before product-service system characteristics can be successfully integrated into the project delivery method. Therefore, they are put at the start of the lifecycle.



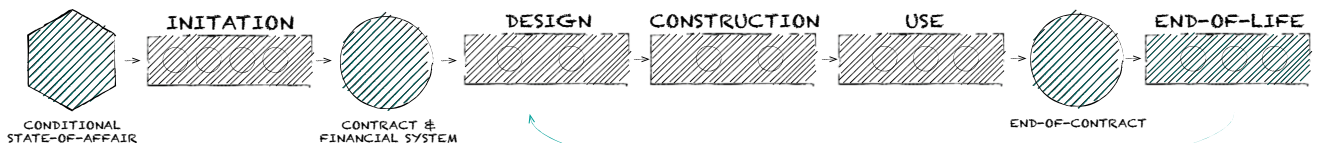
- 6) Further, it is identified that in the contract as well as in the financial system necessary changes will take place when implementing PSS aspects in projects. Especially a change in the distribution of responsibilities is seen as a key element that influences the current contract and financial system of projects. In addition, incorporating (residual) values of materials in the financial system of projects does influence the existing system, and therefore requires change. Because of that, the contract and financial system will be incorporated as state-of-affair after the initiation phase and before the preparation phase. To clarify the difference between conditional state-of-affairs and required changes, it is decided to present the required changes as circles.



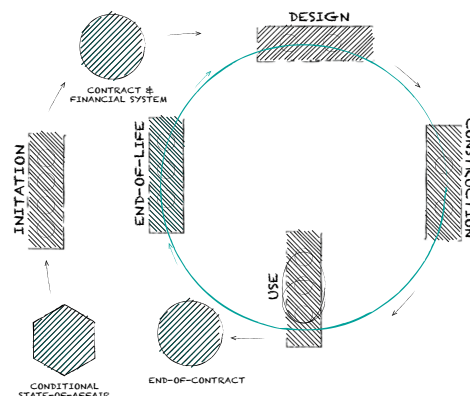
- 7) The previous step already shows a change on contract level, especially in relation to the distribution of responsibilities. Projects are characterised to be finite, and therefore it is important that the end-of-contract is also included in the partial design. In the case study it becomes clear that the contractor noticed that it is important to notify what happens after termination of the contract with the product over which the service is delivered (consultation meeting DCW, personal communication, June 27, 2018). Further, the project lifecycle is not parallel on the lifecycle of materials. Therefore, it is identified that this required state-of-affair should be incorporated between the use phase and the end-of-life phase.



- 8) To actually realise closing the material loop it is important that materials can flow during the end-of-life phase (depending on their value and possibilities for re-use, refurbishment or recycling) into new project life cycles. Therefore, the material cycle should be included in the lifecycle of projects. Most important is that the outflow is coupled with the design-phase as an input. In comparison to the other arrows, it is chosen that this arrow should have another colour (blue), to clarify that this is a material loop and differs from the black arrows between the different stages of the life cycle.



- 9) The last step in the development of the partial design is to put the preparation, execution, use and end-of-life phase in a loop. This points out the circular character when implementing the circular principles. Further, it is noticed that in the use phase sub-cycles should also be incorporated for reconstruction and maintenance to keep the function of the actual product running.



4.2. APPLICATION OF CHANGES IN PROJECT LIFECYCLE

In this paragraph, the partial design shown in figure 9. will be used for presenting the results. To present the results in a structured manner, it is decided to describe the changes by following the project lifecycle as developed in section 4.1. The heading in the text corresponds to the relevant phase or state-of-affair to clarify which changes should take place when PSS characteristics will be applied to infrastructure projects. Besides presenting the results, adopted from the case study and interviews, also solutions will be further explained.

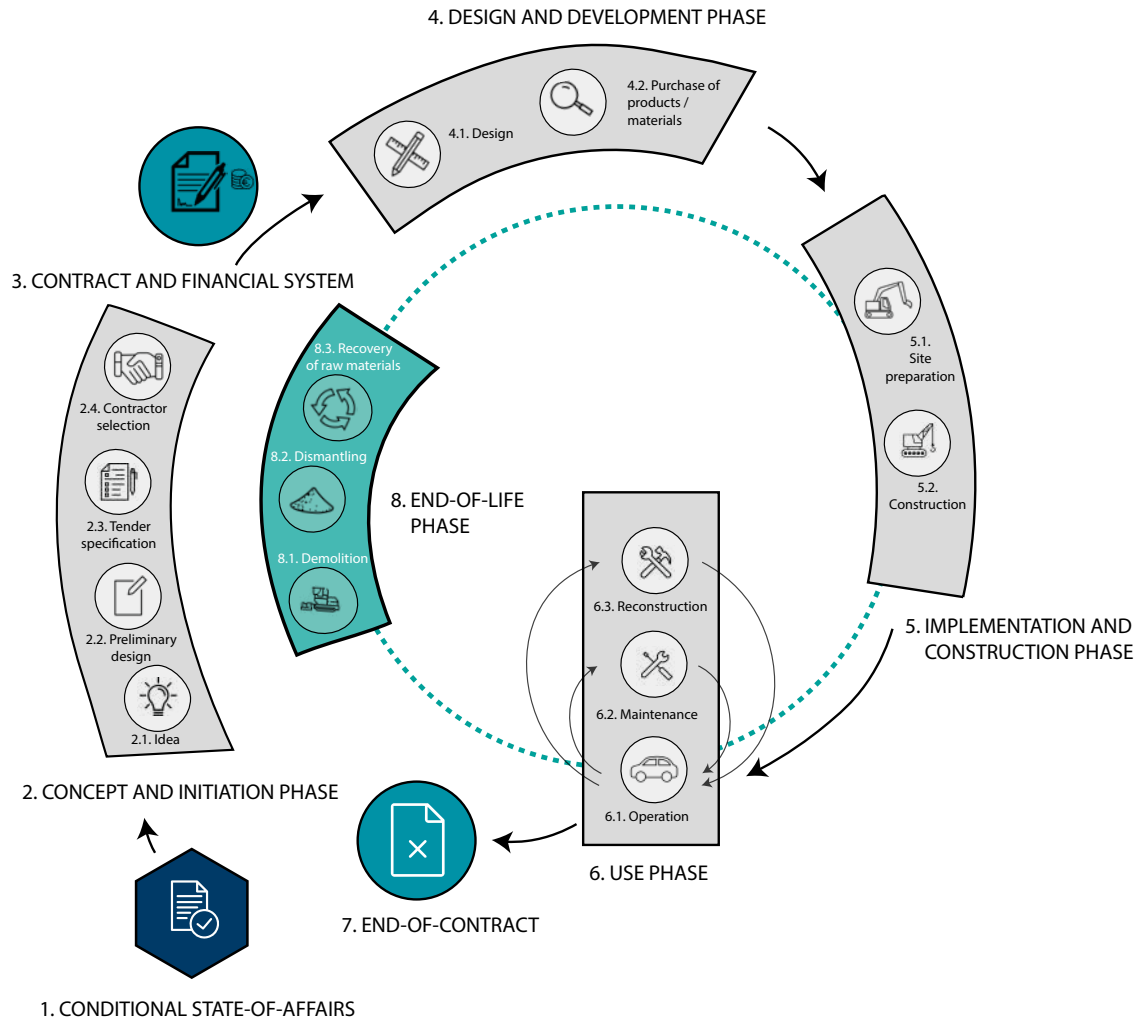


FIGURE 9. PARTIAL DESIGN FOR PRESENTING THE RESEARCH FINDINGS

4.2.1. CONDITIONAL STATE-OF-AFFAIRS

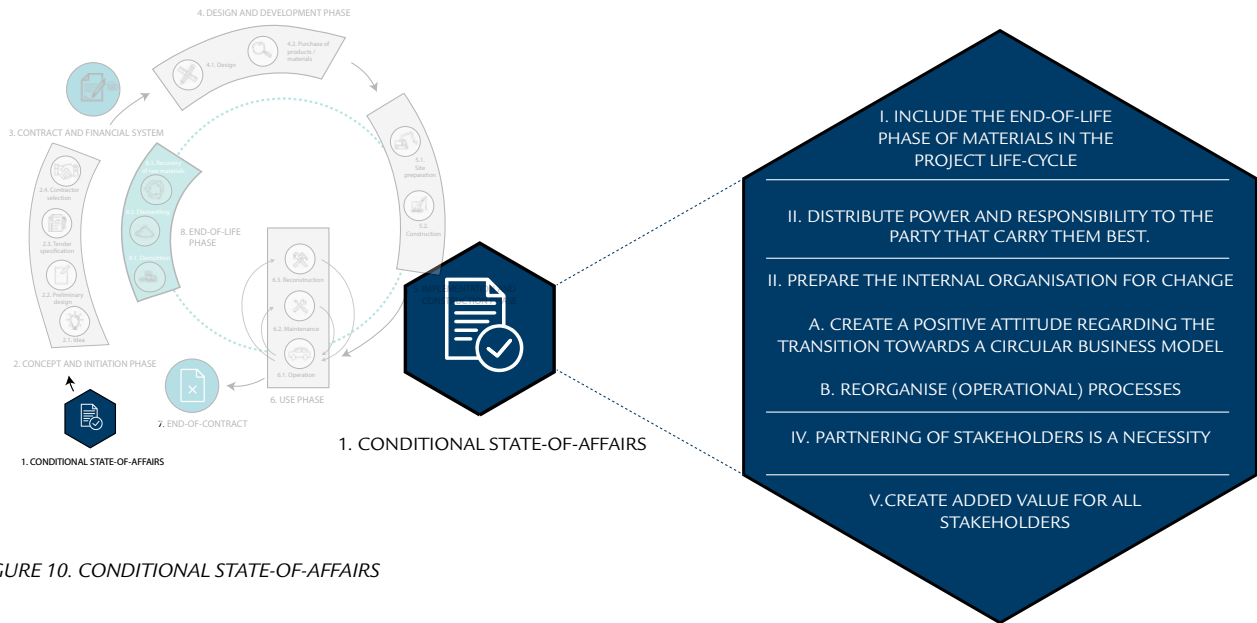


FIGURE 10. CONDITIONAL STATE-OF-AFFAIRS

I. INCLUDE THE END-OF-LIFE PHASE OF MATERIALS IN THE PROJECT LIFE CYCLE

Sustainability and circular economy are embedded on policy level at public clients, suppliers, as well as the contractor. All involved suppliers indicate that they were consciously engaged with the sustainability and circularity. From the supplier interviews it was observed that the end-of-life phase of materials is important to take in consideration when developing a project delivery method. A supplier underpinned this as follows: “Projects last for a certain period, however after termination of the contract the materials still have residual value and a certain technical lifespan. Therefore, it is important that both the material cycle as well as the project phases are considered to develop the best solution to support circular economy on a project level.” (Van den Bosch Beton, personal communication, October 17, 2018). In addition, in the case study of the development of the circular road as a service, it was observed that expansion of the lifecycle in a construction project with an end-of-life phase seems to be necessary to close the material loop in infrastructure projects (consultation meeting DCW, personal communication, November 2, 2018). Therefore, this is seen as a conditional change. Part of this phase are processes such as demolition, dismantling, and recovery of materials which need to be incorporated to close the material loop. This implication does change the traditional project delivery lifecycle since an end-of-life phase will be added after the use-phase.

II. DISTRIBUTE POWER AND RESPONSIBILITY TO THE PARTY THAT CARRY THEM BEST

The characteristics of PSS suggest that a redistribution of ownership is important to make the transition towards service delivery. In traditional project delivery methods, power and responsibilities are separately distributed among the client and the contractor. In the construction phase the contractor is assigned by the client to be responsible for the execution of an infrastructural project. Hereby, the contractor uses his resources and knowledge to deliver an

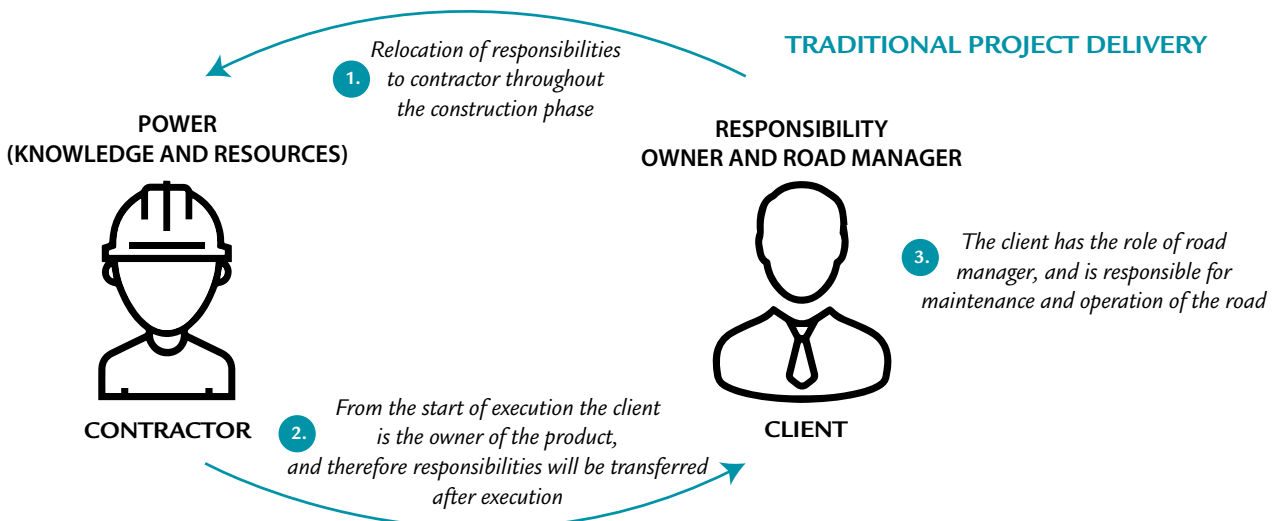


FIGURE 11. DISTRIBUTION POWER AND RESPONSIBILITIES IN TRADITIONAL PROJECT DELIVERY

infrastructural product, which is in this research assigned as having a certain level of power. When the construction period comes to an end, the responsibilities will be handed over to the client. The client acts as road manager, and therefore has the responsibilities regarding the operation of the product (see figure 11.). According to the road law (Weg.w), the public organisation is the owner of the road. In addition, public governments are obligated by legislation to be responsible for the use-phase of the road (art. 1:13 Weg.w). As can be seen in figure 11., power and responsibility (partly due to ownership which brings certain responsibility) are separately distributed in a traditional project delivery method.

Throughout the research, it turns out that the characteristics of PSS, relating to the reallocation of ownership, was the biggest challenge for stakeholders. Most of the clients were proponents of a different way of organising this in the infrastructure. For example, in a client interview the participant argues as follows: *“Changing the distribution of ownership could result into a major change relating to the organisation of infrastructure. There will be opportunities to organize the product as a network, instead as separate pieces of road owned by different governments. This could stimulate the application of services since this is no longer needs to be linked to integrated contracts.”* (Provincie Overijssel, personal communication, September 3, 2018). However, throughout the client interviews, it was noted that reallocation of ownership is not desirable. Because, there is a big risk of losing their role as the provider of a range of necessary services to citizens, achieving societal goals and secure the value of the taxpayer.

As observed in the literature about PSS and circular economy, it is necessary that ownership will be allocated to the producer. This is in contrast with current project delivery methods in the infrastructure sector. In the infrastructure sector the supplier is the producer of infrastructural products, and must retain the ownership of the delivered products. Nevertheless it is noticed, in the interviews with the suppliers, that due to high risks and shifts in their financial system, it is not possible to retain ownership of the products. The main reason given for this was that they need to prepay for their raw materials, so before the production of the desired product starts (Asphalt producer, personal communication, October 23, 2018; Natural Plastics, personal communication, September 21, 2018). Therefore, when combining the product and service (operation, maintenance, and repair), it is observed by the participants that the contractor is the stakeholder who can carry all the risks best throughout the different phases of a project. The main reason given by other stakeholders is that the contractor is involved in each phase of the project lifecycle, besides that they already have some experience and knowledge adopted in integrated contracts. Further, it was noticed in the interview with the asphalt producer (personal communication, October 23, 2018) that they cannot guarantee the highest value throughout the lifecycle, since the contractor takes over the power of the product after purchase. During observation in the case study at the contractor, it was indicated that it is not necessary to get ownership of the infrastructure itself, but to get responsibilities over the applied materials in the infrastructure product.

Therefore, it is indicated that the distribution of power and responsibility to one party is a condition for the application of PSS. According to the participants, this role is best suited for the contractor. In addition, legislation impedes the distribution of legal ownership to different parties than the public client. Due to accession (in Dutch: *natrekking*) (art. 5:20 DC), the reallocation of ownership of the product (e.g. the road) will not be disconnected from ownership of the land, and therefore the client will still be the owner of the product (see figure 12.).

APPLICATION OF PRODUCT-SERVICE SYSTEM

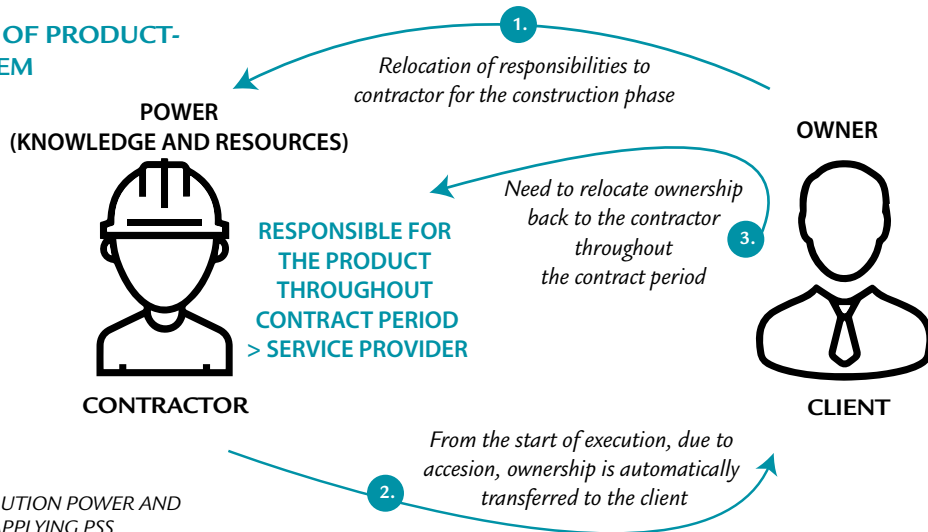


FIGURE 12. DISTRIBUTION POWER AND RESPONSIBILITIES APPLYING PSS

As shown in figure 12. power and responsibility are still separated due to legislation regarding ownership. The contractor will take over the role as road manager, since he is assigned as a service provider throughout the contract period. However, the responsibilities are automatically transferred to the client. The legal expert at Dura Vermeer

noticed “Due to legislation, power and responsibilities (which is linked to ownership) are still separately distributed among the client and contractor. However, to make a transition work, it is necessary that the responsibilities will be transferred back to the contractor since he is obliged to provide a service to the client. This is the only way to align the interest from both parties.” (Legal expert DCW, personal communication, October 18, 2018).

To relocate the responsibilities regarding the product back to the contractor there are two possible solutions identified with the current legislation:

- 1) Breaking accession with the right of superficies (art 5:101 DC) or ground lease (art 5:85 DC) to relocate legal ownership (see figure 13).
- 2) Relocate responsibilities by a contractual arrangement in which economic ownership is distributed to the contractor. Whereby the contractor will be entitled to the value of the use of an object as well as the positive or negative value change (see figure 14). Hereby, the legal owner (public client) remains visible to third parties as the owner at the land register.

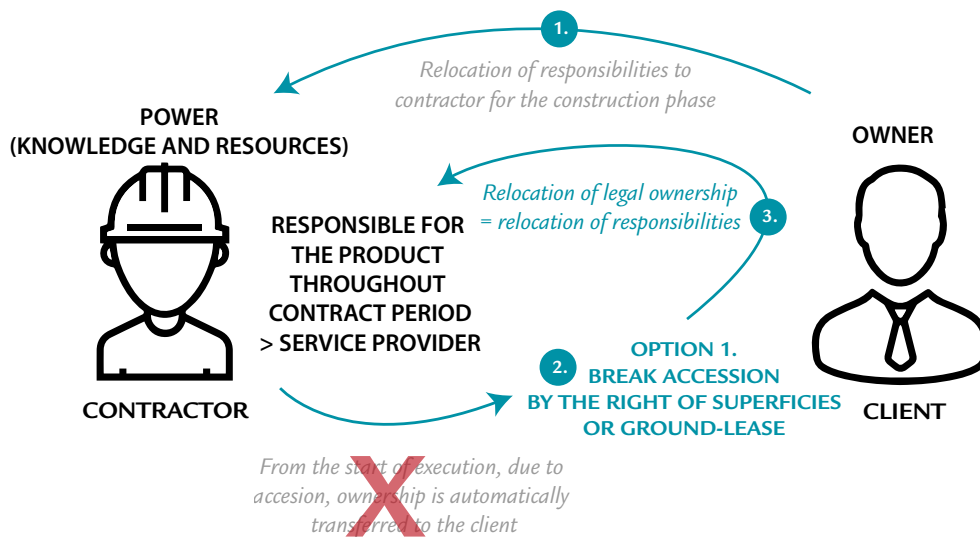


FIGURE 13. OPTION 1) LEGAL OWNERSHIP

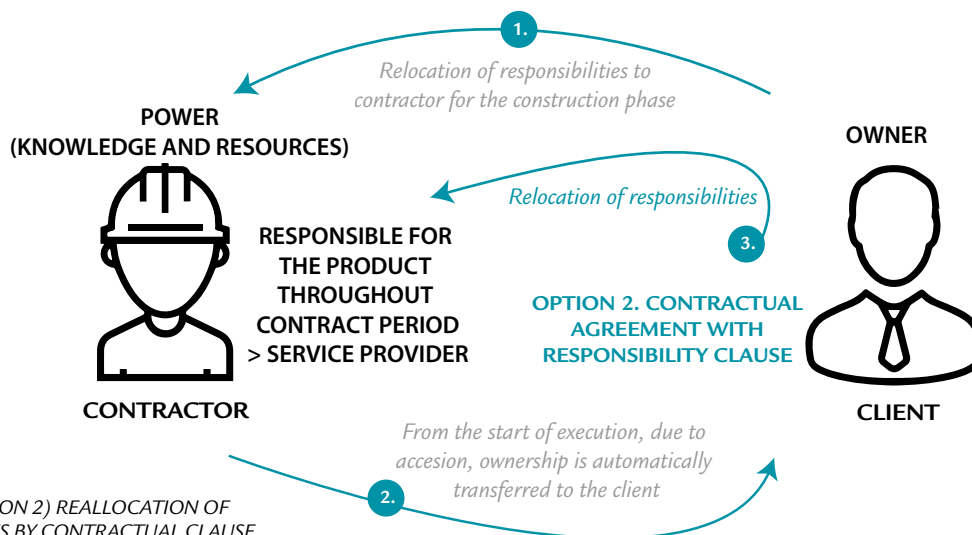


FIGURE 14. OPTION 2) REALLOCATION OF RESPONSIBILITIES BY CONTRACTUAL CLAUSE

III. PREPARE THE INTERNAL ORGANISATION FOR CHANGE

A. CREATE A POSITIVE ATTITUDE REGARDING THE TRANSITION TOWARDS A CIRCULAR BUSINESS MODEL

The interviews have shown that the human factor in the transition towards a new business model should not be underestimated. In the analysis of data, it is observed by both clients and suppliers that the human factor still hinders the transition towards a circular economy. Further, it was argued by an interviewee that “the construction sector is still a conservative sector, and that the human aversion against change is thereby indicated as an opposing factor when transforming to another business model” (Provincie Overijssel, personal communication, September 3, 2018).

During research, mainly proponents of the transition to a circular economy in the infrastructure sector were involved. However, in the interviews with both client and supplier, as well as in the case study at the contractor, it was observed that colleagues within their organisations are not ready for change. The conservative environment was given as the main reason. In the interviews, it was identified that the employees' reason for resistance against change in general is job loss, poor communication and engagement, and probably the unknown due to a lack of knowledge. In the end, it is the people who make the transition work, and therefore the aversion against change needs to be broken. A positive attitude regarding the transition towards a circular economy, and thereby towards a circular business model, should be created. This is seen as a conditional state-of-affair.

Research shows that there are social, cognitive and motivational forces that drive the phenomenon of resistance to change (Jost, 2015). Due to these forces people resist to undertake certain actions for a more sustainable environment (Jost, 2015). In addition, Harich (2010, p.37) argued that *“change resistance is the tendency for a system to continue its current behaviour, despite the application of force to change that behaviour”*. It was also argued that barriers to change will be strengthened when problem solvers force change, since the people will then automatically stick to their current operations (Harich, 2010). According to Berna-martinez & Macia-perez (2012), resistance to change business innovation is seen as a key factor leading to failure of innovation.

These findings in literature are comparable to the observed research findings, and therefore this is noticed as a conditional state-of-affair. To make a difference, in terms of sustainability impact and sustainable patterns, it is necessary that the involved people are well-informed about the choices related to the transition (United Nations Environment Programme, 2015). In addition, it is identified by the United Nations Environment Program (2015) that this choice not only should be optimised in terms of costs, but also fulfils the needs that are necessary for a sustainable environment.

In literature several strategies are identified to overcome resistance and effectively implement change. In the first place, to alleviate the problem, it is important to effectively engage the people who are opposed to change early in the process (Berna-martinez & Macia-perez, 2012). Further, Berna-martinez & Macia-perez (2012) indicated that communication about the change is seen as necessary, in order to show the employee that the innovation has several goals that are aligned with the overall objective. Besides that, it is noticed that communication of the change, by explicitly telling employees what is going on, is important. In addition, educating employees in the new technological environment is seen as a solution to involve them, as well as to create a certain level of confidence about the changing circumstances (Berna-martinez & Macia-perez, 2012). Hereby, it is suggested to take time to spread knowledge regarding the effect

of the implementation to create awareness, and reduce the resistance to change. Further, it was indicated that applying product-service systems in infrastructure requires new competencies (people and experience) for all stakeholders. To create a positive attitude, these new competencies should be further developed in the organisation, as well as between diverse organisations.

B. REORGANISE (OPERATIONAL) PROCESSES

During observation it was identified that the transition from product to service delivery does require organisational changes. Especially when responsibility will be distributed to the party that provides the service, reorganisation of operational processes is needed. The contractor organisation should change into a service-oriented company, which requires processes that are in line with this role. To bear and guarantee responsibilities throughout the lifecycle of projects, it is necessary that the contractor gains the capabilities to implement the service characteristics also on the operational level.

From the interviews with the suppliers it is identified that all of them do not have any experience with service-related offers. Furthermore, the contractor mentioned that due to the integration of different lifecycle phases it is important that knowledge is guaranteed throughout the contract period, as well as after termination of the contract (consultation meeting DCW, personal communication, November 19, 2018). This requires administrative activities for all stakeholders during the contract period, since they must guarantee that knowledge is recorded throughout the lifecycle of projects. In one of the client interviewees, it was indicated that contract management will be a challenge when infrastructure is delivered as a product-service system (Gemeente Haarlemmermeer, personal communication, October 2, 2018). *“Long-term contracts result in an extended collaboration between certain parties. When several roads are offered as a service under various contractual agreements in one area, the management of these different contracts will be a major challenge for the public organisation.”* (Gemeente Haarlemmermeer, personal communication, October 2, 2018). To be able to do proper contract management it is indicated by the interviewee that the client organisation needs people who have the capacity to manage this. Further, the number of contracts depends on how ownership is divided among stakeholders. A big diversity in contracts is seen as an obstacle regarding the application of product-service in infrastructure (Gemeente Rotterdam, personal communication, September 26, 2018). In addition, the interviewee indicates that the management of contracts at the contractor's organisation will also be a big challenge. The contractor will enter into long-term contracts with the client, as well as with suppliers. This also implies a big diversity of contracts. To implement PSS on a project level it is necessary that a reorganisation of (operational) processes will take place, and is therefore identified as a conditional state-of-affair at the start of the lifecycle of projects.

IV. PARTNERING OF STAKEHOLDERS IS A NECESSITY

The case study, as well as the interviews, clarify that product-service offering should fit the firm's capabilities, resources, and organisation. This is underlined by a supplier that stated "to close the loop it is necessary that we, as a material supplier, closely collaborate with recycling organisations. However, recycling organisations must also start a close collaboration with demolition companies" (Van den Bosch Beton, personal communication, October 17, 2018). In addition, in a client interview it was noticed that for the transition towards a different system it is important that contractor and clients understand each other (Gemeente Rotterdam, personal communication, September 29, 2018). Also, in other interviews it was noticed that partnering of stakeholders in the chain is an important aspect to solve capability gaps. Early collaboration is, according to the contractor, client, and supplier, a basis for long term intensive collaboration. Due to the impactful change to release the certainty of technical specification, for a lot of clients it is necessary that clients and contractor do understand each other. In 4 out of the 6 semi-structured interviews with clients, the term trust was explicitly mentioned as an important factor for collaboration. It is observed that close collaboration between the client and contractor is, due to the long-term contractual relation, seen as an important component to create a cooperation based on trust and solidarity. Especially when transforming to a new business model. Therefore, partnering of stakeholders to support change in the infrastructure sector is seen as a conditional state-of-affair. This need for collaboration between various stakeholders is presented in figure 15.

In addition to the analysis, also vision documents as e.g. Marktvisie (2016) and Transitieagenda (Nelissen et al., 2018) appoint collaboration as a condition in the transition towards a circular economy. To close the material cycle, and stimulate change to a new business model, it is necessary that stakeholders start to closely collaborate with each other (MVO Nederland, 2018; The Ellen MacArthur Foundation, 2015).

Further, in the analysis it was indicated that the contractor and clients do not have a sufficient understanding of each other's organisation and working methods. To overcome this, it is suggested to talk more often about a circular economy with stakeholders, and discuss the consequences and requirements of the organisation.

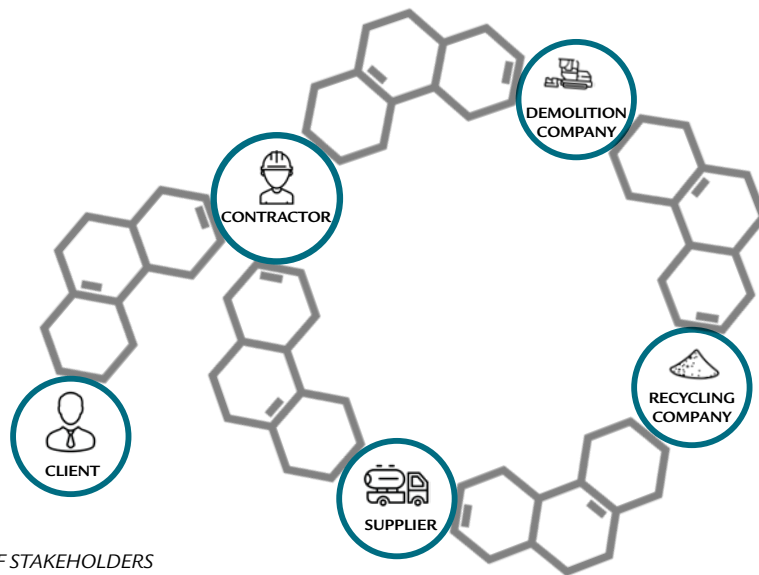


FIGURE 15. PARTNERING OF STAKEHOLDERS

CREATE ADDED VALUE FOR ALL STAKEHOLDERS

For all stakeholders involved in infrastructure projects, it is important that the application of PSS in projects has added value, not just financially or economically, but also socially. According to one of the clients the necessity of added value is underpinned as follows "There is a need for change. To move to a circular economy in the infrastructure sector, it is necessary that an incentive for parties will be created. This incentive means that parties in the chain would be better off economically. This is always a better motivator than to comply with the law, or to have the obligation to do it sustainable." (Rijkswaterstaat, personal communication, September 14, 2018).

In the analysis, it became clear that public clients have the task to provide a range of necessary services to citizens, achieving societal goals and secure the value to the taxpayer. From the interviews with clients it turns out that it is important that they can still fulfil their task to society. Besides that, change is also important for political reasons since the demonstrability of making a difference, in relation to circularity and sustainability. With the objectives in the field of circularity, it will be important that the application of PSS also creates added value in comparison to the current project delivery methods. For the private parties (e.g. the contractor and supplier) it is important that they can still achieve their business purposes. However, it was observed, both in the interviews as the case study, that they also have purpose to transform towards a circular way of doing business (consultation meeting DCW, personal communication, November 29, 2018). The implementation of PSS characteristics in projects must create an added value for all involved stakeholders, and is therefore identified as a conditional state-of-affair.

Due to the reallocation of responsibilities to the contractor, it is important that a certain economic incentive will be created that supports the transition. In the case study it was noted that it is important to include the (residual) value of materials in the financial system. In addition, also in the interviews with the clients, it turns out that assigning value to materials could add purpose to incorporate the material flow in projects. As a supplier argued, “*circular economy makes sense since reuse of materials can save costs*” (Van den Bosch Beton, personal communication, October 17, 2018). The expansion of the lifecycle of products is for clients an important added value, since they can use the products for a longer period, and thereby have an opportunity to save on the total cost of use.

Referring to paragraph 4.1., it is important that the incentives for the client and contractor are aligned. In the end, the client wants a product that can fulfil the function for a long time. Since the client will get paid for the function (and indirectly the quality) there is a comparable incentive for quality and long lifetime for the contractor.

4.2.2. CONCEPT AND INITIATION PHASE

In the concept and initiation phase, it is important that the client clarifies his request to the market and therefore a change in tender specification is a prerequisite.

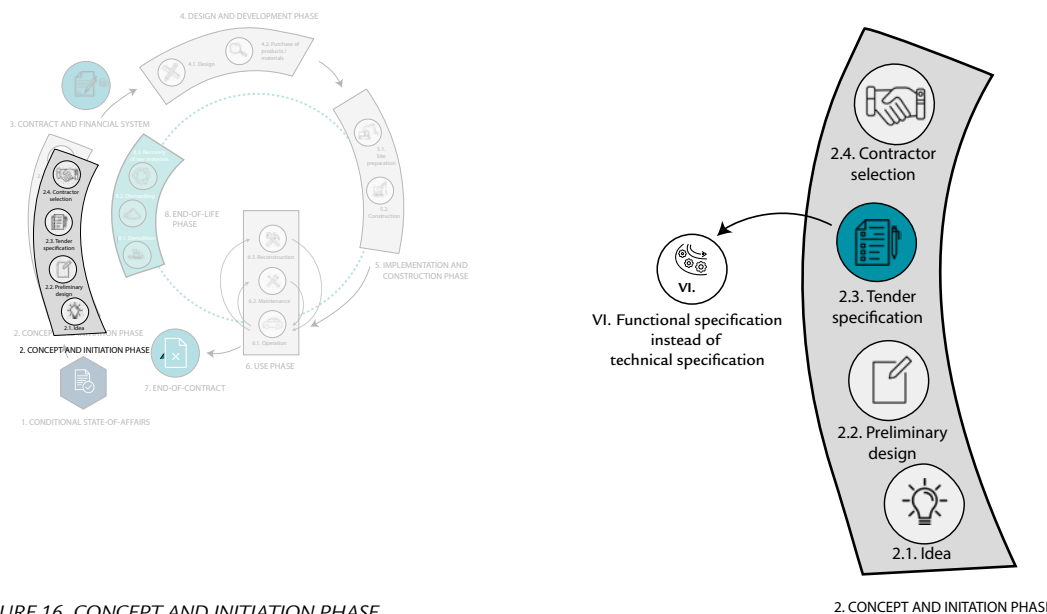


FIGURE 16. CONCEPT AND INITIATION PHASE

VI. FUNCTIONAL SPECIFICATION INSTEAD OF TECHNICAL SPECIFICATION

Analysis of data shows that functional procurement, instead of technical specification, is necessary for the application of product-service systems in the infrastructure. In one of the client interviews, the interviewee indicated that in the client organisation it is common to prescribe the entire project technically, since this gives a higher level of certainty to the client to get what is needed (Provincie Overijssel, personal communication, September 3, 2018).

The change towards more functional specification will be a major shift for the current employees. “*As far as I concern, it does not take place because there is a lack of knowledge, daring, and guts. When making the transition towards services it is necessary that the focus of the client is on the function of the product - accessibility, safety, and availability - instead of the technical specification of the product.*” (Provincie Overijssel, personal communication, September 3, 2018).

The main difference, argued by the contractor and supplier, is that functional procurement creates more room for applying innovative and circular solutions. Therefore, it was indicated that for the application of PSS the function of the product (accessibility, safety, availability) must be more important for the client than the product itself (technically). Following the life cycle of projects, this change should be incorporated at 2.3. tender specification. Additionally, this change has implications on the traditional process and should be applied in the tender specification, which is part of the initiation phase.

In a functional specification the focus will be on the user’s need, which can be fulfilled with various solutions (Tukker & Tischner, 2006; United Nations Environment Programme, 2015). Research by United Nations Environment Programme (2015) argued that sustainability public procurement could be a solution for public clients to come up with a process that meets their needs. Sustainability public procurement is characterised by the fact that it produces value for money, as well as benefits for the society, while it minimizes the negative impact on the environment (United Nations Environment Program, 2015). In addition, it is important that the client attentions a ‘closed-loop’ production and the consumption cycles in its tenders, since it potentially results in resource efficiencies, a reduction of risks and creates solutions for strategies at the end-of-life phase. Most important, in relation to the procurement of PSS, is that the government needs to verify that the entire life cycle should be included.

4.2.3. CONTRACT AND FINANCIAL SYSTEM

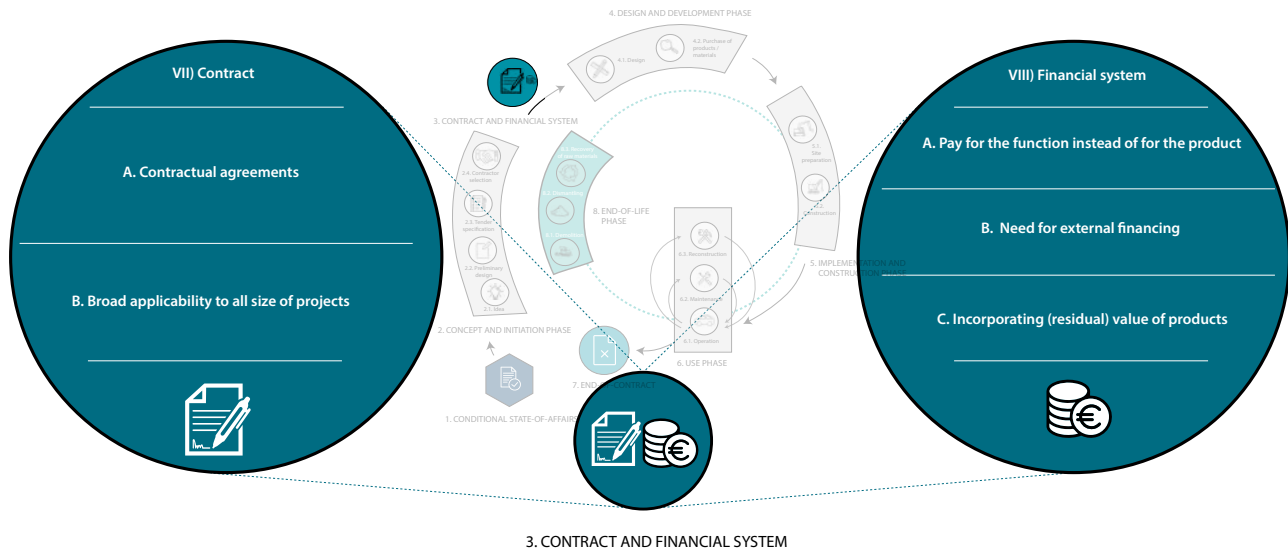


FIGURE 17. CONTRACT AND FINANCIAL SYSTEM

VII. CONTRACT

A. CONTRACTUAL AGREEMENTS

The change from a product delivery to a service delivery requires significant changes in the contract. The role of the contractor changes from execution party into a service party, which also brings a redistribution of certain responsibilities. During analysis, mostly by observation in the case study, it was identified that for application of product-service systems in the construction industry the following three aspects are important: 1) the allocation of risks among parties, 2) the distribution of the costs, in relation to the service fee, among the contractor and client, and 3) the allocation of rights for decision-making. These three conditions should be considered by defining the contractual agreements. The required changes on contract level are not specifically related to one phase, but to several phases of the project life cycle, and are therefore appointed as required state-of-affair. Also, the end-of-contract is seen as an important state-of-affair in the transition towards a service-oriented project delivery method. Additionally, it is argued by several participants that it is important for the right distribution of responsibilities that the end-of-contract is also considered.

B. BROAD APPLICABILITY TO ALL SIZES OF PROJECTS

To make the transition towards a service-oriented infrastructure sector it is noticed by the contractor as a prerequisite that the application of PSS in project delivery methods must be applicable for all sizes of projects (Legal memo Dura Vermeer, personal communication, October 9, 2018). The legal expert of the development group DCW argued this as follows: *“The delivery of a road as a service can only have a major impact when this business model is able to be applied to a diverse scale of projects. From small municipal infrastructure projects, to big national infrastructure projects. If the PSS aspects or the economic model would only be applicable to a certain size of project, then a total transition will not be stimulated.”* (personal communication, October 18, 2018). This is in line with the problems that were observed in the existing integrated contracts, since these contracts are only applicable to big complex projects due to the complexity of settlement of a suitable agreement. Therefore, scalability of application to projects is seen as a required change in order to successfully implement PSS characteristics on project level in the infrastructure sector. For the application of product-service systems, transparency and standardisation are in the analysis identified as important conditions for scalability of the application (consultation meeting DCW, October 18, 2018).

In addition, recognisability for the public client is noted to be an important aspect regarding the contract. Reason being that, for instance, the existing DBFM contracts are fairly complex, and hence not understood by less sophisticated public clients. This would mean that the transaction costs are high (legal counsel for the client) and the project becomes economically not viable. Additionally, a public client might not be comfortable with a contract it does not understand. Therefore, it was indicated by the contractor that the UAV-GC can act as the basis for the contract when applying PSS in the infrastructure sector, since UAV-GC is recognised by almost all public clients. In addition to this, components such as maintenance, finance, and circularity should be added. This circular component is important from the perspective of the contractor, since the reallocation of responsibilities also means having the responsibility over the applied materials (consultation meeting DCW, personal communication, October 18, 2018). This provides an incentive for the contractor to incorporate the (residual) value of the materials into its design decisions. Resulting in optimisation of the residual value of the materials. In addition, it influences the maintenance decisions, since the contractor will take “good care” of its materials as it represents value to him.

In the first place, the contractor indicated that a standard contract is necessary to make the concept scalable for all types of projects. According to the financial expert of DCW (consultation meeting DCW, personal communication, October 18, 2018), external project financing is only possible for projects with a threshold of ca. EUR 10 to 15 million. Reason for this is to keep it financially attractive, as more corporate finance constructions should be possible. However, the financing costs are higher, and it involves additional risks. The project is not economically feasible, and therefore DBM-contracts shall be more interesting for the client. Standardisation at contract level can ensure that it is also possible to attract funding for several smaller projects together. Because financiers recognise the contract, and hence do not require due diligence per project. This lowers the transaction costs. If a non-standard contract is applied, then due diligence is required for each contract (e.g. legal advice). Also, once the threshold is met (the above-mentioned EUR 10M to 15M) financiers only need to “tick the boxes” and can easily lend to project.

VIII. FINANCIAL SYSTEM

When implementing PSS characteristics in the project delivery method it is indicated that the client no longer pays for the product, but for the service. Therefore, it is identified that changes in the financial model of projects also take place. In addition, to achieve a circular economy the (residual) value of materials should be incorporated in the financial model. Therefore, the financial model is seen as an important implication that needs to be considered when developing a new project delivery method for projects, in which PSS characteristics will be applied. Financing is related to the contractual arrangements and will, therefore, be placed next to the contract after the initiation phase.

A. PAY FOR THE FUNCTION INSTEAD OF PRODUCT

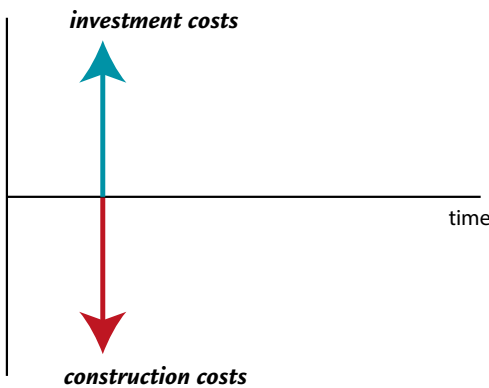
Due to the transformation from a product to a combination of a product and services, changes to the revenue model will take place, which is in line with the characteristics of PSS identified by Tukker and Tischner

(2006). In the theoretical framework, it was identified that different types of transactions can be distinguished for the business model. Traditionally a buy-transaction takes place (see the left side of figure 18), which means a one-off payment for the client. For the application of a result-oriented PSS, which is found in the theoretical framework most attractive in relation to CE and sustainability, the full-service lease or pay-per-use transaction is applicable. Here, the client pays a periodic service fee throughout the contract period. Furthermore, when applying PSS in projects in the revenue streams it is important to take the (residual) value of materials into account (as shown in figure 18). This will result into a settlement between the client and the contractor at the end of contract (in case the public client elects to retain the materials), which will be further discussed in paragraph 4.2.7.

Since the contractor will get paid regarding the level of service, it is necessary to also stipulate the periodic service fee in the contract. This price could be influenced by i) penalties for bad performance/unavailability of the road and ii) ensuring the (residual) value is optimised (Financial expert Dura Vermeer, personal communications, October 30, 2018). The change from possession to use could be noticed as a chance to have more continuity of income over a longer period, and thereby a higher revenue. In relation to traditional projects, the provision of service is accompanied by additional services (advice, maintenance, and repair) that provide recurring income during the use phase. As indicated in research, long-term product-service system contracts and reallocation of responsibilities ask for a higher risk profile (Financial expert DCW, personal communication, October 30, 2018).

These risks should be determined in a risk assessment and should be incorporated in the life cycle assessment to determine the value of the projects. Further, it is identified that the consequences when the service provider does not meet the agreed requirements must also be stipulated in the contract. In relation to this, it is necessary that upfront agreements are made regarding the termination of the contract. The (residual) value of the materials/product is proven to be a fundamental aspect with (early)

REVENUE STREAM - TRADITIONAL



REVENUE STREAM - PSS

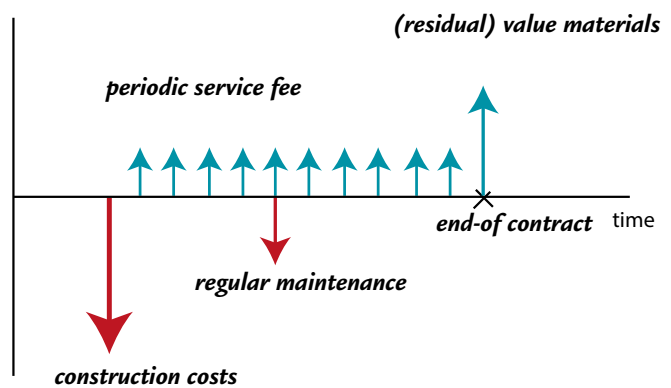


FIGURE 18. REVENUE STREAM PSS

termination of the contract. In research, it is identified that one of the biggest risks for the contractor is an early termination when he cannot fulfil the agreed service level. Consequently, it is essential that proper agreements are made in the contract relating to a termination fee.

B. NEED FOR EXTERNAL FINANCING

Cash flow will be spread over time due to the application of PSS cash flows, this is where the payback period and investment costs become relevant. The periodic service fee pays back the investment costs spread over the contract period. The gap between construction costs and the periodic service fee creates a need for more capital (debt and equity) to pre-finance projects. Therefore, external financing by banks (senior debt) and investors (equity) is most likely applicable. However, this also asks for a risk assessment from the banks. For long term contracts the risks become higher for banks and investors (Financial expert Dura Vermeer, personal communications, October 30, 2018). Furthermore, it appears that external financing by banks is interesting for a total required capital around of ca. EUR 10 to 15 million euro. The expectation is that not all PSS projects meet the required capital threshold on a stand-alone basis. The contractor suggested to finance the PSS projects on its balance sheet and, once the threshold is met, refinances the PSS project with external project finances. Taking the projects on the balance sheet up to the moment the critical size, required for external financing, is reached is called “warehousing” by the financial expert (personal communications, October 30, 2018). Therefore, ‘warehousing’ of multiple smaller projects is a possibility to make it interesting for lenders and investors. This was underpinned by the financial expert as follows: *“Where normally the credit risks of the client is important for financiers, is this for infrastructure projects minimal. The Dutch infrastructure sector is driven by public clients who are often stable and hardly go bankrupt. Therefore, the credit worthiness of public entities is deemed as excellent.”* (Financial Expert Dura Vermeer, personal communications, October 30, 2018).

C. INCORPORATING VALUE OF MATERIALS

A circular product differs from a linear product, since products in a linear economy are recognized to be waste products at the end of their useful life. As a result, the linear product does not have a useful value, and

therefore also no economic value. A road or construction work consists of a lot of diverse materials. Each of these materials does have another technical, as well as economic, lifespan. This lifespan does often differ from the length of a contract period, and therefore it is necessary to make contractual agreements regarding the end of the lifecycle of materials.

The participants of this research indicated that the first step for incorporating the value of materials in the financial system is to determine which materials will be applied, or have already been applied, in an infrastructure ‘product’, as well as capturing the value of these materials as data (Consultation meeting DCW, personal communication, November 2, 2018; Natural Plastics, personal communication, September 21, 2018). This can be done with programs like BIM or Madaster. The (residual) value of the material depends on a certain market operation, which is supply versus demand. However, it is questionable whether each product has a market effect. This should be concluded into the calculation of the value of the product. Thereafter, it is important that there are contractual agreements to ensure that this information is kept up-to-date throughout the different phases of the cycle. The residual value of a product can be defined as the value at the end of its useful life. The contractor needs to preserve this value throughout the use-phase to ensure that at the end of the contract this value is as high as possible. It is possible that, after multiple cyclic application of the product, the residual value comes to an end, which is when the product can no longer meet the performance requirements that have been set. This can be caused due to the termination of the economic, technical or functional lifecycle.

The aim at the end of the contract is to clarify what the conditions are regarding the value, but also of the quality of materials. Interesting about the (residual) value of materials is i) a certain part of the loan can be sized on the (residual) value. As the public client only needs to repay the loan minus the residual value (see figure 19). The effect of the principal payments are lower. The contractor passes through this advantage by lowering its required service fee. ii) This also means that the value of the applied materials is made “liquid” for the public client.

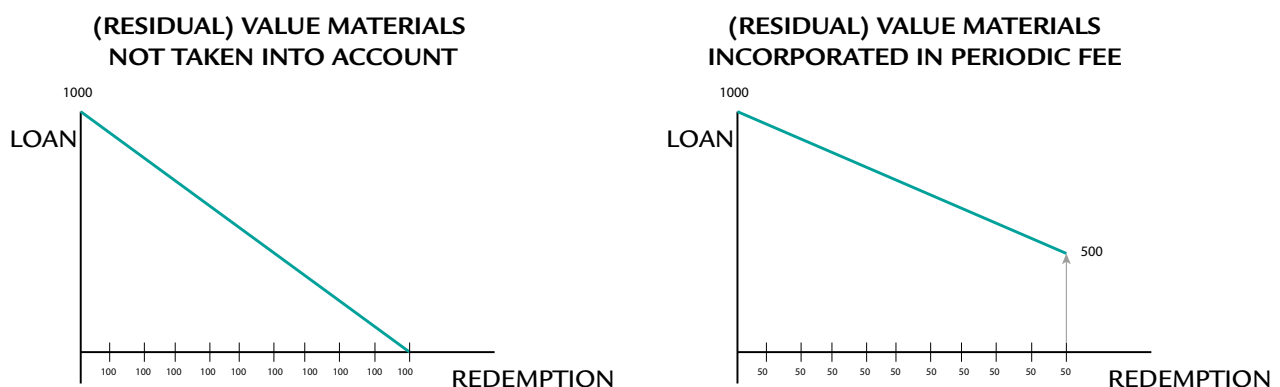


FIGURE 19. EFFECT OF INCORPORATING VALUE OF MATERIALS IN FINANCIAL SYSTEM

4.2.4. DESIGN AND DEVELOPMENT PHASE

IX. HIGH-VALUE TECHNICAL DESIGN

Due to the shifting of responsibilities to the contractor, it turns out that there is an incentive to extend the lifespan of the product. The application of high value materials with a long lifespan is an important required change to achieve a high-value product. The value of materials have a certain influence on the quality of the product, which also has an influence on the service level that can be delivered. This required change should, therefore, be incorporated in the design phase of the project lifecycle.

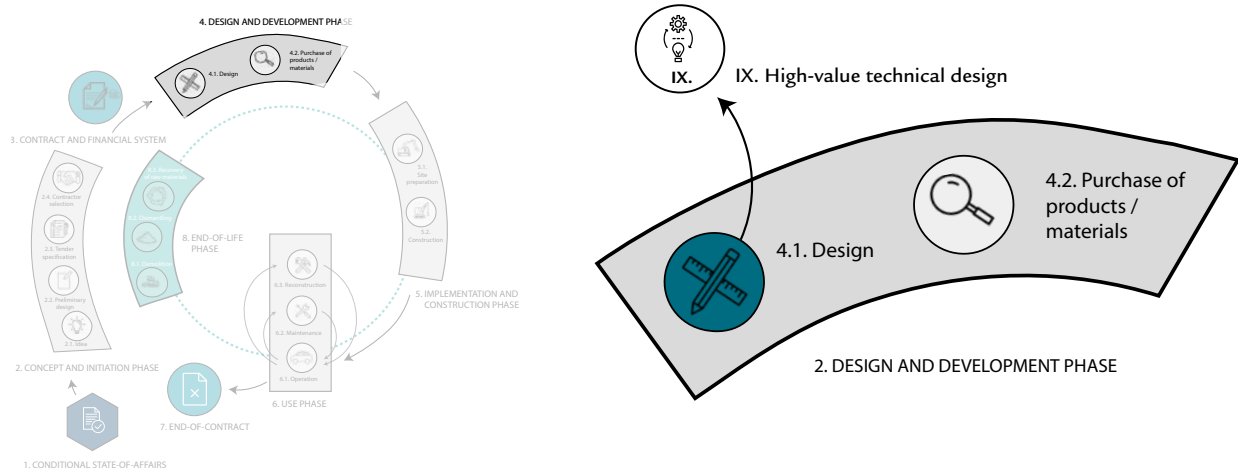


FIGURE 20. DESIGN AND DEVELOPMENT PHASE

In the first place it is important that the product will be designed according to circular principles. When transforming to a service-oriented project delivery, the contractor is responsible for the product throughout the contract period. Especially when the (residual) value of materials will be used as a settlement at the end of the contract, it is in the interest of the contractor to make the product last as long as possible, and to allow reuse of its parts rather than scrapping them.

However, according to Ashby (2016) a higher specification of design requirements, as well as the choice of materials, increases the lifetime of a product and its durability. Retention of the value will be kept at the maximum by first considering the reuse of a product as a whole, the reuse of parts and at last the recycling of raw materials. Van der Pijl (2017) indicated that when products will be refurbished at the end of their life it important that during the design steps are already taken to stimulate this. Therefore, it is identified that disassembly and separation of materials need to be incorporated in the design phase.

According to the clients, it is seen as necessary that products are designed and manufactured in such a way that the product is easily dismantlable at the end of the use-phase (Provincie Overijssel, personal communication, September 3, 2018; Gemeente Haarlemmermeer, personal communication, October 2, 2018). In addition, it is identified to be important that the material flow can be easily separated. In the interview with the municipality of Rotterdam it was argued that the current design of infrastructure roads cannot easily adapt adjustments in the function of the road (personal communication, September 26, 2018). Therefore, in relation to a change of the function during or after the contract period, adopting a dismantlable product design is seen as a chance to increase flexibility. In addition, materials can fulfil their function over a longer period, which support the way of circular thinking in projects. Further, the bio-based supplier suggested that it is important that components and raw materials of the infrastructural products are best biodegradable. This is underlined by the following statement: *“To achieve circular economy it is important that material flows are closed. Bio-based products return in an automatic biological process to nature at a certain moment.”* (Natural Plastics, personal communication, September 21, 2018). The aim of the design phase is to design a product, by extraction, manufacturing, and assembly of the components, which adds value to the product. When the product is developed for having a long life, it will also be suitable for good maintenance and repair, which reduces the need for resources and prolongs the use phase.

4.2.5. IMPLEMENTATION AND CONSTRUCTION PHASE

The construction phase starts with the preparation of the building site. Hereby, the contractor should take care when removing old elements to make it possible to re-use these old elements on the construction site. Reuse and high-quality recycling of products is an important component of the circular economy. For example, the asphalt producer indicated that he can guarantee a 99,9% high-quality reuse. *“A road consists of several layers, in which the bottom layer consists of low-grade materials and the upper layers of high-quality materials. If these layers were selectively removed layer for layer and supplied to an asphalt plant, it is almost suitable for a reuse percentage of hundred. Due to time and money restrictions this is currently not the case.”* (Asphalt producer, personal communication, October 23, 2018). This indicates that it is from a technical perspective already possible to optimally recycle, however, the current way of organising projects is not in line with the

perspectives of a circular economy. Comparable to the design phase, here value will also be created for the product. During execution, it is important to take care of the materials that are present, as well as of the product that will be constructed. Further, no significant changes are identified for the execution phase

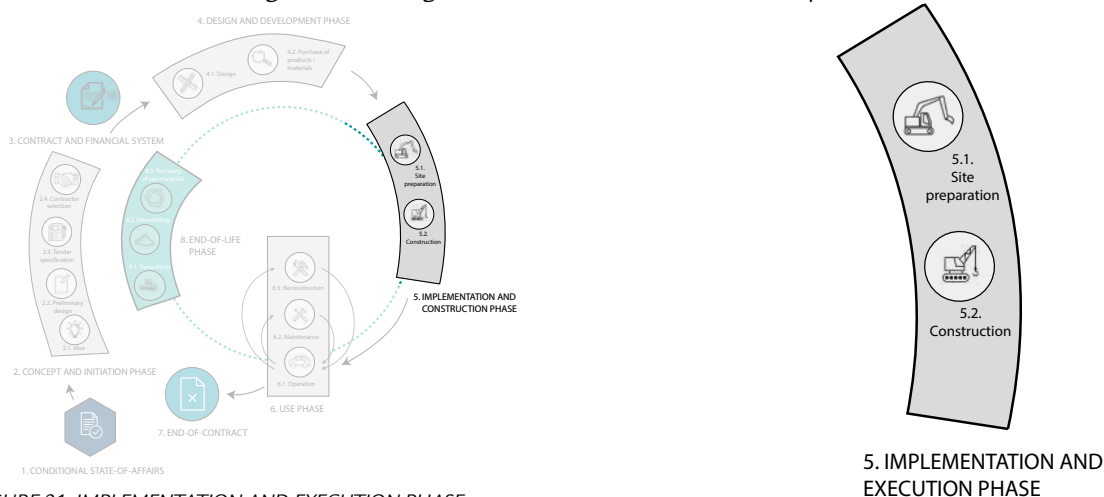


FIGURE 21. IMPLEMENTATION AND EXECUTION PHASE

4.2.6. USE PHASE

As mentioned earlier, the use-phase will be included in the project lifecycle when applying PSS characteristics. In this phase the most important change is that the contractor should act as a service provider. During the use phase, it is necessary that the contractor monitors the status of the infrastructure work and the conditions of materials. This needs to be done to indicate when products are going towards the end of their lifespan and need to be replaced. In the end, the contractor needs to keep control over the resources and preserve the value that was added in earlier phases.

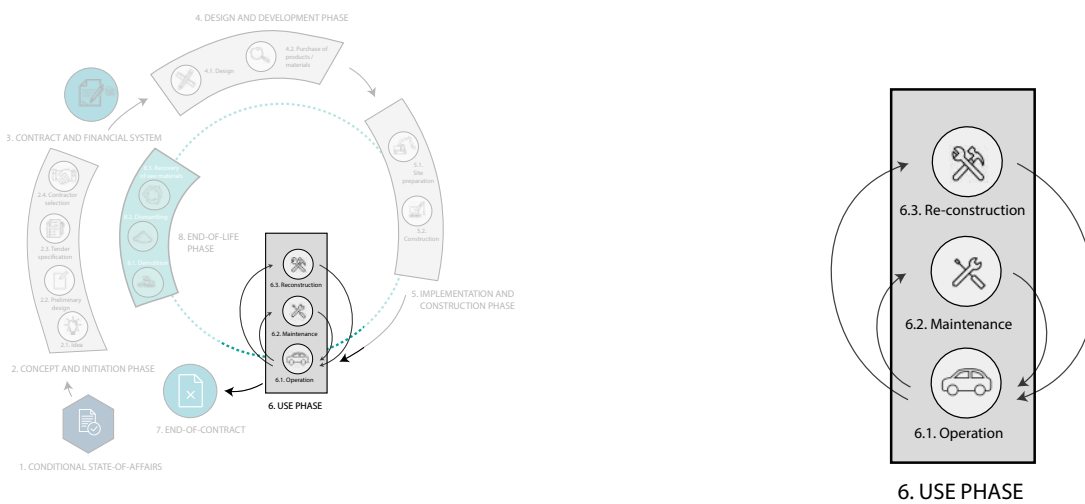


FIGURE 22. USE PHASE

4.2.7. END-OF-CONTRACT

X. END-OF-CONTRACT MUST BE TAKEN INTO ACCOUNT AT THE START OF A PROJECT

During the case study, it is observed that for a service-oriented project delivery it is important to consider the end-of-contract. The end-of-contract depends on how responsibilities are distributed among the client and contractor. It is important to clarify how responsibilities and power will be distributed among stakeholders when the contracts come to an end.

In paragraph 4.2.1. it was mentioned that there are different options identified to relocate responsibilities and power to the contractor. The options for the end-of-contract depends on which option is chosen for the reallocation of responsibilities.

Therefore, two situations will be described:

1. When legal ownership of the materials (the product) belongs to contractor A. (see figure 24).
2. When the contractor has contractual responsibilities during the contract period. (see figure 25).

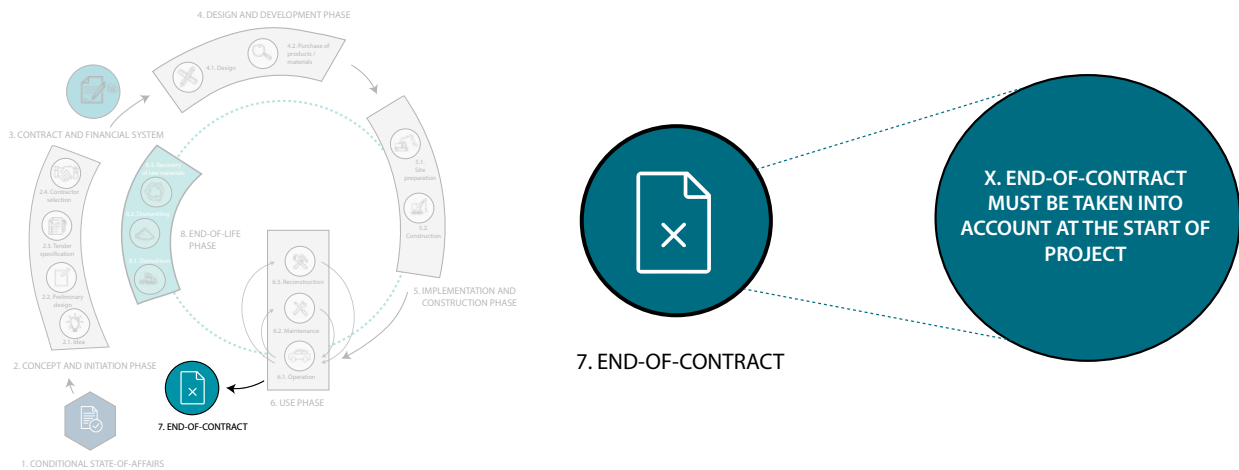


FIGURE 23. END-OF-CONTRACT

When legal ownership of the materials is assigned to the contractor for the contract period, it is observed that there are multiple possibilities to transfer the legal ownership back to the client or contractor (see figure 24).

- In the first place, option 1A, is not favourable since the client does not want to end up without the infrastructural product when the contract ends. In addition, removing the road is not in line with the aim to extend the lifecycle of materials as much as possible and therefore not a circular solution. Additionally, removal of the construction costs energy and negatively impacts the environment.
- When the client decides not to extend the product-service delivery (1B), he must buy the materials from contractor A. This is, according to the theoretical framework, a lease-purchase transaction. Additionally, it is important that the contractor relocates power (knowledge) to the client, since this is necessary for the preservation of the value of a product.
- When a new procurement procedure starts and contractor A wins, there are no far-reaching actions. However, when another contractor wins the tender, since this requires many actions to reorganise the product-service structure, and to redistribute power and responsibilities to another contractor.

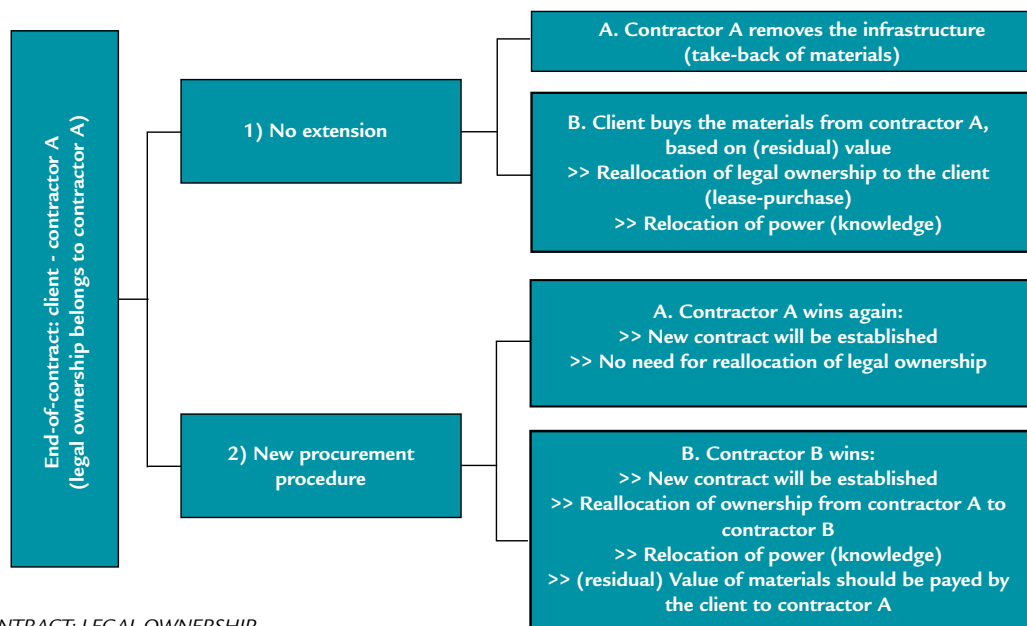


FIGURE 24. END-OF-CONTRACT: LEGAL OWNERSHIP

When ownership is not legally distributed, but contractor A is only responsible for the product during the contract period, less end-of-contract issues are identified (see figure 25. on the next page).

- After end-of-contract, there is no need for reallocation of responsibilities, since it is already terminated.
- However, when there is no extension of the contract the client should, for example, pay the contractor a bonus (depending on what is stated in the contract) in relation to the residual value of materials. Further, to locate power and responsibilities at the same stakeholder, knowledge regarding the product must also be shared with the client.
- When the contract comes to an end, the client is obligated to start a new procurement procedure. In case of the selection of a new contractor, contractor A must guarantee the reallocation of power (knowledge) and responsibilities to contractor B.

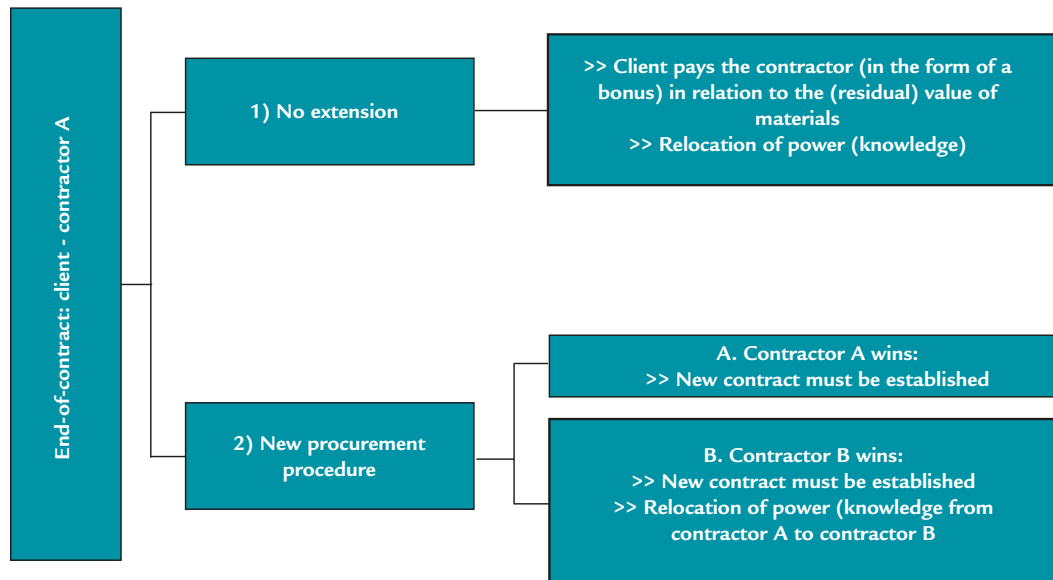


FIGURE 25. END-OF-CONTRACT: ECONOMIC OWNERSHIP

4.2.8. END-OF-LIFE PHASE

XI. CLOSING THE MATERIAL LOOP

In a circular economy, materials remain in the chain as long as possible and will be optimally used and reused. To achieve this, it is important that stakeholders of a project take their responsibility of keeping materials in the cycle, because they all indicate that is important to close the loop. The participants clarify that it is important that actors are contractually obligated to support activities to stimulate a circular economy. The strategy that will be applied at the end of their functional, economic and technical lifecycle is especially noticed to be important.

As shown in figure 27, the material life cycle starts with the request for high value products with a long lifespan. Suppliers deliver high value products to the contractor for execution. Due to the role of service provider, the contractor is responsible to achieve optimal extension of the lifecycle through repair and maintenance during the use phase. When the functional lifespan of a product, material, or component is achieved, it is important that the demolition company and the recycling company take care of high value re-use, refurbishment or recycling.

In the analysis, closing the loop is a required change for the transition from the current linear business model into a circular business model. To close the material loop, it is observed in literature, that there are different strategies that can be applied when a product does not fulfil the required function any more.

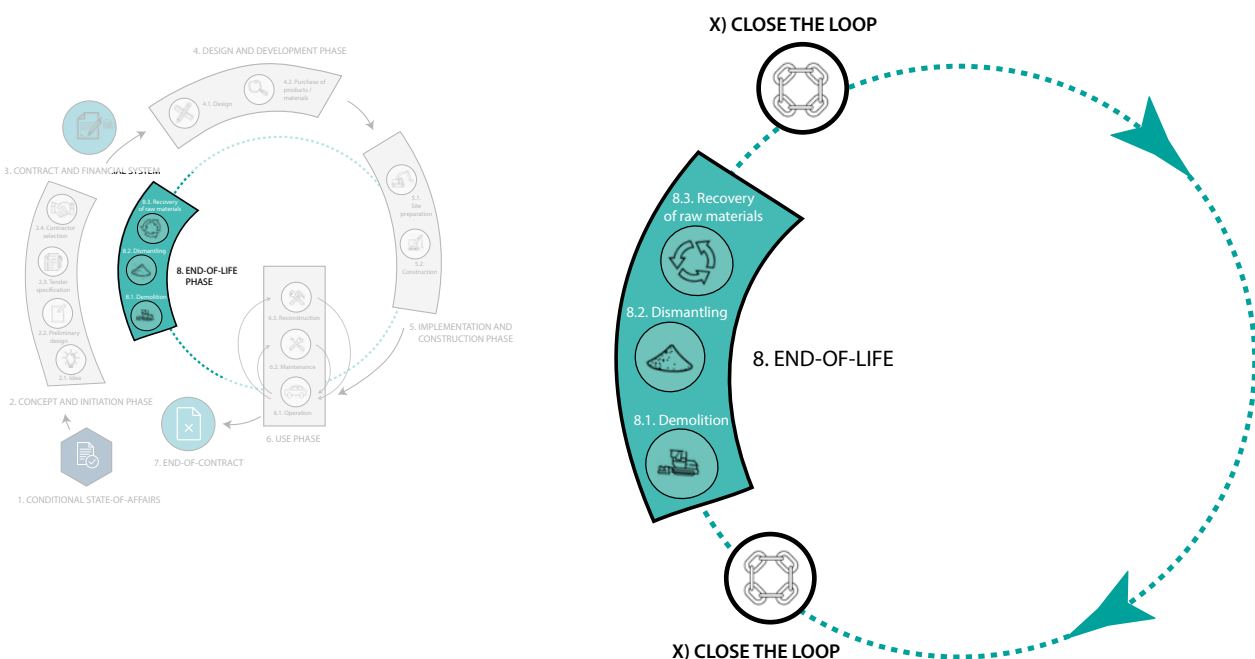


FIGURE 26. END-OF-LIFE PHASE

- The Ellen MacArthur Foundation (2015) indicated the following three strategies: reuse, refurbishment and recycling.
- Re-use: products will be recycled in the same conditions within the reuse cycle and the function does not change. The product will directly be transferred from one project to the next project. This could especially be applied to elements that are dismantlable from bigger infrastructure products.
 - Refurbishment: the product will be disassembled to underlying levels. The product does not have value anymore, but the underlying products still have value. Within this cycle, the products do not have to return to a new project in the same function, but the underlying levels together (where possible) can deliver value to a new product.
 - Recycling: the product is disassembled and transformed into its original raw material, and it can be used in the production of new products.

The strategy for closing the material cycle also depends on how power and responsibilities are distributed among stakeholders. To close the material loop there is a high dependency between stakeholders (figure 27). Each stakeholder has a certain role in the material cycle, whereby e.g. suppliers are dependent on the activities of recycling companies and, additionally, recycling companies are dependent on demolition companies. Therefore, collaboration between stakeholders is seen as a necessity for closing the material cycle.

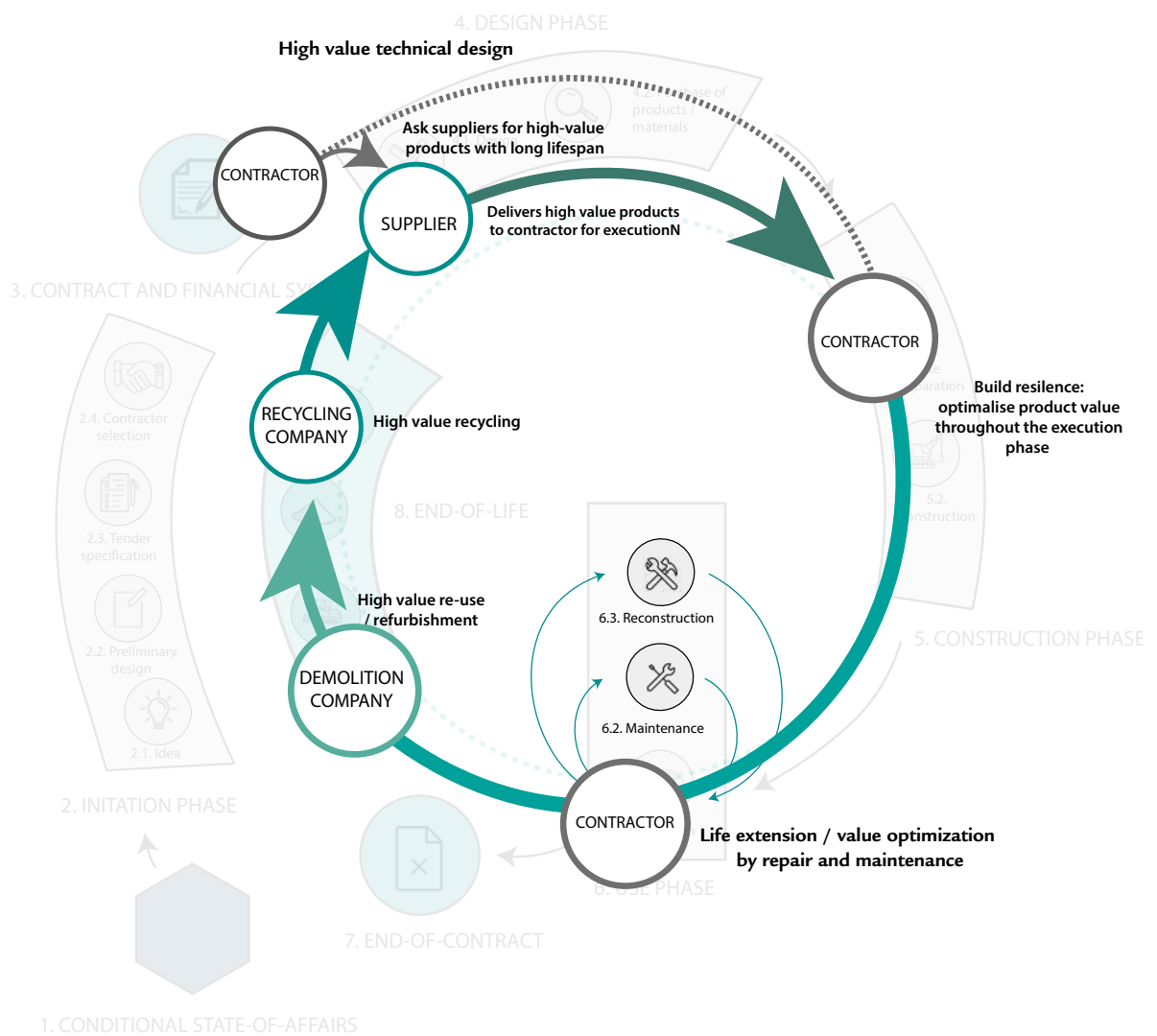


FIGURE 27. CLOSING THE MATERIAL CYCLE

4.3. AGENDA FOR CHANGE

This part summarises the main observations from the results stated in the previous paragraph. This has created a basis for the discussion about the application of product-service system characteristics in project delivery methods in relation to the transformation from product to service delivery.

4.3.1. THE DEVELOPMENT OF AN AGENDA FOR CHANGE

To develop a project delivery method suitable for a circular economy, and incorporating PSS characteristics, it is identified that certain steps need to be taken. As identified in the theoretical framework, multiple categories of a product-service system have specific service types in each category. To support the infrastructure sector in the transition towards the development of a project delivery method that incorporates the principles of a circular economy, an agenda for change is developed following the identified changes (paragraph 4.2.). It is also identified in the theoretical framework that the product-oriented category (A.1.) of PSS is comparable to integrated contracts that are extended with a maintenance contract. To make the transition from product-related services (A.1) towards the result-oriented category (C.), in which service content is of high value, certain steps need to be taken.

To take the first step moving from product to service delivery, the following conditions must be fulfilled to comply with the characteristics of product-oriented services (the first category – A - of the PSS model). Hence, integrated contracts (Design-Build) are used as a starting point to set up the preconditions for change towards more potential PSS categories.

This is in line with a circular economy, because this building model already integrates the design and build phases.

- From research it appears that the main characteristic of a service-based infrastructure is the change in relationship between the client and the contractors, since it asks for a more service-oriented project delivery. To achieve product-oriented services a close collaboration between client and contractor is required. However, not just between a client and contractor, but also with other stakeholders, as this is seen as a precondition for applying the current project delivery method. [III.]
- Knowledge and awareness regarding the need for a circular economy should be increased, so all stakeholder organisations need to invest in getting a positive attitude towards CE and change implying a circular solution. [II.]
- Create more standardization and recognisability on contract level. [VII B.]
- Include a maintenance contract (DBM) to extend the project lifecycle of the use phase and reallocate responsibilities for the quality of the product over a longer period of time.
- A take-back guarantee on the product could be included

to current integrated contracts. This will automatically extend the lifecycle with the end-of-life phase. Further, this creates an incentive to preserve value throughout the lifecycle of the product. [I.]

- Hereby, an incentive is created for creating a high value product in the design and development phase. [IX.] Further, due to the take-back guarantee, it is desirable to develop a product with a long-life span. The contractor is in the position to preserve the value during the use phase through maintenance. Additionally, when a material reaches its end of life the contractor is able to take the materials back and start the activities with other partners to close the material loop.

When transforming to use-oriented services (the second category – B - of the PSS model) the following steps are considered as being important, in addition to the strategies that are applied for product-oriented services:

- Allocating power and responsibility with one party will create an automatic incentive for a more resource-efficient infrastructure design. The focus in the design phase will be on the extension of the lifecycle of the assets, as well as enable a solution for easier remanufacturing or recycling at the end-of-life of a product. The distribution of legal ownership is not favourable based on the following identified reasons.
 - For establishment of rights in rem, the consent of the owner is required. However, infrastructure often crosses many cadastral parcels and therefore there is a possibility that many different public clients do have to give their consent to the contractor. This will require a great deal of notarial work, which could probably lead to high notary fees.
 - Further, the client noticed that it does not want to transfer ownership of the ground to private parties, since they will lose their position regarding the public good.
 - Further, relocating legal ownership will make the contractor, as well as the legal owner and road manager, liable for the functioning of the road (also for safety) according to road law (Weg.w), and due to high risks this is not desirable.

Therefore, relocating economic ownership during the contract period is seen as the most suited precondition. Hereby, it is important to set up a contractual agreement in which this is specified. [V.]

- The client must specify infrastructure projects functional, instead of technical. This creates space to come up with a solution that is innovative and circular. [VI.]
- The distribution of responsibilities and power to one party creates an incentive for that party to undertake actions for an optimal life-span of the product. This can be done by life extension due to maintenance and repair.
- Contractual agreements must be made for the distribution of responsibility on contract level. This also requires specific agreements regarding the end-of-contract, (early) termination of the contract, and consequences when the service provider cannot fulfil the required service. [VII A.]
- The client pays for the function instead of the product (based on the agreed quality of the product). [VIII A]

- Due to changing revenue streams there is a need for external financing. [VIII B.]
- Integrate (residual) value of materials in the financial model, in relation to measuring the periodic service fee. Before the start of the project, contractual agreements must be made regarding the (residual) value of materials at the end of the contract. Further, it must be clarified how the (residual) value will be determined, but also how materials will be paid after termination of the contract period (positive or negative depending on the value of the product). [VIII C.]
- Due to incorporating (residual) value of materials in the financial system, the contractor is responsible for achieving the highest value of materials at the end of contract. Therefore, he will preserve the value added in the design and execution phase even more, to optimise the residual value of products after the use-phase.
- At the end-of-contract, it is important that power (knowledge regarding the product) and responsibilities are transferred to the new service provider or to the client. [X.]
- Take care of closing the loop by partnering with stakeholders to keep materials into the chain and preserve their value throughout the material lifecycle. [XI.]

Hereby, all changes that are identified as being necessary are applied. The step towards result-oriented services (the third category - C - of PSS model) is, according

to theory, more in line with the principles of a circular economy. However, the Dutch infrastructure system postpones a transition towards this category. A toll road system applied in foreign countries is comparable to activity management (category C.7. of PSS model). A toll road is characterised by the fact that users pay for the availability of the road that is operated by a private party. The Dutch infrastructure is not organised in a way (e.g. paying by tax) that this could be easily applied at the moment. Substantial change to the system is necessary, and therefore this category could not be achieved from one day to another. To achieve the highest sub-category of the PSS model (C.8. functional result), it is important that the function of infrastructure (e.g. availability and safety) is no longer related to a technical system. However, the infrastructure sector is still dependent on a certain product, since a road is still desirable for the transport of vehicles. Therefore, it turns out that the second category of the PSS model can be achieved without applying major changes

A conceptual model has been created to give insight into the application of PSS characteristics during the different stages of a project. The model can be used as a guideline for contractors, but also for clients to develop a project delivery method which incorporates service aspects to achieve a more circular project delivery method. The conceptual model is designed step by step in the previous paragraph, resulting in the following figure 28.

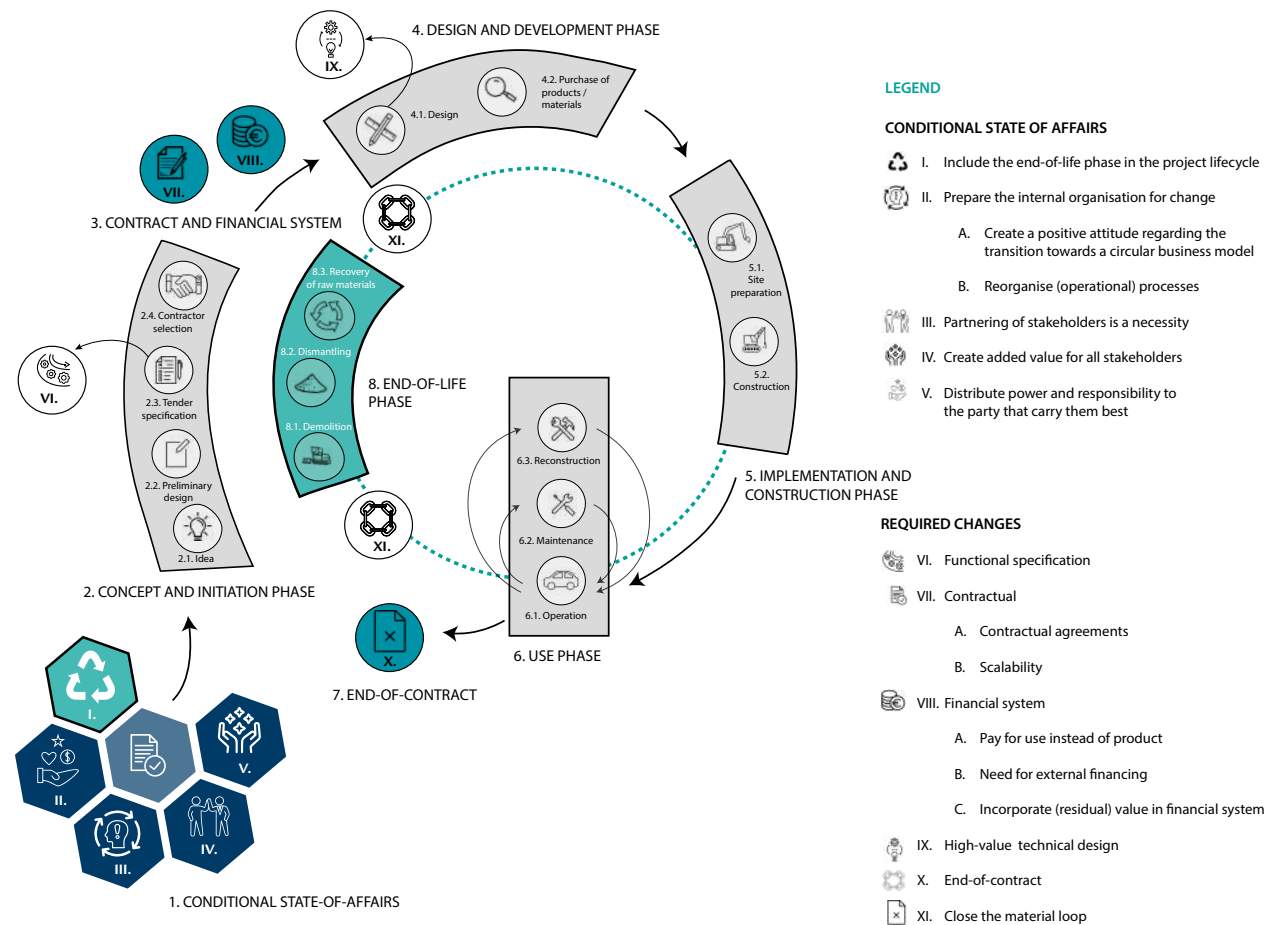


FIGURE 28. CONCEPTUAL MODEL INCORPORATING PSS CHARACTERISTICS

4.4. VALIDATION OF THE MODEL

After developing the conceptual model, a discussion was held with a focus group to determine for each implication if the application is correct. Additionally, the participants were asked to give their opinion on what they think of the development process and the design of this model.

4.4.1. IDENTIFIED CONDITIONAL STATE-OF-AFFAIRS AND REQUIRED CHANGES

The aim of the focus group session was to validate the developed conceptual model. After a short explanation of the model both the conditional state-of-affairs, and the required changes were discussed with the participants to validate whether the application is correct or not. The following table gives an overview of the outcomes of the validation session (see table 6.).

	Identified change	Validation
<i>Conditional state-of-affairs</i>	I. Include the end-of-life phase in the project lifecycle	Accepted, no changes are made to the model.
	II. Distribute power and responsibility to the party that carries them best	Without having the background knowledge of this thesis, it turns out that it was not immediately clear what this conditional change entails. <i>Therefore, it is chosen to rename this conditional state-of-affair in the final model as follows: 'to bring power and responsibilities together at the party that carry them best: responsibilities must be reallocated to the contractor throughout the contract period'.</i>
	III. Prepare the internal organisation for change	Accepted, no changes are made to the model.
	IV. Partnering of stakeholders is a necessity	Accepted, no changes are made to the model.
	V. Added value for all stakeholders	Accepted, no changes are made to the model.
<i>Required changes</i>	VI. Functional specification instead of technical specification	Accepted, no changes are made to the model.
	VII. Contract	Accepted, no changes are made to the model.
	VIII. Financial system	Accepted, no changes are made to the model.
	IX. High-valued technical design	Accepted, no changes are made to the model.
	X. Closing the material loop	During the validation session, it turns out that the required change of closing the material loop is not clearly presented in the conceptual model. At first, it was not directly clear for the participants that the inner cycle represents the material cycle. <i>Therefore, in the final model the material cycle is a bit more emphasized by presenting it in the corresponding colour of the end-of-life phase, and by putting it in bold.</i> Secondly, a participant argued that the material loop was not connected to the design phase. However, during the discussion it appears that the majority of the participants agrees that it is important to consider the reuse of materials in the design phase. Therefore, they indicated that it is important that the material cycle is connected with the design phase in order to close the loop. <i>Therefore, it is decided to add an arrow from the material loop to the design phase.</i>

TABLE 6. VALIDATION OF THE CONCEPTUAL MODEL

In addition to the identified conditional state-of-affairs and required changes, it turns out that the model could be improved by adopting the following points that were discussed in the validation session.

	Suggested changes	Validation
<i>State-of-affair</i>	Contractor will act as service provider throughout the use phase	According to the participants, it was clearly explained that the contractor is going to act as a service provider till the end of contract. This is indicated as a change compared to the current project delivery methods. However, according to the participants of the validation session, this is not clearly presented in the conceptual model since there are no changes identified in the use-phase. To adopt this in the final model, it is chosen to emphasize the use-phase by a coloured line.
<i>Required change</i>	Preserve the value of the product throughout the contract period	The participants of the validation session noticed that reallocating the responsibilities to the contractor is twofold. Next to providing a service, the contractor has the responsibility to preserve the value of the product throughout the use-phase, since the conceptual model implies that the value of materials should be incorporated in the financial system. Therefore, the preservation of value of the product throughout the contract period is adopted by adding this as a required change to the use-phase.

TABLE 7. SUGGESTED CHANGES VALIDATION SESSION

Further, it is indicated by the focus group that some conditional state-of-affairs are currently a huge challenge. It was underlined that the human factor in the transition has a large impact, and therefore requires a lot of attention. Although some adjustments were made to the model, the participants indicated that it creates insight into the changes that are needed for applying PSS in infrastructure projects. The model as developed is also seen as an opportunity to close the material loop, and therefore supports a circular economy on a project level.

4.4.2. RESEARCH PROCESS

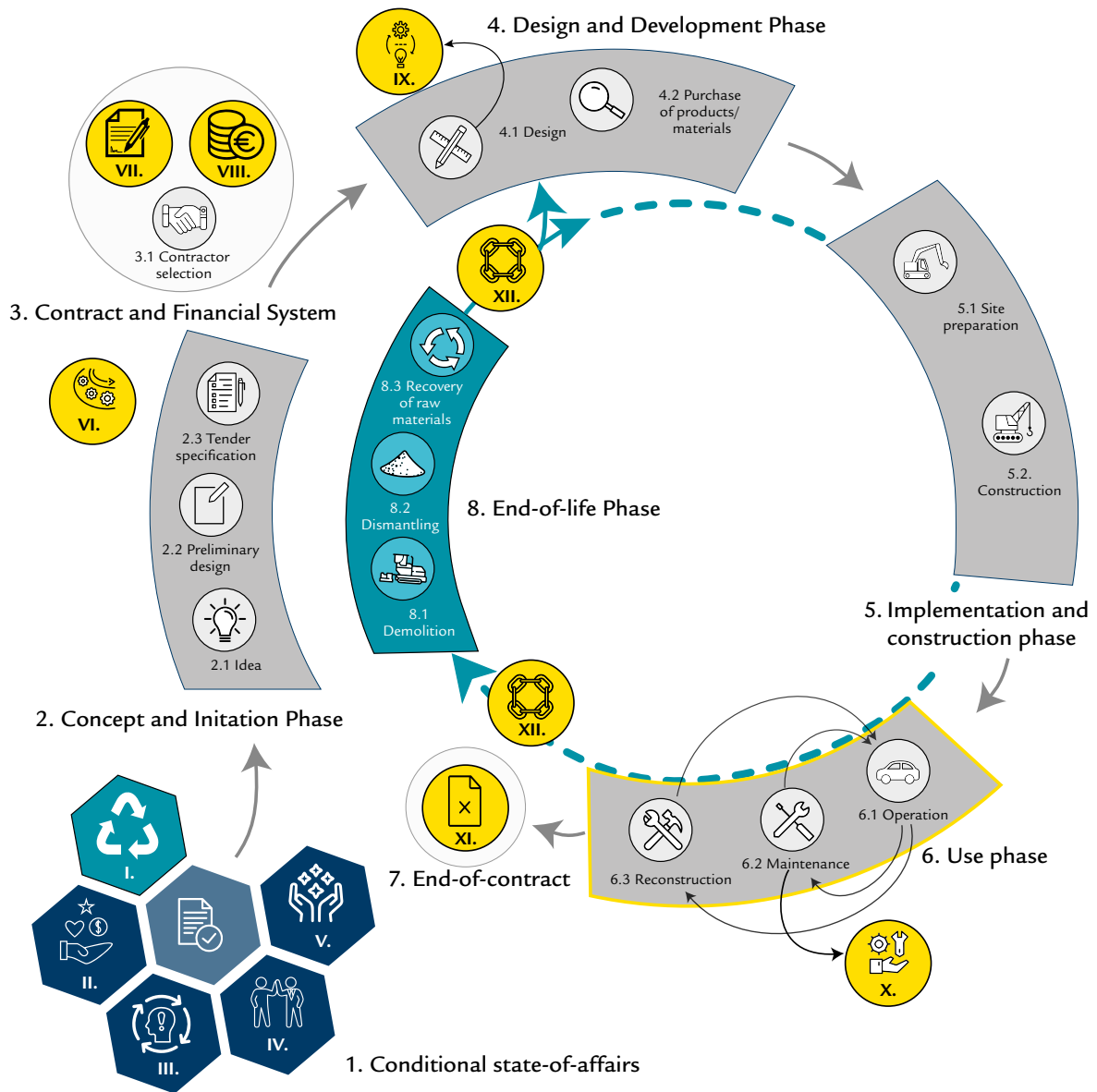
During the focus group it was explained to the participants how the model was developed. The focus group agreed that the number of participants in this research did provide sufficient insight into the consideration of the client, contractor, and supplier regarding the transition from product-oriented projects, towards service-oriented projects. Especially the positioning of statements as an opportunity or threat is seen as valuable for indicating their position regarding this change. The analysis of research, based on interview transcripts and participation in the case study, is seen as useful in order to get a broad insight in the coherence and influence of aspects in relation to the lifecycle of infrastructure projects. The presentation of the results by following the lifecycle is therefore seen as a logical translation of the insights.

4.4.3. DESIGN OF THE MODEL

At the end of the validation session the design of the model was discussed. The first comment made was that a participant had the feeling that the vertical position of the use phase in the conceptual design impedes the cyclic character of the model. This is adopted in the final model by transforming the use phase from a vertical position into a horizontal position. Additionally, the participants stated that the current material cycle was not clearly presented in the conceptual design. To adopt this statement in the final model, it was decided to emphasize on the material cycle by putting it in bold, and in the corresponding colour of the end-of-life phase of materials. Further, it was suggested by the participants that some colour differences could make the model stronger, since the current conceptual model consists of comparable colours, which makes it harder to distinguish the differences.

4.4.4. FINAL MODEL

The final model (figure 29.) is shown on the next page.



LEGEND

CONDITIONAL STATE-OF-AFFAIRS

- I. Include the end-of-life phase of materials in the project life cycle
- II. To bring power and responsibilities together at the party that carry them best: responsibilities should be reallocated to the contractor throughout the contract period
- III. Prepare the internal organisation for change
 - A. Create a positive attitude regarding the transition towards a circular business model
 - B. Reorganise (operational) processes
- IV. Partnering of stakeholders is a necessity
- V. Create added value for all stakeholders

REQUIRED CHANGES

- VI. Functional specification instead of technical specification
- VII. Contract
 - A. Contractual agreements
 - B. Broad applicability to all size of projects
- VIII. Financial system
 - A. Pay for the function instead of product
 - B. Need for external financing
 - C. Incorporating value of material
- IX. High-value technical design
- X. Preserve the value of the product throughout the contractperiod
- XI. End-of-contract must be taken into account at the start of the project
- XII. Closing the material loop

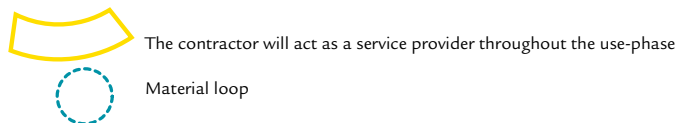


FIGURE 29. FINAL MODEL INCORPORATING PSS CHARACTERISTICS

CHAPTER

5

DISCUSSION

5. DISCUSSION

In the previous chapter, a model is created which shows how product-service systems characteristics can be applied to the project life cycle in order to achieve a service-oriented project delivery method which also incorporates circular economy principles. This chapter will focus on how stakeholders in the infrastructure sector can make use of this model as a guideline to develop a suitable project delivery method for projects. In addition, the limitations that have to be taken into account will be discussed.

Before going deeper into the discussion of the research findings, one issue should be addressed. The changes mentioned in the model will only result in a (circular) service-oriented project delivery method if all stakeholders involved fulfil their responsibilities in the change process. Adapting the changes to only one of the stakeholders will sort no effect.

5.1. RESEARCH FINDINGS

The outcome of this research is focussed on changing the organisation of infrastructure projects towards selling services and performance instead of products. This is introduced as a means to realise a circular economy in infrastructure projects. The development program at the contractor was started from the urgent need to create a sustainable project delivery method contributing to the transition towards a circular economy. The contractor perceived the change from a product to a service delivery approach as a promising approach to achieve sustainability performance. Additionally, during the case study it was observed that the development of the service concept for infrastructure projects is also seen as a business strategy that creates a competitive advantage in comparison to other contractors. In the interviews, it was repeatedly noticed that the construction sector is moving in towards to a circular economy: many contractors are searching for circular solutions. However, most of them still apply circular concepts in a traditional transactional product sale. In addition, as noticed in the major insights of 4.1., the problem of non-alignment of incentives between client and contractors was also observed during the interviews and the case study.

In relation to the insights from the agenda for change, it can be concluded that there are two conditional state-of-affairs that influence the transition the most, 1) the distribution of power and responsibility to one party is the best way to create the conditions to transform towards a service-based project delivery method (comparable to the PSS categories: use-oriented services) and 2) extending the lifecycle with an end-of-life phase is seen as a solution in order to create the circumstances for closing the material cycle.

DISTRIBUTION OF POWER AND RESPONSIBILITY

In contrast to the characteristics of product-service systems, it is identified that for application in the infrastructure there is no necessity to relocate legal ownership to the contractor. In the analysis, it has been found that breaking accession (in Dutch: *natrekking*) does bring limitations and therefore, reallocation of responsibilities could be best organised through a contractual clause. However, the contractual recording of responsibility contractually is also a challenge, since it must ensure that all responsibilities are covered. Further, legislation regarding ownership does not sufficiently show if there is a possibility to split ownership in economic ownership and legal ownership since it is described as one type of ownership in the law. The dependency of the identified changes with the distribution of responsibilities and power to one party is shown in figure 30 (next page).

In order to fulfil one of the conditional state-of-affairs – distributing responsibilities from client to contractor – a focus shift from technical requirements to functional requirements in tender specification is necessary. As a result, the contractor and other stakeholders are stimulated come up with a solution that is most suited for the functionality, which can also positively influence the level of innovation.

CONTRACTUAL AGREEMENT

Furthermore, scalability of the contract was mentioned as a topic of importance. In the model standardisation and transparency are indicated as core elements for the contract. However, to capture the distribution of responsibilities within a specific project with a complicated contractual clause can potentially obstruct this required standardisation and transparency. In the model, the contractor will be responsible for creating value on a product level, as well as on a service level, when the contract is signed. This means that the contractor needs to preserve value through maintenance and repair. As noticed, the distribution of power and responsibility is important during the regular project phases. However, when the contract is terminated there is a need for redistribution of power (i.e. knowledge) and responsibilities to a new contractor or to the client. This is an aspect that should be included in the contract, creating a necessity to have the administration about the transfer of project organised throughout the contract period.

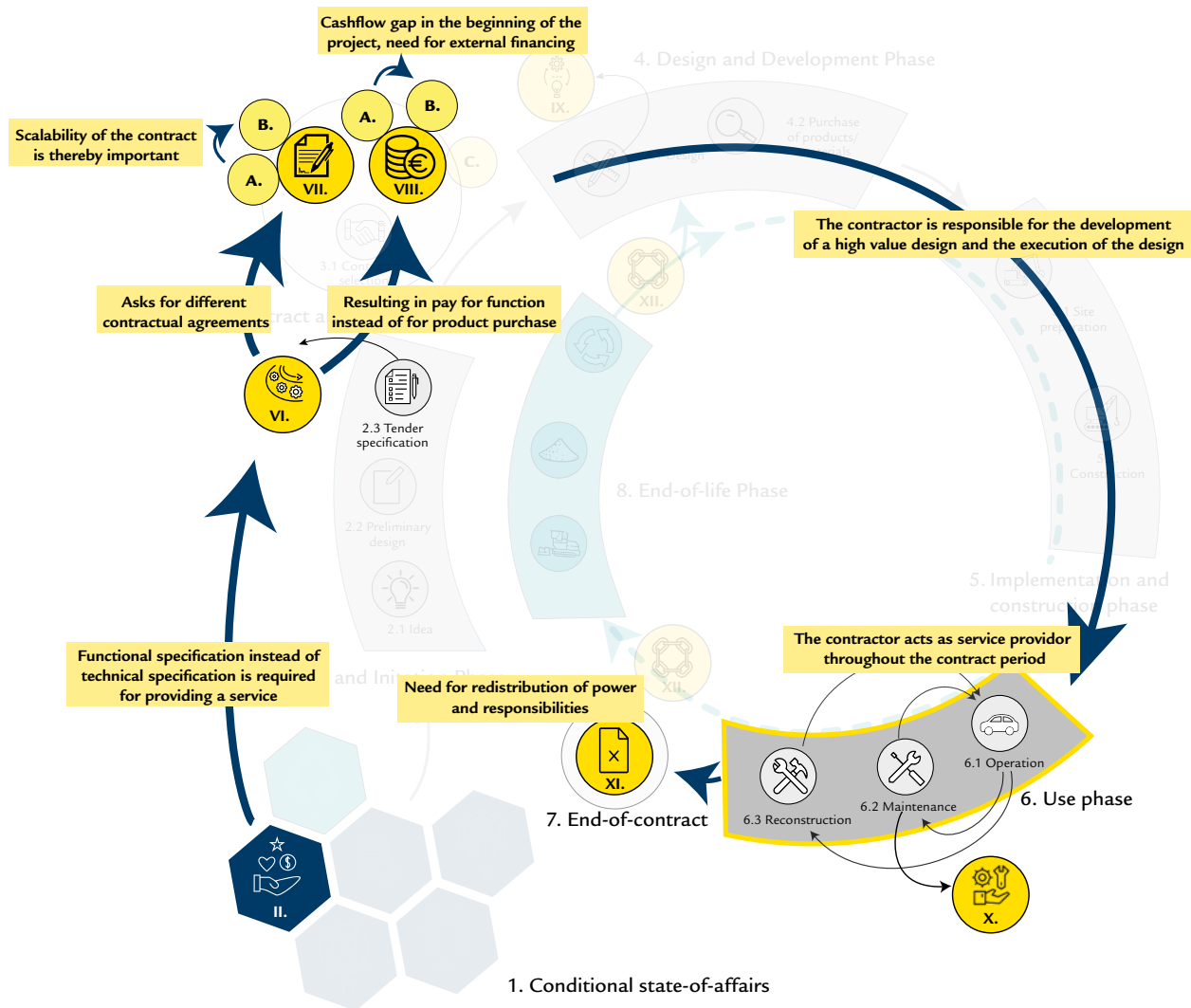


FIGURE 30. COHERENCE BETWEEN ASPECTS - DISTRIBUTION OF POWER AND RESPONSIBILITIES TO ONE PARTY

CURRENT PROJECT DELIVERY METHODS VERSUS THE DEVELOPED MODEL

The research findings show that it is not necessary to relocate ownership. During the focus group session for the validation of the model, the question arises whether the model differs from the existing integrated contracts like DB(F)M. In comparison to these integrated contracts, this model strives for a scalable contract, whereby the complexity will be minimized. Therefore, the applicability to projects of various sizes will increase. In addition, where integrated contracts normally do not take the material cycle of the product into account, whereas this model adopts the end-of-life phase as a conditional state-of-affair. To close the material cycle in infrastructure projects it is important that the material flows are considered from the start of the project. In addition, it is identified that incorporating the (residual) value of materials in the financial system induce an economic incentive that is currently not applied. This gives opportunities to develop a project delivery method that is able to support the transition to a circular economy, which is not applicable to the current integrated project delivery methods.

INCORPORATING THE MATERIAL LOOP IN THE PROJECT LIFECYCLE

Figure 31. (next page) provides an overview on the influence of the extension of the project lifecycle with an end-of-life phase. Extending the lifecycle in combination with incorporating (residual) value of materials creates an incentive for the contractor to create the highest possible value in the design phase. It also incentivises the preservation of the product value throughout the lifecycle. Throughout the use phase the contractor is stimulated to maximize the (residual) value by maintenance and repair instead of only satisfying the technical requirements.

Currently, the Dutch government has not assigned economic value to the applied materials in infrastructure products. There is a huge economic potential for public clients if the large amount of materials used in existing infrastructure is valued. Besides that, it is indicated that the contractor has an economic incentive to design a high value technical product and preserve the value of the product throughout the life cycle. However, there is a lack of knowledge regarding the determination of (residual) value of materials which could obstruct the progression of incorporating value of materials in the financial system.

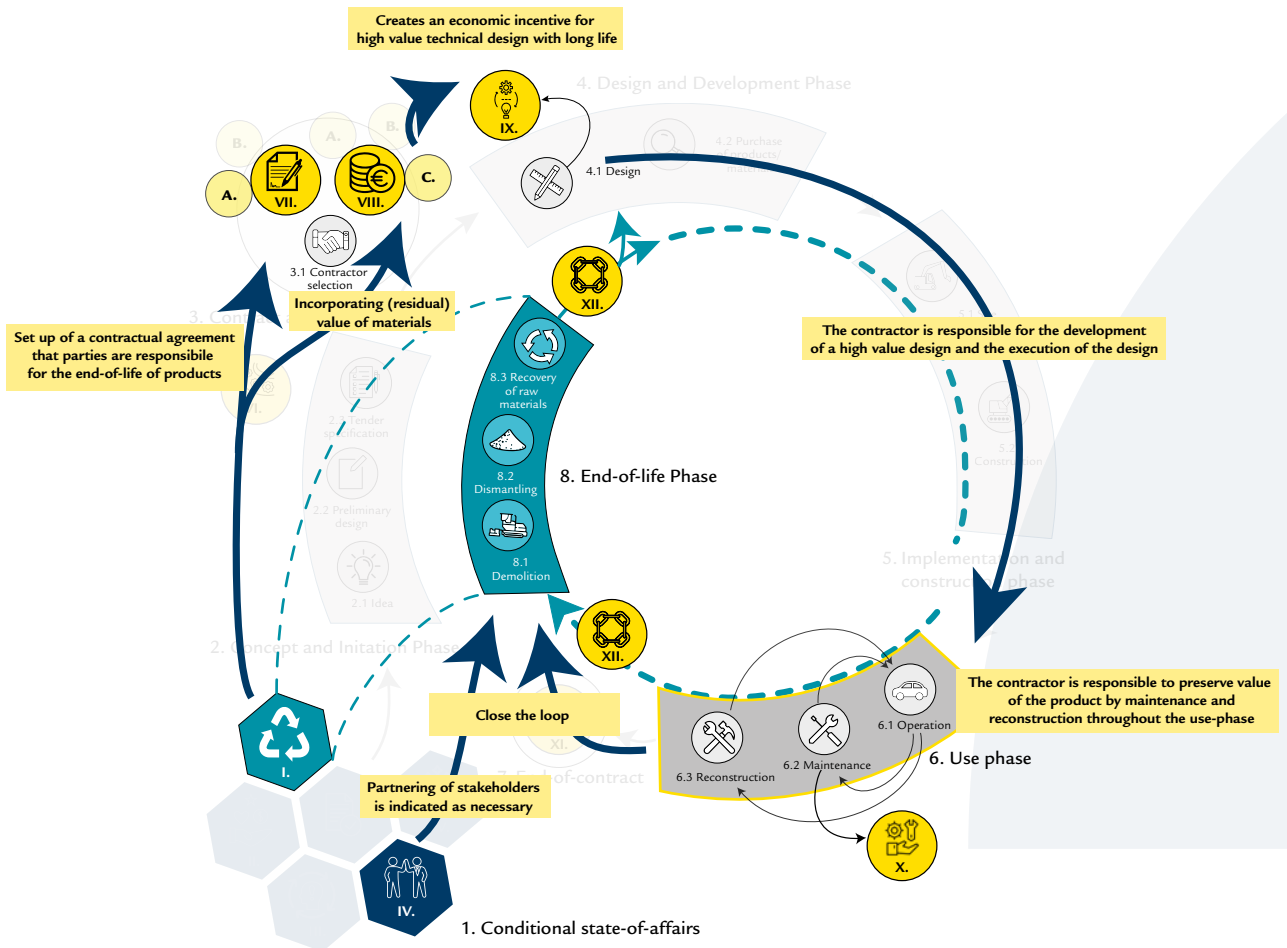


FIGURE 31. COHERENCE BETWEEN ASPECTS - INCORPORATING END-OF-LIFE PHASE IN THE PROJECT LIFECYCLE

FINANCIAL SYSTEM OF THE DEVELOPED MODEL

The shift from product to service is also reflected in specific agreements regarding the financial structuring of the contract. Instead of paying for the initial production costs, clients will now pay a periodic service fee. This results in a gap in the cashflow of the contractor that requires pre-financing, increasing the need for banks and investors to finance the project. The question arises whether the financiers will have sufficient confidence in the contractor's ability to provide the service and can guarantee reimbursement, also in case of early termination of the contract. If a client sticks to a tender focussing on technical requirements instead of functional requirements, the transition towards the development of new project delivery methods will be impeded. In this case, stakeholders will be less inclined to develop new project delivery methods.

In this model the service fee will be determined based on the investment costs, maintenance costs and (residual) value of materials in relation to time. Hereby, the client pays a fee for the service that is applied to the product. However, the change into a different transaction system is associated with the changing role of both the contractor and the public client. The risks of variable costs for maintenance are in the developed model assigned to the contractor, which is in contrast with the current situation where this is assigned as a risk for the public client. However, it is possible to set up a contractual agreement about how much these costs can vary throughout the contract period and what consequences this will have for changes of the service fee.

READY FOR CHANGE?

In the validation session it was questioned by one of the participants whether changing financial system fits in the current economic system and organisation of infrastructure within the Netherlands. As identified in the theoretical framework, several countries use a toll system, whereby a concession agreement is established between a private party and the government. Hereby, the private parties build the road and in addition they will also take care of the function and availability of the road. Additionally, these concession parties have the responsibilities for financing the road. However, the application of a toll system in foreign countries has often been the result of a lack of financing by the public authorities, which is not applicable to the Netherlands. Hereby, the concession party uses the toll revenue for financing the road. However, it is not clear within these concession agreements what happens with the

product (especially the materials applied in the infrastructure product) at the end of the concession period. When the responsibilities of the product will be transferred back to the client, it still does not accomplish the principles of a circular economy since power (knowledge and resources) and responsibilities will again separate. Further, the economic incentive, as proposed in the developed model, which drives the contractor to preserve the highest possible value throughout the lifecycle, is also missing when there is no agreement regarding the value of materials at the end of the concession period.

Further, the results show that it is necessary that all stakeholders in the sector prepare their (internal) organisation for change. As identified, creating a positive attitude in relation to change, is a prerequisite to make it happen. Therefore, it is perceived that the conservative character of the sector must be broken. However, this is a huge challenge and will not be done from one day to another. This is in line with the answers from interviewees regarding their future perspective of application of product-service systems in the infrastructure sector. Most of the interviewees were positive about the change towards a circular economy by implementing service characteristics, however they also noticed that it is not possible to apply the CE principles on a project level immediately. In addition, it was observed throughout the case study that the contractor accelerates the transition towards a service delivery by taking urgent steps for application of the road as a service in consultation with public clients. However, the contractor must be aware of the major change the organisation has to make from construction company towards service provider. In fact, the entire company (or at minimum an entire division) has to become a service-oriented company.

In the agenda for change it was identified how the characteristics of PSS can be implemented in the infrastructure to make a transition towards a more service-oriented PSS category. As noticed earlier, research regarding the application of PSS in other sectors has shown that the more a product is service-oriented, the more it fits with the principles of a circular economy (Michelini et al., 2017). However, as noticed in paragraph 4.3., it is currently not possible to disconnect the product from the function in the infrastructure sector. Referring to the theory of PSS, it is therefore not possible to achieve category C.8. functional result (figure 32).

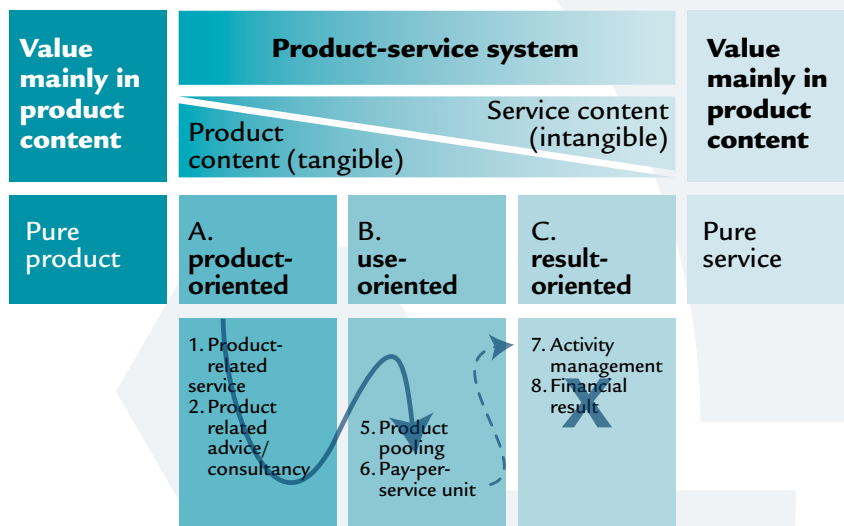


FIGURE 32. AGENDA OF CHANGE TOWARDS RESULT-ORIENTED PSS CATEGORY (MODEL ADOPTED FROM TUKKER, 2004).

5.2. APPLICABILITY RESEARCH OUTCOME

The outcome of this thesis can contribute to the entire infrastructure sector, since the developed model is designed following the standard project lifecycle. Infrastructure projects are always a cooperation between a public client and a contractor. This research is conducted from the perspective of the contractor. However, the model is also interesting for the client and suppliers since it appears that all stakeholders must fulfil their role in order to achieve change. The model is developed by following case-based reasoning, which implies that the model could support the development group of the circular road in generating a project delivery method for the circular road to be applied in practice. The model provides an overview of the steps that need to be taken at the contractors' organisation. However, the initiation of this new concept must be done by the client since the client is subjected to procurement legislation.

Furthermore, there are many generic aspects of procurement involved in this research resulting in the fact that it could be relatively easily transferred to the broader construction sector. It can even contribute to contractors and clients outside the Netherlands, since there are many process similarities in other countries. However, legislation could differ abroad and therefore the legal aspects should be considered in relation to applicable legislation in the country concerned. Concluding, because the model is developed based on a generic project lifecycle, it could relatively easily be translated to other sectors.

CHAPTER

6

CONCLUSION



6. CONCLUSION

6.1. MAJOR INSIGHTS

In this research, the application of service aspects in project delivery methods for infrastructure projects has been analysed. The conclusion of this research is based upon the answers of four sub-questions that have been formulated to answer the main research question.

6.1.1. CONCLUSIONS SUB-QUESTIONS

In this section, the four sub-questions, as introduced in chapter 1, will be answered.

1) What are the characteristics of a product-service system when applied to the infrastructure sector?

The concept of Product-Service Systems (PSS) is defined as the theoretical framework for the application of service aspects in infrastructure projects. Literature identifies that the PSS theory is in line with the principles of circular economy. Based on the characteristics of the various categories of product-service systems (product-oriented, use-oriented and result-oriented) it was identified that several of these characteristics could be applied to the infrastructure sector. The characteristics of these categories contain legal, financial, economic and organisational aspects. These aspects are used in the interviews and the case study to determine which consequences the application has for the organisation of projects.

2) How to compile and analyse the product-service systems characteristics for application in a project delivery method for infrastructure?

To close the gap between theory (PSS in other sectors) and practice (lack of knowledge regarding application in the infrastructure sector) the double diamond method is chosen for this research. The double diamond takes the problem (lack of knowledge regarding incorporating circular principles in projects delivery methods) as the central part of the design cycle. Furthermore, several ideas are generated in the creative process (through divergent thinking), where after the ideas are refined and narrowed down to the best idea (through convergent thinking). To gather information, semi-structured interviews and observations during a case study are applied. For analysis, a conceptual design is used to represent the results in a systematic way.

3) What changes are required for the application of product-service systems characteristics as part of the project delivery method for infrastructure projects?

Overall it was identified that the application of product-service systems characteristics in general require legal, financial, organisational and technical changes. For the application of service aspects in the project life cycle of infrastructure projects it was identified that besides required changes some conditional state-of-affairs should be fulfilled. Since it was aimed in the beginning of this research to develop a model that incorporates circular economy principles the first conditional state-of-

affair is to **include the end-of-life phase in the project lifecycle**. Another conditional state-of-affair is that **power and responsibility should be distributed to the party best equipped for this task**. Further, it is identified that it is important. Because the contractor will have to start acting as a service provider, a lot of operational processes should be reorganised. It is important to **prepare the internal organisation of both contractor and other stakeholders for this change** before applying PSS on a project level. Furthermore, it was found that the current infrastructure sector is conservative, which hampered the transition to a new system. Therefore, **a positive attitude regarding the transition towards a different business model is required** to make change happen. In addition, **partnering of stakeholders is a necessity** and the model should have a certain **added value for all stakeholders**.

Besides these conditional state-of-affairs, multiple required changes throughout the project lifecycle are also recognized to be important. To change from a product to a service delivery approach, whereby the product is subordinate to the function, it is imperative that the clients modify their tenders. It is identified that the client should no longer specify the product technically, but to shift towards **a functional specification**. Certain contractual and financial changes have to be considered when the responsibilities are relocated to other parties than the client. When applying service aspects, the client will no longer finance the purchase of the product but will only **pay for the function or use**. This radically changes the status quo of infrastructure project financing. Further, to increase the applicability of the model it was identified that **scalability** must be considered in the design of the model, mainly related to the contract. An important financial change is to **incorporate (residual) value of materials in the financial system**, since this creates an incentive to shift from maximising production and sales to focus on quality and durability. This will also align the interest of the contractor and client. In line with these changes, the contractor will automatically have the incentive to **design a high-valued product** with a long lifespan. Additionally, it is identified that the contractor **preserves the value of the product** throughout the use-phase. Further, it turns out that the **end-of-contract needs to be considered from the start of a project**. Finally, due to the addition of an end-of-life phase to the lifecycle and with and partnering of stakeholders, the last required change is to **close the material loop** by taking the material flow into account from the moment of initiation. These changes are important to support the infrastructure sector in achieving the goals and ambitions of circular economy.

4) How can the identified changes be incorporated in the project lifecycle to achieve a higher level of product-service system in infrastructure projects?

Based on the literature study it has been identified that existing integrated project delivery methods can serve

as a starting point for the development of an agenda of change, since in these methods the design and execution phase are already combined. When developing an agenda for change it was identified that certain conditional state-of-affairs are not necessary to apply for the first category of product-service systems. Extending the lifecycle with the use phase, by including maintenance and a guarantee for take-back of materials (which involves an end-of-life strategy), is noticed as a first steps towards a more service-oriented project delivery method. To achieve the second category of the PSS model, it is identified that there is a necessity to distribute power and responsibility to one party to ensure that this party can preserve the value of the product throughout the contract. Besides, it is necessary that the client changes the tender specification towards functional specification. This stimulates contractors and suppliers to cooperate and develop the optimal solution to fulfil the functionality of the product. In relation to CE, it is identified that incorporating (residual) value of materials in the financial system is important, which creates an economic incentive. In addition, it appears that the most far service-oriented category of PSS (C. result-oriented) could not be achieved in the current situation, since the functionality of infrastructure is still dependent on the product as it is.

6.1.2. CONCLUSION OF THE MAIN RESEARCH QUESTION

The aim of this graduation research was to gain insight into the application of service aspects in the project life cycle. For this purpose, the following main research question was determined:

“How can product-service system characteristics be implemented in project delivery methods to support a circular economy in infrastructure projects?”

A model incorporating all prerequisites for the application of product-service systems in infrastructure projects was created. This model supports all stakeholders in the infrastructure sector in identifying which aspects should be included to developing a suitable project delivery method for infrastructure projects which comply with the principles of circular economy. Several changes within the infrastructure project lifecycle have to be taken to transform the sector towards a service-oriented sector. For the application of product-service systems it appears to be necessary that public clients tender for a functionality instead of a technicality. This is how contractors and other stakeholders are challenged to come up with innovative solutions incorporating CE. The most significant change is the reallocation of responsibilities for the product during the contract to the contractor. It appears that the contractor should beat the responsibilities since he is involved in most phases of the project life cycle. The contractor will act as service provider to the client, whereby the client will pay for the use

of the product instead of the product itself. In addition, it turns out that incorporating (residual) value of materials in the financial system is necessary to create an economic incentive. This incentive will result in more professional care of the product by the contractor, resulting in a longer product lifetime and higher overall quality. Furthermore, combining this incentive with an end-of-life phase as a standard in the project life cycle will enhance the chance to close the material loop. In the agenda for change it turns out that it is currently not possible to achieve the highest level of PSS (C.8. functional result). The agenda of change shows that it is possible to obtain category B.6. pay-per-service. Including all the identified changes will lead to a higher level of service in contrast to current project delivery methods. According to literature, every step towards the result-oriented category of PSS is a step towards a circular economy. However, to achieve a 100% circular infrastructure sector, there is a need for innovations. Therefore, it is recommended to stimulate innovation in the transportation sector and to challenge innovators to come up with solutions for transport that support the sector to achieve the highest service-related category of the PSS model.

6.2. LIMITATIONS OF RESEARCH

To determine the value of the research, discussion of the research limitations is necessary. Although sufficient answers were given to the research questions of this thesis, there are some limitations to be mentioned. Based on the limitations and research outcome, recommendations will be given to the company, as well as recommendations regarding future research.

The following limitations are indicated due to various choices made during the research process.

- This research was conducted in consultation with Dura Vermeer, whereby the researcher had the opportunity to participate in a development program relating to the transition from product to service delivering in infrastructure projects. A lot of information was gathered throughout this development program. For identifying the contractor’s perspective, due to confidentiality of the development program, it was not possible to involve other contractors. This might create a certain bias in the research.
- This research attempts to indicate what changes are necessary for the application of PSS on a project level. However, due to the broadness of the PSS concept it was not possible to elaborate on all aspects to the fullest extent. For example, the technical aspect regarding the application of product-service systems is not discussed fully.
- The Double Diamond methodology is not often used in research within the construction industry. This methodology is often used in designing a specific product outcome (e.g. a game, chair or phone), and not often in designing a model. Due to the relative uncommon application of this methodology not many comparable papers could be found. Therefore, it’s validity of application and the way it is interpreted and applied cannot easily be verified.

- In research, clients and suppliers were interviewed to get a clear image of their view regarding the application of product-service system characteristics to project delivery methods. However, the findings depend on a limited number of interviewees. In the client sector six interviews were conducted at three different levels (national, regional, municipal) and three supplier organisations were involved. Therefore, an unfair distribution of interviews per sector is collected. This was a conscious choice since the contractual arrangements are between the client and the contractor, but this limits the view of the supplier in this research.
- Due to time constraints it was not possible to test the model in practice and to validate the final model with other stakeholders than the contractor. Therefore, the final model is only validated on applicability from a contractors' perspective.

6.3. RECOMMENDATIONS

6.3.1. RECOMMENDATIONS FOR FUTURE APPLICATION OF PRODUCT-SERVICE SYSTEMS IN INFRASTRUCTURE PROJECTS

It is recommended to all stakeholders in infrastructure projects to start a transition towards service-oriented project delivery since this creates opportunities for incorporating aspects of a circular economy on a project level. When these aspects are applied, circular economy becomes an integral part of the design at the start of the project. The agenda for change indicates what steps need to be taken to transform from integrated projects towards service-oriented project delivery of infrastructure projects. Hereby, it is important that the first focus is on the conditional state-of-affairs, since they are prerequisite for the application on project level. Further, it is indicated that all stakeholders must fulfil their role in a project to support change and partnering is noticed as necessary. The application of product-service systems characteristics in the project delivery of infrastructure projects requires a significant change. The agenda for change gives an overview of the steps that need to be fulfilled to achieve a higher level of service.

The model, as developed in this research, can be used in advance of a project to define how the project must be organised throughout the different lifecycle phases. In addition, the model clarifies that certain contractual agreements and a different financial system must be developed to make the transition towards a service-oriented project delivery possible. In contrast with earlier project delivery methods the main idea is that all project phases, including the end-of-life phase, should be considered to fulfil the service as requested by the client. Hereby, close collaboration between client and contractor is necessary. In addition, the model supports incorporation of circular economy due to the material flow that is included.

6.3.2. RECOMMENDATIONS FOR FUTURE RESEARCH

The limitations that are indicated brought forward recommendations for future research regarding the application of product-service systems. These are summarized as follows.

- Due to the application of a single case study at one contractor, future research could make a comparison between different companies in the same sector or to compare the application with other sectors.
- In literature of PSS it is suggested that reallocation of ownership is a conditional state-of-affair. This research shows that there are two different options to relocate the responsibilities to the contractor. However, it appears that reallocation of legal ownership is obstructed. Since the researcher lacked knowledge in the field of legal aspects, it is suggested to do further research on how responsibilities could be best reallocated to the contractor. Reallocation of responsibilities also requires reorganisation of risks amongst stakeholders and therefore it is recommended to come up with a legal framework for circular economy within the infrastructure sector.
- It turns out that it is currently not possible to achieve the third category of PSS in the Dutch infrastructure sector. Therefore, it is recommended to do further research on what changes must take place for achieving the third category of the PSS model since this requires substantial changes in the organisation of Dutch infrastructure.
- The change from product to service delivery requires a different financial system around a project: the client will pay for the service by a periodic fee. However, there are a lot of different transactions that could be identified. Due to the lack of financial knowledge by the author, further research is suggested to find the most suitable financial system needed to change infrastructure sector. Researching the financial system in which the actual user (e.g. road users) pays for the use could be of special interest, since this will have an impact on how the Dutch infrastructure sector is organised in general.
- Identifying the perspective of investors to find out what considerations they make when financing service-oriented projects is recommended as further research. Currently, this perspective is not taken sufficiently in to account, but for the validation of applicability of the model it is useful to acquire more knowledge on what risks and opportunities the application of product-service systems in the infrastructure could bring to investors and financiers.
- To create a financial and economic incentive for contractors in order to preserve value of the product throughout the lifecycle, the (residual) value of materials should be included into the financial system. However, there is not sufficient knowledge on how this value can be determined upfront, during and at the end of contract. Therefore, it is recommended to do further research on how the (residual) value of materials can be determined in the infrastructure sector.

CHAPTER

7

REFLECTION

7. REFLECTION

This graduation process started with the decision to do research in a field that was still unexplored. As written in the preface, sustainability is a topic which has always been of interest. Therefore, the decision to investigate a new way of organising infrastructure projects in relation to a circular economy was something that is in line with my interest. Before starting with my master thesis, I started to look for a contractor that was interested in my research topic. Dura Vermeer was the first company I had contact with and they were immediately very interested. That was the first win in this process!

Writing a master thesis was not an easy task, since it consists of several steps to come to this result. It all starts with framing a first research proposal, which was something that cost me a lot of time as I changed my research plans several times. In addition, it took time to find a methodology that suited my research goal. It became clear that the writing of a thesis is an iterative process, with several moments going back and forth. Although this was something I experienced as difficult and frustrating, in the end, it helped me to gain more information and to improve the research outcome step by step. During the period of the research proposal formulation, Dura Vermeer had started a development program in line with my research topic. It was a great opportunity for me to participate in this group of multidisciplinary experts to get insight on the development process on how a road can be delivered as a service (from the perspective of the contractor). In addition, the development group member gave me access to their network of public clients and suppliers, to let me gain a broader insight into the opportunities and threats related to the transition from product delivery to service delivery. During the interviews, it became clear that this research topic was indeed still unexplored, and therefore relevant to the infrastructure sector. This gave me self-confidence because I had the feeling that I was really contributing to an unexplored field of research.

My research approach consisted of three core elements: determining the most important changes that organisations need to make to realise new ways of working, gather a broad knowledge regarding the challenge of the sector in relation to a circular economy and a design process which gave me guidance by diverging and converging stages to keep progressing to an end-result. In the end, I think these core elements did help me to stick to the plan. I really like doing a design-based research, since this really suits my way of working as I learned during my bachelors.

Throughout the process of this graduation research, I experienced a lot of ups and downs, however it brought me a lot of valuable lessons. In the first place, doing such a research all by myself was harder than I expected upfront. For example, doing a literature study was a difficult part for me. Where I normally had no problems reading

scientific papers throughout my master courses, I did not get a lot of energy from reading scientific articles all day for several weeks. Sometimes, I even experienced some loneliness during this period. Luckily, after the literature study it was time to start exploring my research topic in practice. This was great, as I got to talk to various public clients about this unexplored topic. During the interviews I noticed that they were curious and enthusiastic, which also gave me the motivation to get even more out of the conversations than expected. In addition, I spoke to several suppliers who were really looking for solutions in relation to a circular economy. In one of the visits to a supplier, I even had the chance to look in the factory where pavers were made. I really liked it to have these alternations throughout my research period.

Further, I also got to know myself better during this graduation process. For instance, I found out that I am a person who likes to work in a team, I really get energy from discussing topics with others to come up with better ideas together. Luckily, my graduation committee was always open for having a discussion and my colleagues at Dura Vermeer were always open for sparring about insights I gathered throughout my process. However, in the end, most of the time I worked on this thesis by myself. Afterwards, I realized that I could have asked for more brainstorm sessions with my supervisors or colleagues. But, I have noticed that I did not like to disturb people in their daily work with my research, however when I did, they were often enthusiastic and willing to help me. A lesson learned is that I should not feel burdened to ask people to think along, since it appears that most of the time people really like to do so.

In addition, I have experienced to have difficulties with letting things go. I am a control freak and a perfectionist, I already knew about that before I started with my master thesis, however, this has slowed down the progression of my research. It prevented me from sending my drafts to my committee, because I had difficulties with the fact that it was not finished yet. However, it became clear to me during this process that the thesis will only be finished when I accept the help of my supervisors by sending them my drafts. Further, writing a thesis has an iterative nature, whereby it is normal to revise the work several times. However, I found it difficult to keep being critical, since you already revised some parts for four or five times. Although I like dynamic processes, I have experienced it as a bit obstructing and demotivating at times.

Looking back at my graduation period, I can say that it has been an instructive period. Of course, with the knowledge I have now, I would have dealt with things differently. But in the end, I am happy with my outcomes, though it can always be better ;).

CHAPTER

8

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APPENDIX A.

CIRCULAR ECONOMY PRINCIPLES

This visual overview of the concept of CE is adopted from research of B. Mentink (2014, p.17). The EMF's CE principles are displayed in red. The square indicates that this research is related to the think in systems principle, whereby collaboration with customers changes to gather more insight in customers' needs. In the end, it would be best if mutually (business) activities and resources also will be adopted in the model.

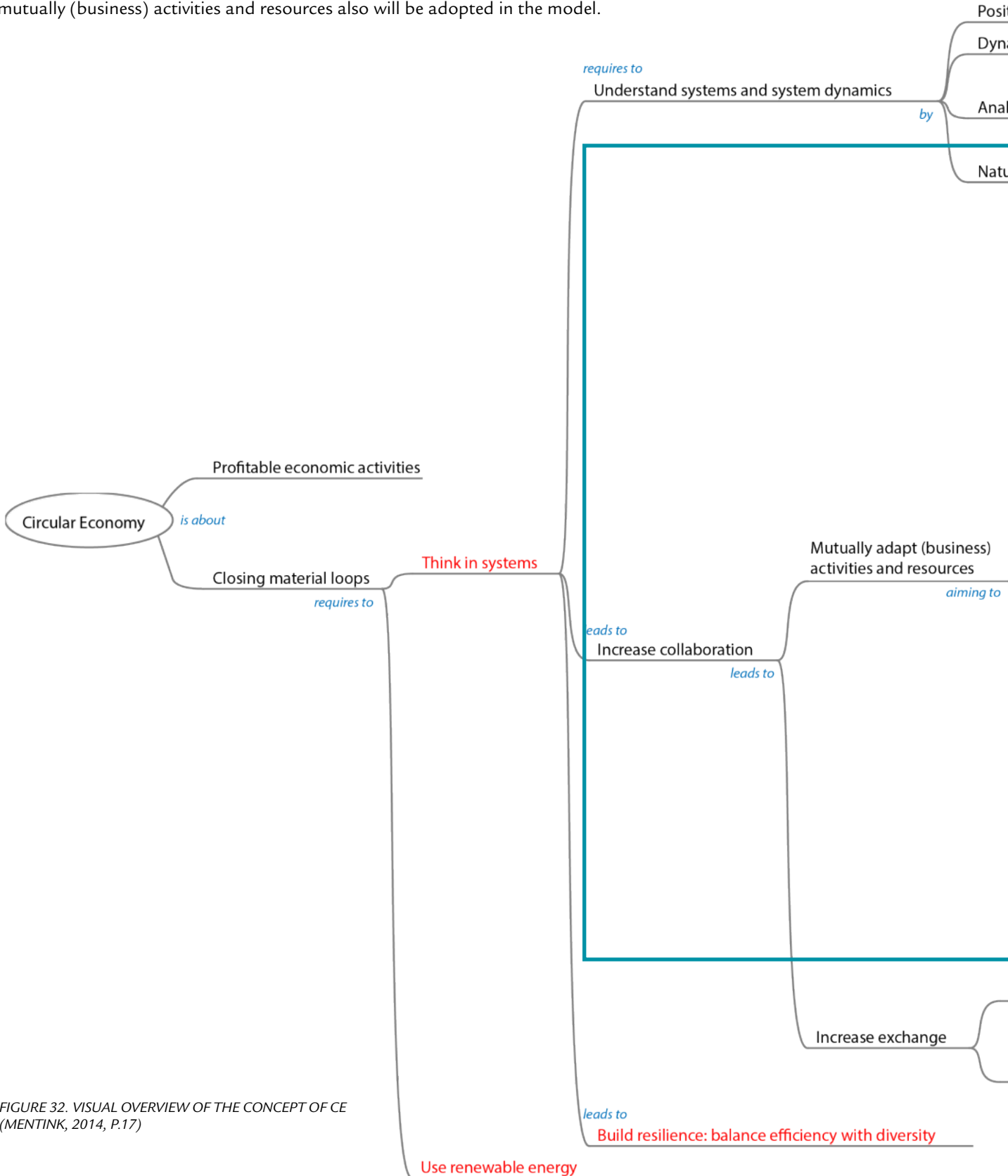
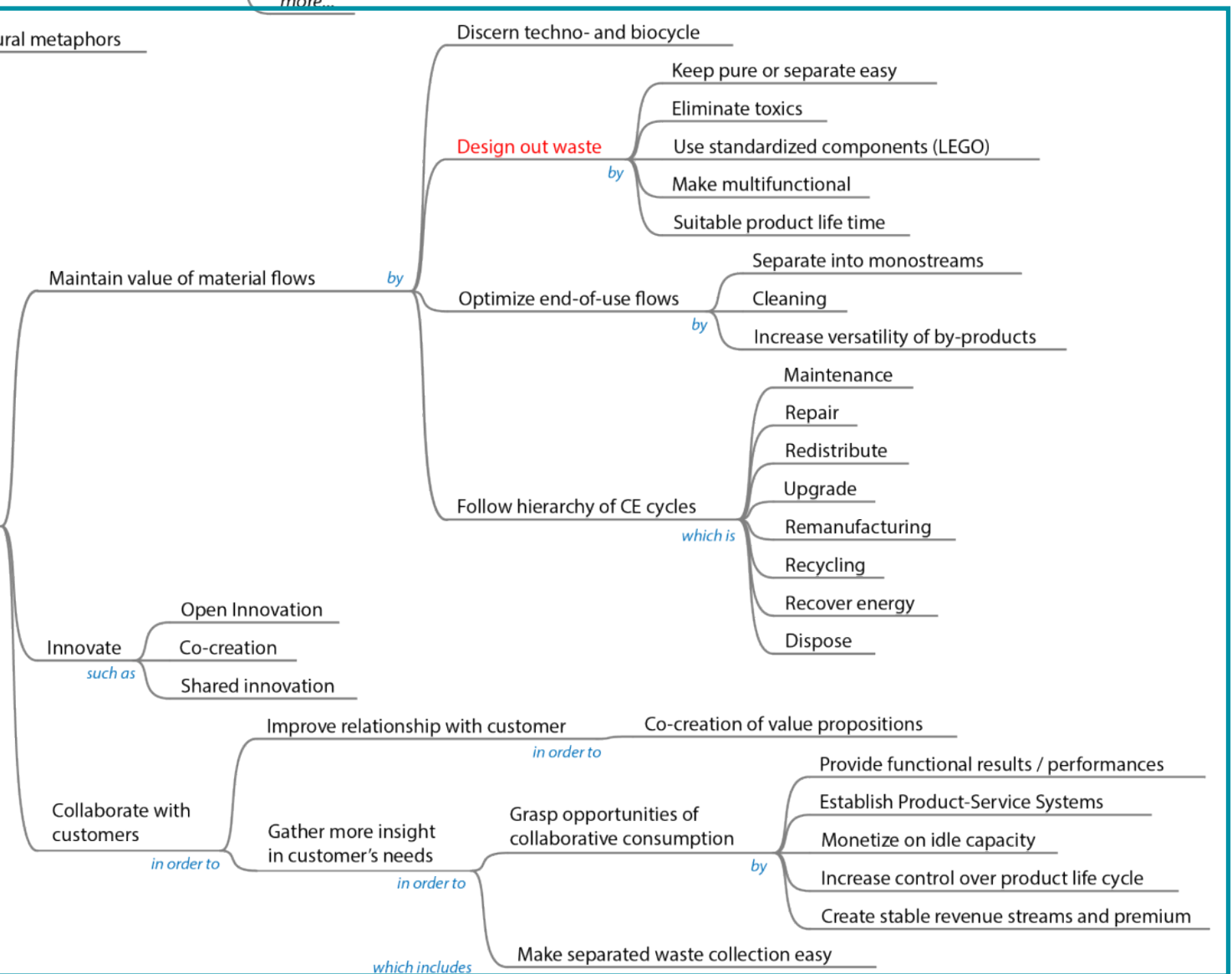


FIGURE 32. VISUAL OVERVIEW OF THE CONCEPT OF CE (MENTINK, 2014, P.17)

... of material and negative feedback loops
 ... of stocks and flows

... of analytical methods and tools
such as Life Cycle Assessment
 Material or Substance Flow Analysis
more...

... of natural metaphors



APPENDIX B. DEFINITIONS SERVICE DELIVERY

During research the following definitions of service delivery are found as possible for application to define service in relation to the infrastructure sector.

TABLE 7. OVERVIEW SUPPLIER INTERVIEWEES

TERM	DEFINITION	AUTHOR
SERVITIZATION	<i>“Modern corporations are offering fuller market packages or ‘bundles’ of customer-focused combinations of goods, services support, self-service and knowledge. But services beginning to dominate.”</i>	(Van der Merwe & Rada, 1988, p. 314)
ECO-EFFICIENT SERVICES	<i>“Systems of products and services, which are developed to cause a minimum environmental impact with a maximum added value.”</i>	(Brezet, Bijma, Ehrenfeld, & Silvester, 2001, p. 8)
PSS	<i>“A product-service system is a system of products, service supporting networks and infrastructure that is designed to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models.”</i>	(Mont, 2006, p. 4)
INTEGRATED SOLUTION	<i>“Integrated solutions involve the bringing together of products and services in order to address a customer’s particular business or operational needs.”</i>	(Brady et al., 2005, p. 542)
SERVICE-LED CONSTRUCTION	<i>“A service led projects is a complex project where the project life cycle is extended into the operation phase of activity which is driven by the client’s service requirements manifested during this operation phase”</i>	(Alderman et al., 2005, p. 380)
PRODUCT SERVICE SYSTEM	<i>“A value proposition that consist of a mix of tangible products and intangible services designed and combined so that they jointly are capable of fulfilling final customer needs.”</i>	(Tukker & Tischner, 2006, p. 12)
PSS	<i>“Market proposition that extends the traditional functionality of a product by incorporating additional services. Here the emphasis is on the ‘sale of use’ rather than the ‘sale of product.’ The customer pays for using an asset, rather than its purchase, and so benefits from a restructuring of the risks, responsibilities, and costs traditionally associated with ownership.”</i>	(Baines et al., 2007, p. 1)
PSS	<i>“A product service system (PSS) is an integrated bundle of products and services which aims at creating utility and generating value.”</i>	(Boehm & Thomas, 2013, p. 245)
PSS	<i>“A product-service system (PSS) is an integrated offering of products and services with a revenue mechanism that is based on selling availability, usage or performance.”</i>	(Van Ostaeyen et al., 2013, p. 261)
SERVITIZATION	<i>“The re-positioning of business towards offering supplementary through-life services with their products.”</i>	(Robinson & Chan, 2014, p. 905)
INFRASTRUCTURE-AS-A-SERVICE	<i>“Infrastructure-as-a-Service (IaaS) is a provisioning model in which an organization outsources the equipment used to support operations, (including storage, hardware, servers and networking components). The service provider owns the equipment and is responsible for housing, running and maintaining it. Typical to this model is that the client pays on a per-use basis.”</i>	(Bigbyte, 2012, p. 4)

APPENDIX C. SUMMARY OF THE BUILDING MODELS

In this appendix a summary of the building models are representing advantages, disadvantages and the related contracts to each building model.

TRADITIONAL MODEL (CORRESPONDING TO DESIGN-BID-BUILD PDM)

In this traditional form of collaboration organisation is based on the 'classic triangle', which is a triangular relationship between client, contractor and architect or consultant. Traditional contracts are based on the general terms and conditions, called Uniform Administrative Conditions for Execution of Works and Technical Installation Works 2012 (UAV-2012) (Chao-Duivis et al., 2013). The client first enters separate contracts for the design phase and the execution phase (Chao-Duivis et al., 2013). The client is responsible for the design and the contractor for the execution. In this method, there is a hierarchical relation between the client and contractor (Chao-Duivis et al., 2013).

DESIGN TEAM MODEL

The characteristic of the design team model is the fact that the contractor is involved in the design. This means that the client and diverse other parties already come together in an early stage of the process, resulting in expertised advice (Chao-Duivis et al., 2013). Design and construction are still separate, which means that the parties involved with the design not naturally also involved in execution. Responsibilities for failures are with the party that brings the wrong idea.

INTEGRATED MODEL (CORRESPONDING TO DESIGN-BUILD PDM)

In this form of collaboration, the different phases of the construction project are combined within one contract. This often involves a service and product combination since integrating more phases in one contract means that a contract becomes more and more service oriented (Castelein, 2018). In the integrated model the contract is between the client and one contractor, who takes the responsibility for the realization of all construction phases described in the contract. Comparable to the traditional model there is still a hierarchical relation between client and contractor, while in this contract responsibilities shift from client to contractor and there are less diverse parties involved (Chao-Duivis et al., 2013). Since integrated contracts embrace design, production and facilities management the construction needs to change the dimension of projects from product delivery towards satisfying the clients need for the whole-life consideration of the product. Integral contracts are increasingly applied in the Netherlands as well in other European countries (Eggers & Startup, 2006; Lenferink et al., 2013). In the Design-Build-Finance-Maintain (DBFM) contracts a private party is entitled to be responsible for design,

construction, financing and maintenance (Lenferink et al., 2013). These integrated contracts are comparable with the Build-Operate-Transfer (BOT) and Build-own-Operate-transfer (BOOT) contracts, however these contracts are not applied in the Netherlands but in the United States (Lenferink et al., 2013). A DBFM contract is distinguished from a traditional contract by merging design, realization and maintenance into one contract with the payment mechanism, the 'F component' (Rezelman & van den Bosch, 2018).

ALLIANCES

In an alliance model is the client in fact more involved in design and execution comparable to the other models (Chao-Duivis et al., 2013). The client and a contractor enter into a partnership where parties treat one another as equals. In this form of collaboration there is no building contract, but there are some cooperation partnership contracts. Currently standards for this model are lacking, and with the far-reaching organizational changes it requires this form is not yet often used in projects in the Netherlands (Chao-Duivis et al., 2013).

PROJECT MANAGEMENT CONTRACT (CORRESPONDING TO CONSTRUCTION MANAGEMENT PDM)

This is an agreement between client and consultants. In this model, the consultant is commissioned to manage a construction project for the client (Chao-Duivis et al., 2013). Traditionally, construction contracts are used to design and construct infrastructural work. Contractors were in some extent already involved in services related to the operation and maintenance of construction (Robinson & Chan, 2014). In other industries, the transition towards a more service-oriented business occurs due to changing customer demands. Supplementary service will ensure that products are aligned to the customer's function, the performance of products and the reliability of products (Robinson & Chan, 2014). Since the Dutch government stated that the Netherlands should be circular in 2050, clients are more often demanding for circular solutions. Integrated models already include the delivery of a product as well as a service and, therefore, it is important to further investigate what this combination entails. Leiringer and Brochner (2010) argued that contractors already share characteristics with firms in the service sector since production take place at point of purchase, it is always a co-operation between client and contractor.

APPENDIX D. CASE STUDY DESCRIPTION 'DE CIRCULAIRE WEG'

DESCRIPTION OF THE DEVELOPMENT PROGRAM 'DE CIRCULAIRE WEG'

Dura Vermeer is working on the development and sustainability of their current business operations. As a contractor, they also see that the transition from a linear economy to a circular economy is necessary, not only because of the pressure that our current economy has on earth but also in relation to their future business opportunities. Fitting circular economics principles in projects means for Dura Vermeer dealing with the procurement of circular products and services that are necessary for business operations (Dura Vermeer, 2017). In addition, it is important that the economic model of the company is adapted to a model that fits in a circular economy, with the aim of making the transition from product-oriented projects to service-oriented projects. The case of 'De Circulaire Weg' is a program at Dura Vermeer which aims to develop a concept in which infrastructure will be delivered according to the principles of circular economy. In this research, the development of the concept will be studied to get insight into the opportunities and barriers to implement service aspects in project delivery of infrastructure projects.

In the development group of 'De Circulaire Weg' different field of expertise (legal, financial, procurement, sustainability and maintenance) are represented by employees of Dura Vermeer. On two weekly basis progress meetings take place with the project team in which each member updates the exploration of certain topics related to their field of expertise. In addition to the progress meetings diverse consultations take place in smaller groups. Besides that, there are also interviews with parties outside the company to gain more insight into issues surrounding the change from product based project delivery towards delivery of infrastructure as a service (e.g. consultation meetings with banks, or examples from other sectors).

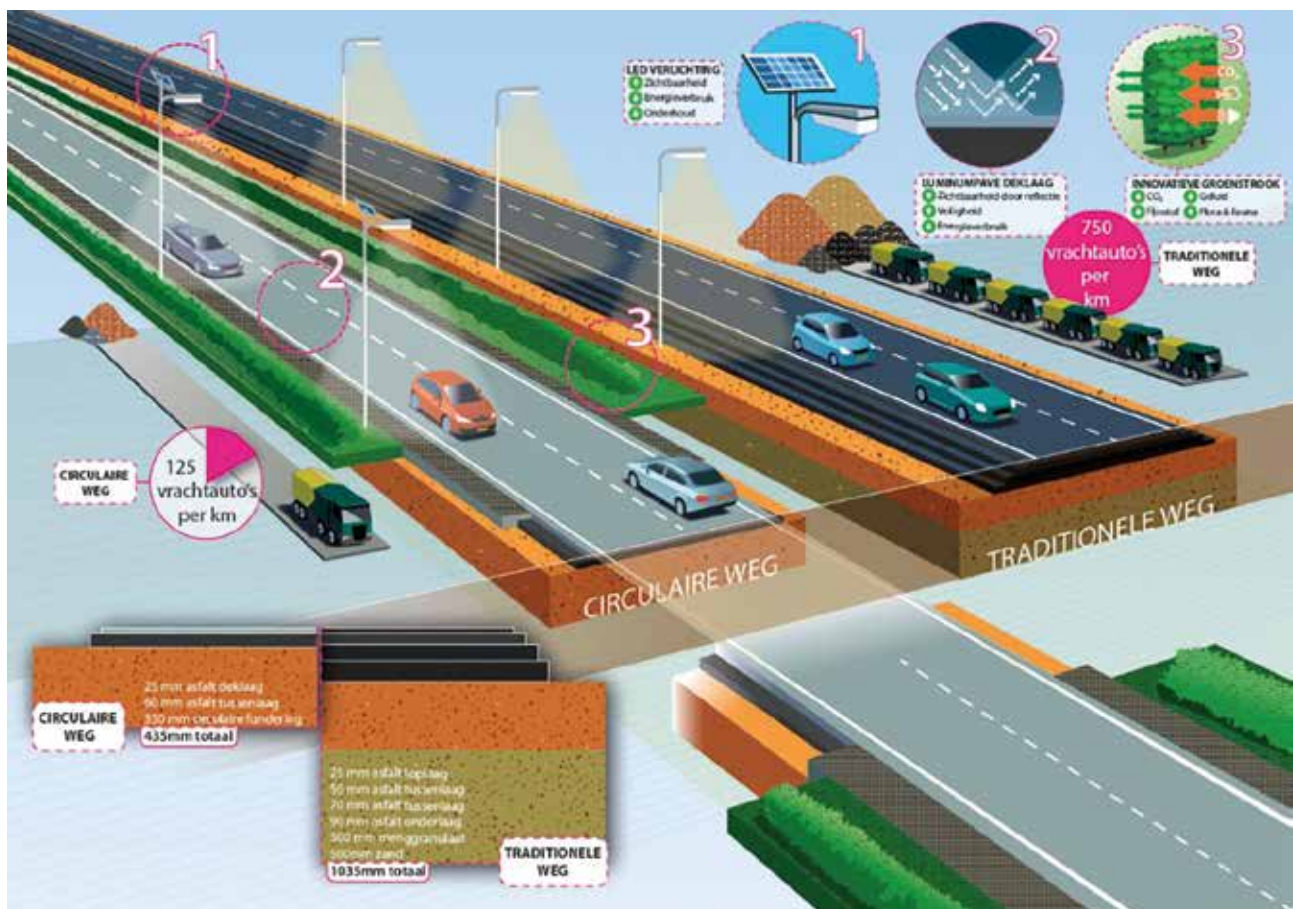


FIGURE 34. CONCEPT OF THE CIRCULAR ROAD 1.0 (DURA VERMEER, 2016)



At the beginning of this research, the concept of 'De Circulaire Weg' has already been developed quite well at product level (see figure 37). As described earlier, circular economics discards two cycles (the biological and technical cycle), which ultimately revolves around efficient and effective use of raw materials (The Ellen MacArthur Foundation, 2015). Within a circular economy, raw materials, materials and products are reused in the best possible way (The Ellen MacArthur Foundation, 2015). These principles of circular economy are also central in the case of 'De Circulaire Weg' (de Kruijf, van der Meer, Verbaan, & Winter, 2017). First, the road is built up from numerous raw materials. Often these raw materials are supplied by partners, but a large part also comes from their own production of Asphalt. On material level the concept of the circular road is already far developed. The design of the road becomes thinner compared to traditional roads and the materials used in the design are often biobased raw materials or materials that have a long lifespan. During production less CO₂ will be released due to reduction of materials and efficient organisation.

The next step in the development of the circular road is to close the economic cycle. As mentioned earlier, also the contractor is aware that in a circular economy the ownership of raw materials will ideally remain with the producer (de Kruijf et al., 2017), since the producer can best determine the value of raw material at all stages of the cycle, and influences the application and development of the value of these materials. In relation to close the biological and technical cycle the contractor can best decide what could be done with the product or materials when they reach their functional end-of-life, and therefore best take care of closing the loop (in close collaboration with other stakeholders). However, the application of service aspects in the project delivery of infrastructure projects needs further exploration and therefore the development program of 'De Circulaire Weg' will be used as a central case in this research.

APPENDIX E. INTERVIEW PROTOCOL

DATUM		
ORGANISATIE		
INTERVIEWER	Denise Huizing	d.huizing@outlook.com
GEÏNTERVIEWDE		

- Allereerst bedankt voor het vrijmaken van tijd om bij te dragen aan dit onderzoek. Voordat we aanvangen met het interview zou ik willen vragen of het mogelijk is om dit gesprek op te nemen.

VOORSTELLEN

- Master Construction Management and Engineering aan de TU Delft
- Uitvoering van onderzoek in samenwerking met Dura Vermeer – werkmatschappij Participaties
- Onderzoek maakt deel uit van een ontwikkelingsprogramma ‘De Circulaire Weg’ van DV om te onderzoeken hoe infrastructuurprojecten als een service aangeboden kunnen worden.
- Wat is uw functie binnen uw organisatie? Hoe lang werkt u al bij uw organisatie?

ONDERZOEKSDOEL

Het doel van mijn onderzoek is om te onderzoeken welke veranderingen er nodig zijn in ‘project delivery methods’ (simpelweg de organisatie en het daarbij behorende financiële model van een project waarbij alle fasen in acht zijn genomen) om van product naar dienst levering te gaan in de infrastructuur sector. Momenteel suggereert de definitie van product-service systems nog een lineair proces te zijn, gezien het project na oplevering veelal direct wordt overgedragen aan de opdrachtgever. In sommige gevallen wordt er echter wel een onderhoudscontract aan gekoppeld, waarmee de levenscyclus van het project verlengd wordt. In dit onderzoek streef ik ernaar om te kijken hoe we met behulp van product-service systems naar een circulaire levenscyclus kunnen gaan, zodat er handvatten ontstaan voor opdrachtgevers en opdrachtnemers om een invulling te geven aan de noodzakelijke transitie naar een circulaire economie.

Door middel van participatie in het ontwikkelingsprogramma van de Circulaire Weg verzamel ik inzichten in de afwegingen van de aannemer in relatie tot de transitie naar een dienst levering in de infrastructuursector. Om inzicht te krijgen in de verschillende perspectieven van opdrachtgevers en leveranciers is gekozen om semigestructureerde interviews af te nemen op verschillende niveaus.

DOEL VAN HET GESPREK

Het doel van het gesprek is om inzicht te krijgen in de kansen en belemmeringen die stakeholders zien bij de toepassing van service aspecten in het kader van circulariteit in infrastructuurprojecten.

STRUCTUUR VAN HET INTERVIEW

Het interview bestaat uit drie delen. Het eerste deel zal zich voornamelijk richten op circulaire economie. Vervolgens zal het tweede deel bestaan uit topics die overeenkomen met PSS karakteristieken zoals geïdentificeerd in het literatuuronderzoek. Tot slot, zullen er vragen gesteld worden naar uw mening gericht op de toekomst van de infrastructuur sector. Ik zou graag met jullie het gesprek aangaan over de punten die gerelateerd zijn aan het concept infrastructuur als een service. Belangrijk is dat we tijdens het gesprek gaan ondervinden of iets als een kans of belemmering werkt en of dit effect intern of extern van toepassing is. Deze zullen worden geplot op het A0 papier wat ik meegebracht heb.

UITLEG THEORETISCH KADER PSS

[WERKDEFINITIE TIJDENS DIT ONDERZOEK]

Uit literatuuronderzoek is gebleken dat infrastructuur als een service altijd gaat over een samenwerking tussen de opdrachtgever en de opdrachtnemer (en zijn leveranciers en onderaannemers) over de gehele levenscyclus van de weg. Uit literatuur is gebleken dat hoe meer men naar een dienst gestuurde levering van projecten gaat, hoe meer dit aansluit bij een circulaire economie. Om de transitie te maken van product-oriented services naar result-oriented services is het noodzakelijk dat er veranderingen plaatsvinden in de organisatie van projecten. Om deze veranderingen te identificeren en in het perspectief van de infrastructuur te plaatsen is ervoor gekozen om in kaart te brengen welke kansen en belemmeringen stakeholders zien met betrekking tot deze veranderingen voor de toepasbaarheid in de infrastructuur.

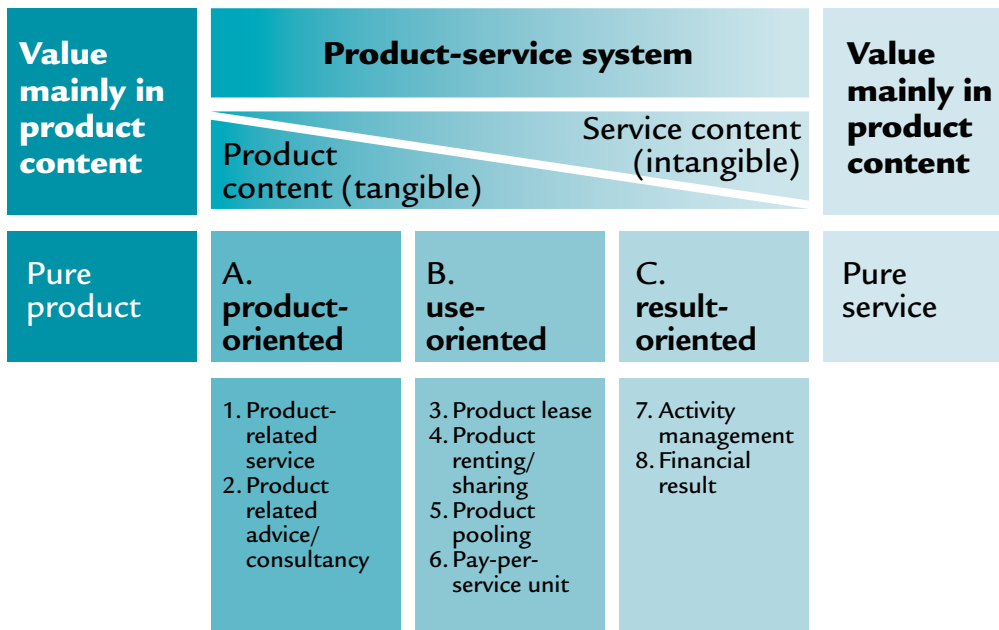


FIGURE 35. PRODUCT-SERVICE SYSTEM (TUKKER & TISCHNER, 2006B)

INTERVIEW

INTRODUCTIE

- Wat is jouw perspectief met betrekking tot circulaire economie?
- Wat voor activiteiten onderneemt jouw organisatie met betrekking tot circulaire economie?

TOPICS

- Juridische aspecten:
 - Aanbesteding / specificeren van projecten
 - Huidige (geïntegreerde) contractvormen
 - Eigendomsverplaatsing
 - Contractuele afspraken
 - Wetgeving
- Financiële aspecten:
 - Betaalmodel
 - Financiële risico's
 - Waarde van materialen
- Organisatorische aspecten:
 - Samenwerking
 - Levenscyclus van projecten
 - Processen en interne organisatie
- Technische aspecten:
 - Ontwerpen van product
 - Lifecycle assessment

TOEKOMSTPERSPECTIEF M.B.T. TOEPASSING INFRASTRUCTUUR ALS EEN SERVICE

- Wat is uw toekomstperspectief ten aanzien van de toepassing van product-service system karakteristieken in de infrastructuur sector? Hoe wegen de bedreigingen af in relatie tot de kansen?
- Past de toepassing van service aspecten bij de behoefte van opdrachtgevers/leveranciers op het gebied van circulaire economie.

Bedankt voor uw tijd en deelname. Ik zal het interview transcriberen en vervolgens naar u toesturen ter beoordeling. Uiteraard zal u bij afronding van het onderzoek een kopie ontvangen.

APPENDIX F. COMPREHENSIVE OVERVIEW RESEARCH FINDINGS AND ANALYSIS

This appendix shows a summarized analysis of the different perspectives of the contractor, client and supplier regarding the application of product-service system in the infrastructure sector. The characteristics as obtained in the literature study are used as central topics during the research. The following reference system is used in this analysis:

Contractor references	Client references	Supplier references
<p>[FE] = Interview Financial Expert Dura Vermeer, personal communication, October 30, 2018</p> <p>[FEmem] = Memo Financieel, personal communication, October 1, 2018</p> <p>[LEmem1] = Memo legal DCW, personal communication, June 26, 2018</p> <p>[LEmem2] = Memo legal DCW, personal communication, October 5, 2018</p> <p>[CMm#] = Consultation meeting minutes DCW + # (number meeting), personal communication, 2018</p> <p>[VD/DCW] = Visie document De Circulaire Weg, personal communication, October, 2017</p> <p>[EXP] = Expedition Next, September 13, 2018</p>	<p>[ALL] = all interviews</p> <p>[RWS] = interview Rijkswaterstaat, personal communication, September 18, 2018</p> <p>[PR] = interview ProRail, personal communication, October 18, 2018</p> <p>[PNH] = interview Provincie Noord-Holland, personal communication, September 14, 2018</p> <p>[POV] = interview Provincie Overijssel, personal communication, September 3, 2018</p> <p>[GRdam] = interview Gemeente Rotterdam, personal communication, September 26, 2018</p> <p>[GHmeer] = interview Gemeente Haarlemmermeer, personal communication, October 2, 2018</p>	<p>[ALL] = all interviews</p> <p>[NP] = interview Natural Plastics, personal communication, September 21, 2018</p> <p>[VDBB] = interview van den Bosch Beton, personal communication, October 17, 2018</p> <p>[AP] = interview Asfaltcentrale, personal communication, October 23, 2018</p>

1. CIRCULAR ECONOMY

Utilising the results from the interviews as well as the case study, this paragraph provides an analysis of the perspective of different construction stakeholders regarding circular economy awareness, challenges and actions. The participants in this research were all aware of the concept of CE. At first, it can be concluded that in all organisations circularity and sustainability are important disciplines in policy as well as in activities.

POLICY

To get insight in the embedding of the governmental policy regarding circular economy at the stakeholder organisations information was gathered on policy regarding circular economy.

TABLE 9. RESEARCH FINDINGS - POLICY REGARDING CE

CONTRACTOR	CLIENT	SUPPLIER
<p>The involved contractor has set ambitions within their policy regarding circular economy [VD/DCW]</p> <p>A vision document of the contractor noticed that the contractor wants to be leader in circularity of 2030. They have set themselves targets to ensure that in 2020 approximately 50% of the raw materials have circular alternatives and by 2030 they are able to deliver 100% circular solution. [VD/DCW].</p>	<p>All involved client organisations indicate that they are consciously engaged with sustainability and circularity. [ALL]</p> <p>From the public organisation involved in this research, all of them have a program for sustainability in which circularity was often part. Furthermore, also each of the involved client organisations have a vision or program document in which policy regarding sustainability or circularity is explained. [ALL]</p>	<p>All involved suppliers indicate to be actively engaged in sustainability and circular economy. [ALL]</p> <p>Not all suppliers do already have total circular products, however recycling and reuse are noticed as important aspects regarding product policy. Two of the suppliers indicate to deliver products with a guarantee regarding circularity ([NP]: bio based product, which will disappear after certain time and [VDBB] cement less concrete which will be delivered as a certified product regarding CO2 reduction).</p>

From this table, it can be observed that sustainability and circular economy are embedded at the policy level. Setting ambitions and goals for the transition to a circular economy is a starting point for change, however the translation of these policy objectives into actions is even more important.

ACTIONS

To make a transition in the construction industry towards circular economy it is important to identify what activities are already taking place to start transforming. Therefore, all stakeholders were asked to indicate what actions they undertake themselves, but also what changes they see happen in the market regarding transition towards circular economy. Table 10. summarizes the actions of the three different stakeholders in relation to circular economy.

TABLE 10. RESEARCH FINDINGS - ACTIONS CE

CONTRACTOR	CLIENT	SUPPLIER
<p>The development of the circular road is an initiative of the contractor to explore the possibilities regarding application of PSS as circular business models for infrastructure sector [VD/DCW]</p> <p>The construction sector is moving regarding circular economy, since clients increasingly put sustainability and CE as part of the tender procedure. [CMm2]</p> <p>Other contractor organisations are also developing circular product concepts. However, it was indicated that these are all separate concepts with still having a linear business model. For a transition towards CE it was indicated, by the contractor, as necessary that the business model also change. [VD/DCW]</p>	<p>Sustainability and circular economy are often part of the tender specification, in which the client incorporates his goals regarding the transition. [ALL]</p> <p>A client representative pinpointed that almost all organisations are looking for circular or sustainable solutions within the current linear business economy while this is according to the representative not in line with the principles of a circular economy. [RWS, PNH]</p> <p>All public clients involved in this research apply circular procurement as much as possible, whereby agreements are made with stakeholders about stimulating and facilitating the reuse of products, components and raw materials. [ALL]</p>	<p>Two out of three involved suppliers have developed a product that has less impact on the environment. [VDBB, NP]</p> <p>A supplier indicates that another reason for change towards a more sustainable product is due to shortage of raw materials which indirectly forced to look for an innovative solution for their product. [VDBB]</p> <p>One of the suppliers' designs, manufactures and sells products that do not damage nature, because these products are bio based and originate from residual flows from agriculture and horticulture. [NP]</p>

All stakeholders in the construction sector undertake actions regarding circular economy. Since the clients are the initiating party for new projects they are initiated by the contractor as the leading party to start the change. Suppliers are developing circular products that can be applied on high scale, however they noticed that due to lack of experience with their products contractors and clients are not willing to apply it on big scale.

KNOWLEDGE

During the selection of interviewees, it was determined that the persons involved do have knowledge regarding project delivery and circular economy. This preselection does not give insight in the status of knowledge regarding circular economy and therefore it was specifically questioned to the interviewees. Table 11. gives a summary of the three different perspectives regarding knowledge of circular economy within their organisation and the sector in general.

TABLE 11. RESEARCH FINDINGS - KNOWLEDGE REGARDING CE

CONTRACTOR	CLIENT	SUPPLIER
<p>Knowledge regarding the principles of circular economy are growing since CE becomes more often an integral theme in projects. [CMm2]</p> <p>Awareness and importance of change are growing at the contractor organisation. Currently programs to develop knowledge in the contractor organisations are performed, to grow and share knowledge intern. [EXP]</p>	<p>In the client organisations, it was noticed that knowledge regarding circular economy is growing, however a lot of people in the organisation do not yet see the incentive to undertake action. [RWS, PNH, PO, GRdam, PR]</p> <p>The construction sector is by the client seen as a conservative sector and therefore knowledge regarding CE is necessary to break the conservatives and start the transformation towards circularity. [RWS, PO, GRdam]</p>	<p>All supplier interviewees indicate that knowledge regarding circular economy in the construction sector must grow to stimulate the transition. [ALL]</p> <p>Contractors do not sufficiently know what circular or sustainable solutions already exist on product level in relation to circular and bio based. Therefore, knowledge regarding circular solutions must be exchanged between stakeholders in the construction sector. [NP]</p>



In general, it can be observed that knowledge regarding circular economy should be improved in the sector to develop a business model that complies with the principles of circular economy and will stimulate to achieve the CE goals in 2050. However, in many the involved organisations is already a development going in relation to increase knowledge regarding circular economy in the entire organisation. Exchange of knowledge and experiences between stakeholders and disciplines is noticed as an important factor to grow the awareness that the industry must change.

2. LEGAL ASPECTS

As identified in the theoretical framework regarding application of PSS in the infrastructure sector, a few legal oriented changes are necessary. In this paragraph, analysis regarding the legal aspects is conducted to find out what legal changes are necessary for application of PSS.

TABLE 12. RESEARCH FINDINGS - PROCUREMENT

CONTRACTOR	CLIENT	SUPPLIER
<p>Currently tenders are mostly technical-ly specified, whereby implementation of innovative and circular ideas are not stimulated. Therefore, functional specification is noticed as an important step to create room for innovation [CMm2].</p> <p>Procurement law does not have to adopted to promote circular construction, because procurement law (both in terms of procedure and in terms of the request) provide sufficient room for the government to purchase in a circular manner. [LeMEM1]</p> <p>Public clients are obligated to Dutch procurement law. For projects under the European threshold, there is room for clients to choose the procedure that is most suitable and proportionate. However, above the European threshold strict rules apply and there is no room to deviate from tendering policy (and therefore room for innovative solutions can be degraded. [LEmem1]</p> <p>It must be an assignment in which parties are asked to facilitate a road, whereby it is responsible for all aspects of design and construction, but also maintenance accessibility and safety until the end of contract [LEmem1, LEmem2].</p> <p>Procurement legislation is a possible obstacle for the application of service in infrastructure, due to threshold amounts that have been set out which indicates the needed procurement process. If the value of a project is equal to or exceeds the threshold amount, the public client must put out an European tender. From the legal perspective, the questions arise whether it is necessary for the provision of service that public organisations also requested infrastructure projects as a service. [CMm2]</p>	<p>Since the infrastructure sector is dominated by public clients, a client interviewee indicates that the clients are in the position to change their request and integrate circularity in procurement as first step in the transition [RWS, POV].</p> <p>According to the client organisations, the contractors also must be willing to accept tenders in a different way [RWS, PR].</p> <p>Specification should no longer take place on product level, but at functional level when asking for product-service systems. However, this change is a challenge in a conservative organisation [POV, GHmeer, GRdam, PR, RWS].</p> <p>When applying PSS in infrastructure projects the assessment must take place on best price-quality ratio and no longer on the lowest price, since linear business models do have an unfair benefit in relation to circular business models (indicated as cheaper). Further, circularity must be an assessment criterion in procurement to stimulate the contractor and supplier to think about (circular) innovative solutions [GHmeer, Grdam, PNH, RWS].</p>	<p>Innovation is necessary in relation to sustainability or circularity and should therefore get more attention in the procurement strategy of clients. [AP, NP]</p> <p>To ensure a circular economy in procurement of projects it is important that the tender was thoroughly (all phases of the lifecycle of a project) considered at various levels in the organisation [NP]</p> <p>Technical specification means that the contractor is obliged to deliver what was asked by the client, however functional specification can give freedom to provide the best possible solution regarding the function. [AP]</p> <p>It is important that clients think through their tender integral within the organisation to create a broadly supported request on which the market can respond [NP].</p>

PROCUREMENT

All stakeholders appoint procurement as an important legal aspect to change towards application of PSS in the infrastructure sector. Table 12. summarises the statement that are made about procurement by the participants of this research. To stimulate the application of PSS in the infrastructure sector it is indicated that public clients must change in procurement towards more functional specification to stimulate the contractor as well as the supplier to come up with innovative and circular solutions. In the interviews with representatives of the suppliers, procurement did not clearly appear as a point of change, which can be explained by the fact that suppliers are often not yet involved in the tendering of projects. Further, it emerged that the change to functional specification in public organisations still causes some internal difficulties. Many employees at public authorities are technically skilled and the interviewee indicates that this could be difficult for changing towards functional specification.

REALLOCATION OF OWNERSHIP

To get insight in the perspective of the different stakeholders' questions were asked in relation to the reallocation of ownership. Table 13. summarises the statements that are made regarding ownership of the infrastructural product.

TABLE 13. RESEARCH FINDINGS - REALLOCATION OF OWNERSHIP

CONTRACTOR	CLIENT	SUPPLIER
<p>The contractor indicates to be the designated party who can take care of the entire building process to ensure the highest possible value throughout the whole lifecycle of an infrastructure project (e.g. from the design and construction of the road, maintenance, accessibility and the safety of the infrastructure). [CMm1]</p> <p>Shifting responsibilities by reallocation of ownership create an economic stimulant to achieve the most optimal value of a product throughout and after the entire lifecycle. [CMm2]</p> <p>Due to accession and constituent formation (based on the Dutch civil code, book 5 article 1) legislation could be, according to the legal expert of the contractor, an obstacle for reallocation of legal ownership. [LEmem1]</p> <p>(Legal) ownership of the road is not seen as necessary to facilitate the product as a service, however it is noticed as important that power and responsibility remain in one hand. Adjustments of law or a contractual agreements to break through legal rights are possible solutions. [LEmem2]</p> <p>DV must retain the ownership of the materials in DCW and should therefore be responsible for road construction, road maintenance, but also responsible for the materials at the end of contract or when they reach their end-of-life. So DV must ensure that the materials remain the cycle and retain their value [LEmem2].</p>	<p>Responsibilities must be located at the party that is involved in several phases of the lifecycle, whereby a (new) business incentive must be created whereby the highest (residual) value of materials at the end of life is necessary and there is an incentive to keep the materials in the cycle by high value reduce or recycling. [RWS, OV]</p> <p>Reallocation is complex due to the high amount of public clients for the infrastructure network in the Netherlands. More than 400 different cadastral borders and thus landowners are applicable to Dutch infrastructure. [OV, PNH]</p> <p>However, it was indicated by three out of six clients that reallocation of ownership is a mean to distribute responsibilities and must be not a purpose. [PR, RWS, GHmeer]</p> <p>The reallocation of property of the ground to a private party is not desirable since the authorities will lose their position as a governmental organisation. [POV, PNH, GRdam]</p>	<p>Reallocation of ownership is due to conservatism of the sector difficult, since this is an impactful change for all stakeholders. [VDDB]</p> <p>Two suppliers indicate that throughout the lifecycle of an infrastructure project there is no need of maintenance for their products, and therefore their materials keep value and they can ownership over the product. [VDDB, NP]</p> <p>It was indicated that ownership could best be relocated to the contractor, since suppliers indicate that the contractor can due to his role in all phases of the lifecycle could guarantee the most optimal value of the product throughout the lifecycle. [ALL]</p> <p>The risk of ownership is for the supplier to high, since the contractor is the only party that can take his responsibility over the total product instead of over just one material or sub product. [ALL]</p> <p>Relocating ownership and relocating responsibilities will result in application of other more sustainable or circular products with an extended lifecycle, instead of the cheapest option. [AP]</p>

In the case study, it was observed that the contractor identified it necessary that the business model is no longer geared towards selling products, but that the associated service becomes more important. The product in relation to infrastructure is seen by all participant still as important, however reallocation of ownership of the product could be used as a means to relocate responsibilities. In the infrastructure reallocation of ownership is not seen as an easy step, since the applied materials will be automatically relocated to the client. Based on the statements out of the case study and the interviews, it is necessary that power (knowledge and resources) and responsibilities are distributed to one party that carry them best. Including value of materials in the product will create an economic incentive for the party that is involved in the whole lifecycle of the project to preserve the value of the product as high as possible to reduce costs throughout the lifecycle.

CONTRACT FORMS

In relation to find a way to change from current project delivery towards service oriented project delivery questions were asked regarding current contract forms and what changes are necessary when transforming to a service in the infrastructure sector. From the research findings it can be observed that when changing from product to service-oriented project delivery methods it is important that the functionality becomes more important than the product. Hereby, performances and the corresponding responsibilities must be stipulated in the contract. Also, the corresponding service fee or performance fee must be captured.

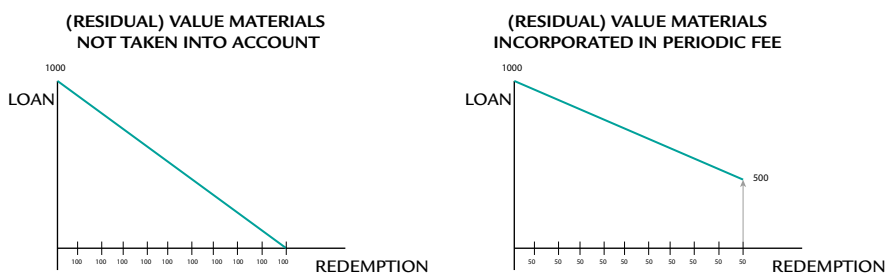
TABLE 14. RESEARCH FINDINGS - CONTRACT FORMS

CONTRACTOR	CLIENT	SUPPLIER
<p>Transparency and recognition is noticed as necessary in order to come up with a contract on which also financing can be attracted. [LEmem2, FE-mem, CMm5]</p> <p>In addition, for recognition of the contract it is suggested to use UAV-GC as starting point and add an M (already applies within UAV-GC 2005), an F (light) and a R (degree of circularity) component [LEmem2, FE-mem].</p> <p>To create confidence in the contract it is necessary to ask a reputable legal office and also tested with financiers [LEmem2, FE-mem].</p> <p>In comparison to current far integrated contracts the concept of delivering a service instead of delivering a product must be applicable on diverse scales. Current far integrated projects are due to the high transaction costs of the contract not applicable to projects of smaller size. Hereby, transparency and standardisation are necessary [CMm3].</p>	<p>Contractual arrangement must be made about what happens to the materials at the end of the contract as well as at the end of the lifespan of materials [PR, GHmeer, POV].</p> <p>Current performance contracts are already a step into the direction of delivering a service. Hereby it is also indicated that when the performance will not be delivered, the client will not pay [PR, RWS, GHmeer].</p> <p>Integrated contracts (including maintenance) are already applied, however these contracts do not have any effect in relation to circularity [RWS, PR].</p> <p>Changing towards a service it is important that responsibilities and functionality of the product is stipulated in the contract, this asks changes on contract level [ALL]</p>	<p>Contractual arrangements regarding recycling and reuse of materials must be made in the contract as well as an obligation to record how materials should be handled before, during and after application. [NP, AP]</p> <p>The main contract about PSS in the project must be between the client and contractor, since the contractor as service provider will serve towards the client. [AP, NP]</p> <p>Most important is that the responsibilities per stakeholder are well defined. [ALL]</p> <p>The supplier indicates that the end-of-life end-of-life contract, but also contract duration, is something that needs to be dealt with in the context of CE. They can not take back the product themselves (because they have no use for it), but cooperation with recycling could be a solution, for example. [VDBB]</p>

2. FINANCIAL ASPECTS
FINANCIAL SYSTEM

The transition from product to service delivery will also change the cashflows in projects. Where traditionally the client has paid for the product at the moment of handover, the client start paying for the performance when starting the use-phase. As indicated in research, diverse financial transaction methods can be applied. In this research it was identified what this change mean for the diverse stakeholders. Table 15. on the next page gives insight in the statements regarding the financial system and what this means for the diverse stakeholders.

As noticed by the contractor incorporating the value of materials do give added value to the business models. Taking the residual value into account does change the financial model of a project, which was underpinned by the following example.



“If you borrow 1000 over 10 years, you pay 100 repayments per year. When you have a residual value of 500 over the product it would mean that you only pay 50 repayment per year.” (Consultation meeting DCW, personal communication, October 30, 2018)

This indicates that infrastructure projects could be less expensive when including residual value, however the financial expert noticed that it is still difficult to determine the residual value. Due to the large number of different materials and the different lifespans of these materials, it is still complex to determine the value of the road in total. In the end, incorporating value of materials in the financial system creates an incentive driven by money which stimulates the

TABLE 15. RESEARCH FINDINGS - FINANCIAL MODEL

CONTRACTOR	CLIENT	SUPPLIER
<p>The realisation of the road is pre-financed by DV. The investment is recouped by operation of the road, whereby the service is reimbursed on the basis of availability fees. [LEmem2]</p> <p>The contractor gets a loan on his balance sheet, due to pre-financing and revenues for the service instead of an initial revenue stream for the investments. [FE, FEmem]</p> <p>Long term contracts do give certainty regarding revenue streams over the whole lifecycle [FE].</p> <p>Due to the need for pre-financing it is desirable to attract a loan from banks to repay the contractors' prefinancing [FEmem]</p> <p>Incorporating the (residual) value of materials in the financial system gives an economic incentive to the contractor to create and preserve value throughout the lifecycle of projects. [FEmem, FE, CMm5,6,7]</p>	<p>The client must no longer pay for the infrastructural product, but for the service. The current system of investing in infrastructure should be reorganised, whereby a shift can be made towards the actual user pays for their use instead of by road tax. [OV, RWS]</p> <p>Materials do have value, however currently the materials are not rated with a financial or economic value. [RWS]</p> <p>Including value of materials in the financial system could bring an economic incentive for the contractor to keep the quality of the product as high as possible. [RWS, POV, PR]</p>	<p>For the supplier it is seen financially not possible to spread revenue streams over the lifecycle, since they still have to pay their materials to the supplier directly. [ALL]</p> <p>Incorporating the value of materials in the financial system could also give opportunities for suppliers. [BM]</p> <p>Biobased products do not have any residual value, since they break down at the end of their life. [NP]</p> <p>The Asphalt supplier noticed that they already work with a certain residual value, since they have an intake policy. After harvesting materials an inspection will take place. When the materials are high-quality, the harvester will receive a certain compensation for the materials. [AP]</p> <p>A periodic fee for the product is for the supplier not seen as a possible solution, since he must pay directly for the materials he need to produce the product [NP].</p>

service provider to enhance and preserve value of materials throughout the different lifecycle phases. Further, it can be observed that external financing is necessary to repay the contractors' prefinancing. Hereby, it is indicated by the financial expert that it is necessary that applying product-service system is also interesting for banks and investors to invest in.



BUSINESS OPPORTUNITIES

To let a business model work it is important that stakeholders see business opportunities in the application of it. Therefore, the following table shows insight in the added value the application of PSS have for the diverse stakeholders.

TABLE 16. RESEARCH FINDINGS - BUSINESS OPPORTUNITIES

CONTRACTOR	CLIENT	SUPPLIER
<p>The development to deliver the circular road as a PSS better fit with the opportunities in the market than a competing product offer, since several contractor are developing circular product concepts [CMm1, VD/DCW]</p> <p>Offering a product-service is a means to improve the bargaining power towards the current service and product offering organisations, since it combines both. [CMm4]</p> <p>In a circular business model materials still have a residual value at the of the contract period. Due to the responsibilities for the product throughout the life cycle (since the contractor will act as service provider) the (residual) value of materials should be incorporated in the financial model. This creates an economic driven incentive to preserve value throughout the lifecycle [CMm5, CMm6].</p>	<p>Giving the materials value and due to reallocation of ownership a business incentive can be generated for the contractor or supplier to keep materials as high valued as possible throughout and after the lifecycle of a project [OV, RWS].</p> <p>Moving the role of service provider in relation to infrastructure from the public clients to private parties can unburden the government, however it also brings some risks that are hard to relocate to private parties (e.g. guarantee safety). [RWS, PR, GHmeer]</p>	<p>Residual value of materials is seen as a business opportunity for the supplier. Especially for the suppliers that have products which have still value after certain period of time. [VDBB]</p> <p>Starting collaboration with recycling parties can ensure that the material cycle will be closed. As a result, due to partnering and (residual) value of materials a financial advantages can arise with regard to purchase of raw materials and the production of the product. [VDBB]</p> <p>It is not the residual value that is interesting, but expansion of the function through optimization at product level / material level. [AP]</p> <p>The contractor will ask for products with a long lifespan, whereby it is possible that clients will specify how long the functionality of a specific product must be, this could lead to overdimensioning of product to be sure that they will reach that lifespan. [NP]</p>

Delivering infrastructure as a service brings for contractors, clients and suppliers diverse business opportunities. However, the business opportunity that all parties have in common is that the product itself (consisting out of materials) will gets a certain value that will be included in the financial model.

3. ORGANISATIONAL COLLABORATION

There are several vision documents that argued that close collaboration between stakeholders is a prerequisite in relation to circular economy. The following table gives an overview of statements that are made in relation to collaboration.

TABLE 17. RESEARCH FINDINGS - COLLABORATION

CONTRACTOR	CLIENT	SUPPLIER
<p>Operational processes need to be reorganised, since the contractor will change his role from execution company towards a service provider. [CMm2,3]</p> <p>The contractor will get an administrative task, since he must be able to transfer knowledge to a new service provider and to the client. Therefore, it is important that information is recorded throughout the lifecycle phases. [CMm2,3,5,6]</p> <p>The human factor in relation to change is obstructing the transition. Therefore, it is important to invest time and money in sharing knowledge regarding CE and the delivery of a service in comparison to the traditional product delivery [CMm4,5]</p>	<p>For a transition towards circularity all stakeholders in the construction process should be involved [POV, PR, GHmeer].</p> <p>The construction industry is seen as a conservative sector. To break through the conservativeness a discussion should start, whereby solution partnering of stakeholders in the construction chain is necessary. [POV, RWS, PR]</p> <p>Trust is seen by the clients as an important factor for collaboration, when applying PSS in the infrastructure sector the government bodies must trust private parties to fulfil a social governmental tasks. [RWS, GRdam, GHmeer, PR]</p>	<p>For collaboration it is important that responsibilities of the different stakeholders is distributed in the right way. [VDBB, NP]</p> <p>Including a take-back guarantee to their products is an opportunity to close the material cycle in projects. However, partnering with other stakeholders is needed (e.g. recycling companies). [VDBB]</p> <p>To provide a long-term service to the client, it is important that the contractor and supplier closely cooperate, since the contractor has knowledge about execution of the total product and the supplier knows everything about the product itself. [AP, NP]</p>

Partnering is seen as an important condition for applying product-service systems. Due to the extension of the project life cycle it is indicated by the participants that close collaboration between stakeholders is prerequisite. In addition, trust must be created between the client and contractor, since the contractor will take over the responsible role of the client as a service provider.

INTERNAL REORGANISATION

In the theoretical framework it was indicated that the change from product-oriented project delivery towards service-oriented project delivery asks the stakeholders to reorganise their processes. During the interviews and case study it was identified what internal reorganisation is necessary to make the application possible. The following table gives insight in the internal reorganisation that is necessary according to the participants of research.

TABLE 18. RESEARCH FINDINGS - INTERNAL (RE)ORGANISATION

CONTRACTOR	CLIENT	SUPPLIER
<p>Operational processes need to be reorganised, since the contractor will change his role from execution company towards a service provider. [CMm2,3]</p> <p>The contractor will get an administrative task, since he must be able to transfer knowledge to a new service provider and to the client. Therefore, it is important that information is recorded throughout the lifecycle phase and especially in the design phase/construction phase. [CMm2,3,5,6]</p> <p>The human factor in relation to change is obstructing the transition. Therefore, it is important to invest time and money in sharing knowledge regarding CE and the delivery of a service in comparison to the traditional product delivery [CMm4,5]</p>	<p>The current separation in the investment and maintenance costs per discipline/activity is seen by the client as an obstacle to pay per use. [GRdam, GHmeer]</p> <p>The board of a public client changes every four years. Thereby, the policy will also change every four years. This obstructs the change towards a circular economy. [POV]</p>	<p>The human factor is seen as important aspect regarding change towards PSS [VDBB, NP].</p> <p>Their will not change a lot in the internal organisation, since the supplier will stay the supplier. The way products are produced will not change. Only the financing structure can change. [AP]</p>



4. TECHNICAL DESIGN

The following aspects regarding application of PSS are identified as being relevant.

TABLE 19. RESEARCH FINDINGS - DESIGN

CONTRACTOR	CLIENT	SUPPLIER
<p>Due to the incorporation of residual value there is need for the contractor to ask suppliers to come up with the most optimal solution in relation to prolong the lifecycle and reduce the costs for maintenance [CMm3,4,6]</p> <p>The product is for the contractor still an important aspects, since this will be the basis on which the service will be provided, therefore there is need to take care during the design and execution phase to add value to the product. [CMm7]</p>	<p>For clients, the application of PSS is seen as complex for the infrastructure sector due to that the product not exists of demountable components [PNH,RWS, GHmeer, GRdam].</p> <p>Since PSS imply long-term contracts, uncertainty of the technical content of the product is at issue from the perspective of the client. Therefore, clients noticed that flexibility in the design of the product is important, so that if the function changes or innovation comes into play the product still can fulfil the clients' needs. [GHmeer]</p> <p>To guarantee materials must be kept high-valued in the chain, according to the interviewee, it must be clear how the road has been constructed. [GRdam, GHmeer, RWS]</p>	<p>The involved suppliers are currently developing methods to make circularity regarding their products measurable. [ALL]</p> <p>'We work often with the cheapest option which agrees upon the requirements, however to prolong the lifespan of the product there is need for high quality products to prolong the lifespan of the product'. [AP].</p>

From these research findings, it can be observed that the technical design is still important. A high valued design, taking into account how it can be processed at the end of life is seen as important in relation to prolong the lifecycle of products. Further, the value created in the design phase will be measured as basis for the value of the product. A good high valued design can reduce maintenance costs, however it is indicated that preserving the value throughout the lifecycle is important.

END-OF-LIFE MATERIALS

Reuse and high-quality recycling of product is an important component of circular economy. Table 20, on the next page, gives insight in the most important statements regarding the end-of-life of materials.

TABLE 20. RESEARCH FINDINGS - END-OF-LIFE PHASE

CONTRACTOR	CLIENT	SUPPLIER
<p>Extension of the lifecycle of a construction project with an end-of-life phase is necessary to close the economic loop and the material as well as the technical loop of the project. [CMm2,3]</p> <p>Currently materials expire to the contractor when a project will start. He is obliged to deal with this in a legal and sound manner, but currently no requirements are made on the high-quality dismantling and bringing materials back in the chain [CMm4,5,6].</p>	<p>Extension of the lifecycle of a construction project with an end-of-life phase is necessary to close the economic loop and the material as well as the technical loop of the project. [ALL]</p> <p>As a client it is necessary that we will think about solutions for storing materials within the municipal boundaries to ensure close the loop and make reuse possible. [GRdam]</p>	<p>The suppliers answered differently on the question regarding guarantee of high-quality reuse. The asphalt producer indicates that he can guarantee an almost 100% high-quality reuse. [AP]</p> <p>The contractor is responsible for reconstruction of the materials and therefore suppliers (and recycling organisations) are dependent on how the contractor removes the product. Therefore, an economic incentive to do this accurately is necessary in relation to the end-of-life of materials. Otherwise they can't be re-used [AP, VDBB]</p> <p>Take-back guarantees is something for which operational processes need be organised. Cooperation with recycling organisations is necessary. [VDBB, AP]</p> <p>Recording materials in a building information system could be a possibility to gather information about materials and how to deal with the materials after the end of contract [NP, AP].</p>

The end-of-life of materials is an important aspect in order to transform towards a circular economy. As indicated by the Asphalt supplier, Asphalt roads consists of several layers in which the bottom layer consist of low-grade materials and the upper layers of high-quality materials. If these layers are selectively removed and supplied to an asphalt plant the supplier is able to bring the materials back in the chain at the same level, since heating of old asphalt is almost suitable for 100% re-use. This indicates that technically optimal recycling of products is already possible, however it was indicated that due to lack of time and the addition costs to remove per layer the total road is removed at once. This indicates that the current way of organising projects is not in line with the perspectives regarding principles of circular economy. Therefore, to couple an economic incentive to the value of materials it is easier to ensure closing the material cycle and bring materials high-valued back in the cycle.

5. FUTURE PERSPECTIVE

At the end of the interview, the interviewees were asked if they see future opportunities for applying product-service system characteristics to the infrastructure sector. The perspectives regarding future application are shown in table 21.

TABLE 21. RESEARCH FINDINGS - FUTURE PERSPECTIVE

CONTRACTOR	CLIENT	SUPPLIER
The contractor sees infrastructure as a service as an opportunity to incorporate circularity in projects. [CMm1,2,4,5]	<p>Yes, it is important that we incorporate service aspects and circular economy principles in project delivery methods to transform to a service oriented and circular project delivery method [NH, PR].</p> <p>No, it is to complex and there are too many parties involved. However, in future it is better that the government get out of his role as operation manager to transfer the responsibilities for mobility to private parties. On short term it is to complex. [NH].</p> <p>No, it is to complex to apply in a dynamic city. Distributing the responsibility from the client to diverse private parties will lead to chaos. To make the transition towards a new model it is necessary to set up an agenda for change [GRdam]</p> <p>Yes, however on short term this is not possible. The Netherlands is not ready for it yet. Further, demountability of the product is seen as a prerequisite to incorporate PSS in order to achieve CE. [GHmeer]</p> <p>Yes, most important is that the responsibilities are distributed to the right party. If a service model can guarantee this, than it is an opportunity for future application [PR].</p>	Yes, however on short term this is not possible. The Netherlands is not ready for it yet. [ALL]

The majority of the stakeholders are positive in relation to the application of PSS characteristics in the infrastructure sector when this is a means for incorporating CE principles in the delivery of infrastructure projects. However, some clients do see to many obstacles in order to make it happen on the short term, and therefore only see possibilities on the long run.



APPENDIX G. PRODUCT-SERVICE SYSTEMS AND CE STRATEGIES

Kjaer et al. (2018, p.1) developed a two-step framework which increases the chance of PSS to lead to absolute resource decoupling through circular economy. According to literature there are five PSS strategies (Kjaer et al, 2018): operational support, product maintenance, product take-back, product sharing and the optimized result. These strategies result in four resource reductions: operational efficiency, product longevity, intensified product usage and product system substitutions. These strategies result in four resource reductions: operational efficiency, product longevity, intensified product usage and product system substitutions. These

resource reductions result into three different resource reduction aims: reduction the need for resources during product use, reduce the need for producing the product and displace more resource intensive systems (Kjaer et al, 2018). To achieve absolute resource decoupling it is necessary to meet three requirements: 1) ensure net resource reduction, 2) avoid burden shifting between life cycle stages and 3) mitigate rebound effects (Kjaer et al., 2018).

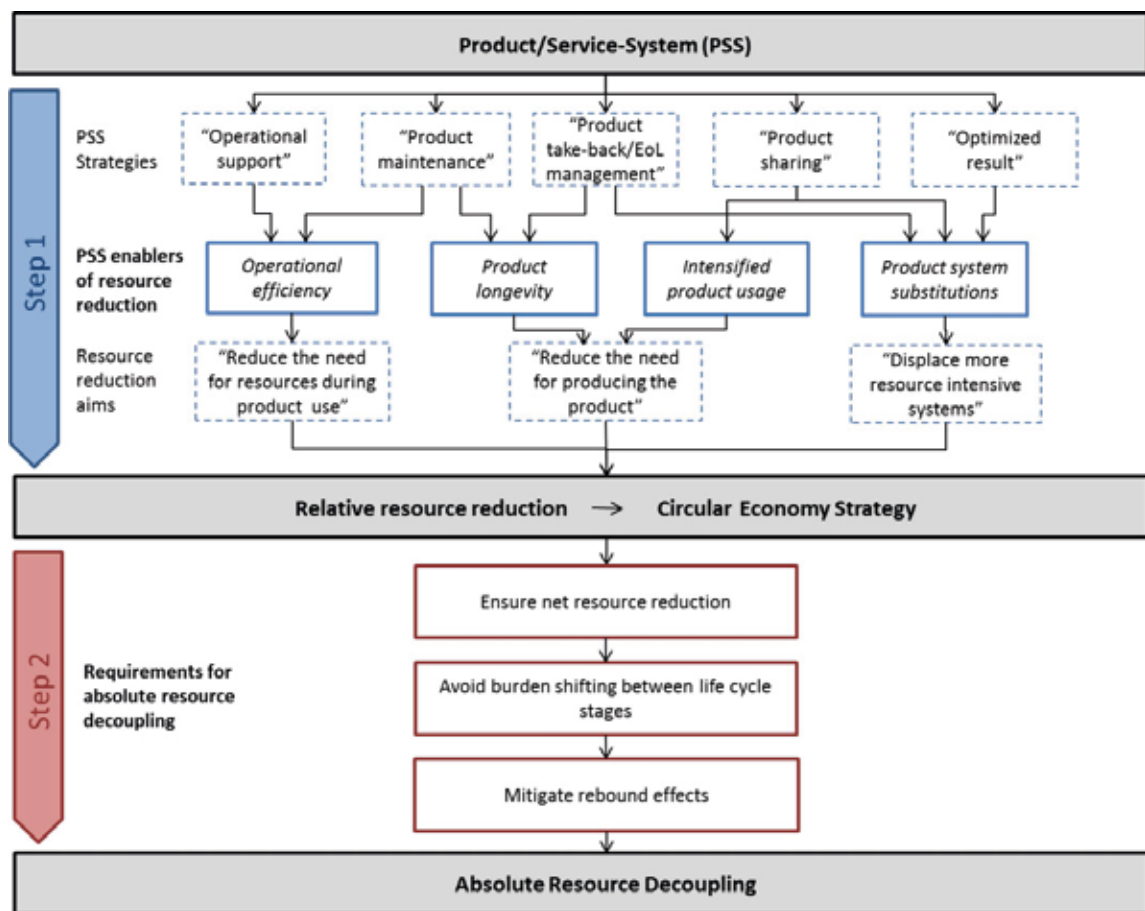


FIGURE 36. A TWO-STEP FRAMEWORK FROM PSS TO CIRCULAR ECONOMY TO ABSOLUTE RESOURCE DECOUPLING (KJAER. ET AL, 2018, p. 4)



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