The transition of construction project organisations towards a Circular Economy, by implementing Product-Service Systems

Restructure the stakeholder network of a construction project organisations to increase value towards a circular economy.

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PREFACE

In the final month of my research, when I really started to enjoy the process, I realised that everything that I have learned so far came together in this project. My bachelors in industrial design engineering provided me with creative insights during the ideation period. Sometimes this creative process took longer than expected, but I loved thinking about possible solutions and changes in the construction industry to become more sustainable. During my bachelors I noticed that my love for the built environment was growing and that I needed to change the direction of my studies. Construction management and engineering was the master which would fit me best. I could implement my knowledge gained during my bachelors here as well. Because in the end, a building is just a big product. But before this step I needed to see if the construction industry was really what I desired. So I moved to Frankfurt for a year where I learned the practical facets of a project and the love grew even more. It was very interesting to see how my theoretical background and practice in the field had similarities, but were so different at the same time.

I would advise each student to work for a year during their study, just to see how an industry is in practice. These practical insights have helped me during my masters, but also during this research. Articles become interesting when you can relate them to the real world and when you can test them with your own experiences. During another internship I was focused on the stakeholder management of an infrastructure project, which came in handy for the restructuring of a construction project organisation. I learned how different stakeholders interact with each other and was able to take this into consideration for my thesis. Finally, I followed some courses at UNSW in Sydney, which focused on the organisational aspects of the construction industry and on sustainability. It was only a month ago when I realised that all these experiences came together in this research.

Before I take you further into my research I would like to start with thanking my TU Delft committee, without them this report would not be as it is. Thanks to Daan Schraven who helped me almost weekly on the structure of my project, and gave me insights on how to approach certain aspects and problems. He showed me how one should execute a design-based research. Thanks to Juan Azcarate Aguerre with whom I had really nice sparring sessions, about the subject, and for organising the student studio, where students shared their knowledge about the subject of product-service systems, super interesting and helpful. Finally I would like to thank Hans Wamelink for his critical point of view and advice, which made my report better in the final weeks. They all helped me, gave me cool insights to look into and finally I would like to thank them all for their endless patience.

Secondly I would like to thank all my colleagues at Drees&Sommer, who invited me into the organisation as if I was one of them. But especially thanks to Rutger Laurs who gave me a perfect perception between the theory and practice. We had many interesting sparring sessions about different subjects and he helped me bring structure to the chaos in my head. He provided me with practical examples and solutions for problems I had to deal with. Thanks to all my colleagues at Drees&Sommer who I interviewed and provided me with interesting insights that I implemented in this research.

I hope you like my research about the transition of construction project organisations towards the circular economy, by implementing product-service systems. In the end I loved working on this subject and I hope there is some useful information for you too!

Have Fun!

Frank Wetsteijn

Amsterdam, February 2021

SUMMARY

The built environment has a huge contribution to the total CO2 and waste production, due to their linear approach of “take, make & dispose”. A shift in construction is needed towards the circular economy to close material loops, decrease and eventually stop the depletion of the earth’s resources. The construction project organisation could be an important vehicle for this transition. The construction project organisation is made up of all actors who, together, realise a project. The outcome of a project is the result of the collaborations, interactions and partner networks within a construction project organisation. Organising these interactions in another way could result in a more effective approach towards the circular economy. The demand for circular projects is increasing and despite this increase in demand, the construction project organisations still approach new types of projects in a linear way. Governments are speeding up this process, by creating regulations, incentives, and deadlines for all industries. The built environment has to change their way of working to commit to these new standards in the future. Product-service systems is a concept which could contribute to this transition in the built environment and reduce the depletion of resources. Consumers will pay for project-use and the producer will maintain ownership which stimulates sustainability. To accomplish this in the built environment and increase project value, construction project organisations have to change their traditional structures and develop new partner networks. The following research question will address this problem:

How can construction project organisations change towards the Circular Economy and add value by implementing Product-Service Systems?

The purpose of this research is to fill the gap between theory and practice. This is done by restructuring the stakeholder network of a construction project organisation, to meet the circular demand, by implementing the concept of product-service systems. The aim is to get a better understanding of the current state of construction project organisations and how they could implement product-service systems more effectively.

THEORETICAL FRAMEWORK

This chapter will show the need for a change towards the circular economy, giving a better understanding of product-service systems as a business model to facilitate this transition. This section will explain the aspects and interactions of a construction project organisation. The theoretical framework will show the scientific gap and will be the starting point of this research.

METHODOLOGY

The methodology will show why and how this design-based research is conducted (figure 1). The different phases of the double diamond method will provide guidance to this study. Experts were interviewed in the discovery phase, they gave a better understanding of the difficulties for construction project organisations to implement product-service systems. Semi-structured interviews were conducted with the guidance of an interview protocol. The second phase will clearly define the current problem definition. The third phase will contribute to the needed changes and to restructure the stakeholder network of a construction project organisation with the help of two interviewees. Lastly one validation interview will contribute to the feasibility and usefulness of the model and new insights will be implemented accordingly.

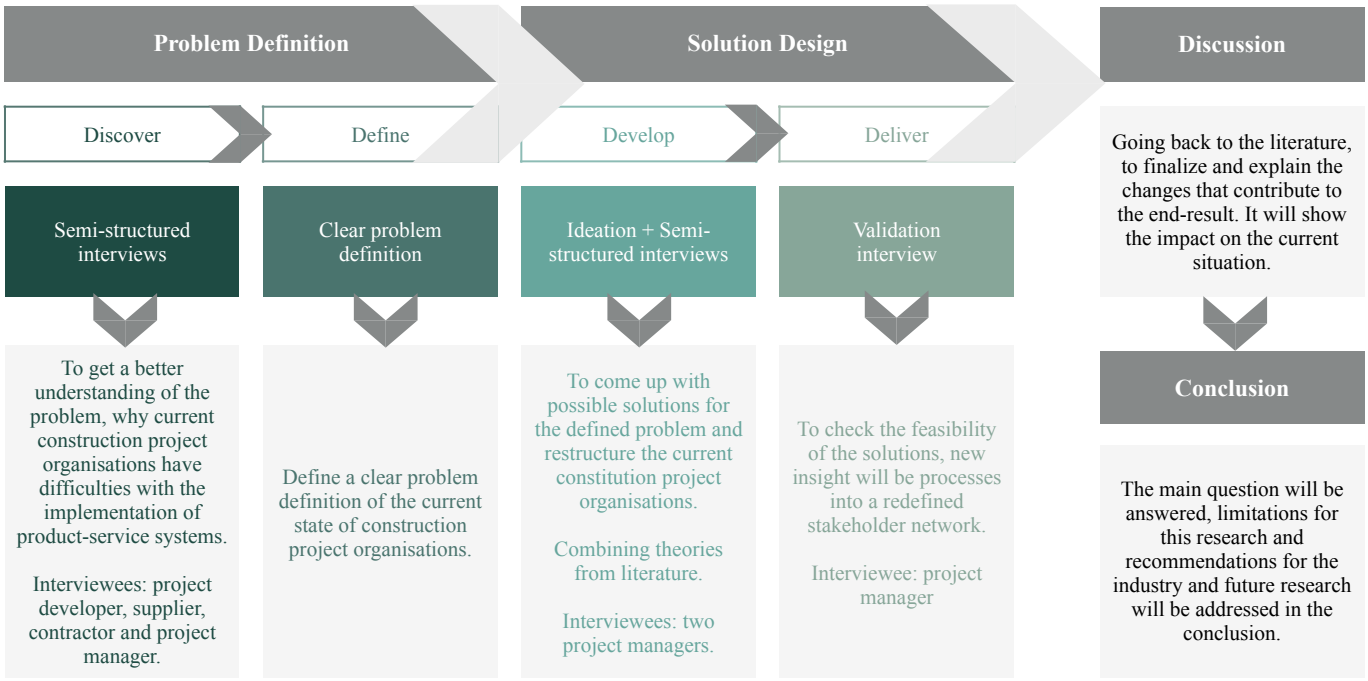

Figure 1: Methodology of design-based research (own figure)

DATA AND ANALYSIS

The focus of this research is the organisational aspects of a building. First, the practical problem was defined as to why construction project organisations have difficulties with the implementation of product-service systems (figure 2). The overarching difficulty is that actors are unfamiliar with the concept of product-service systems. This results in unclear boundaries, no collaboration or interaction, high contrast between short and long term goals, and finally a lack of phase integration.

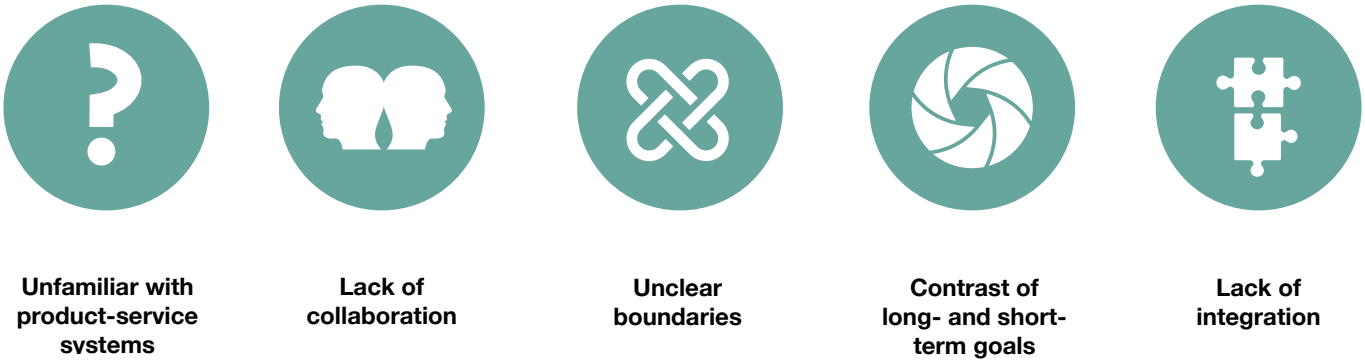

Figure 2: Difficulties for the implementation of product-service systems in the construction project organisation

These difficulties resulted in needed changes (figure 3) for the construction project organisation. First there is a need for promotion of product-service systems, by a driving force within the industry. Building in layers will provide clear boundaries for the stakeholders, there is a need for central organised services when implementing product-service systems. Experts should be involved early in the process to increase innovation and finally there is a need for more in-house knowledge and production.

Figure 3: Needed changes in the construction project organisation to implement product-service systems project organisation

These changes resulted in two new actor roles (figure 4), the system integrator and component providers based on the building layers of Stewart Brand. The system integrator brings all components together and provides all interactions between the different stakeholders. The providers are the owner and responsible for their products over the whole life-cycle including the end-of-life.

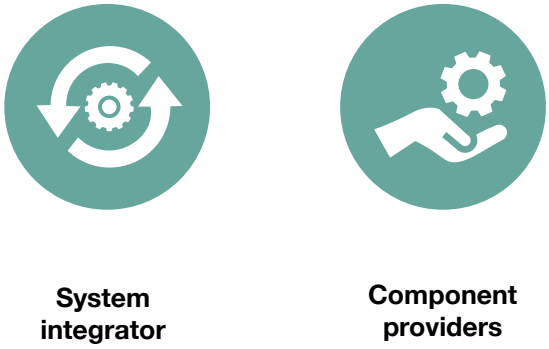

Figure 4: New actor roles for a construction project organisation service systems project organisation

These new actor roles resulted in a restructured stakeholder network of a construction project organisation (figure 5). This realistic restructured stakeholder network, implements the needed changes (figure 3) and with other collaborations and interactions between the actors. The construction project organisation is able to facilitates the implementation of product-service systems towards the circular economy.

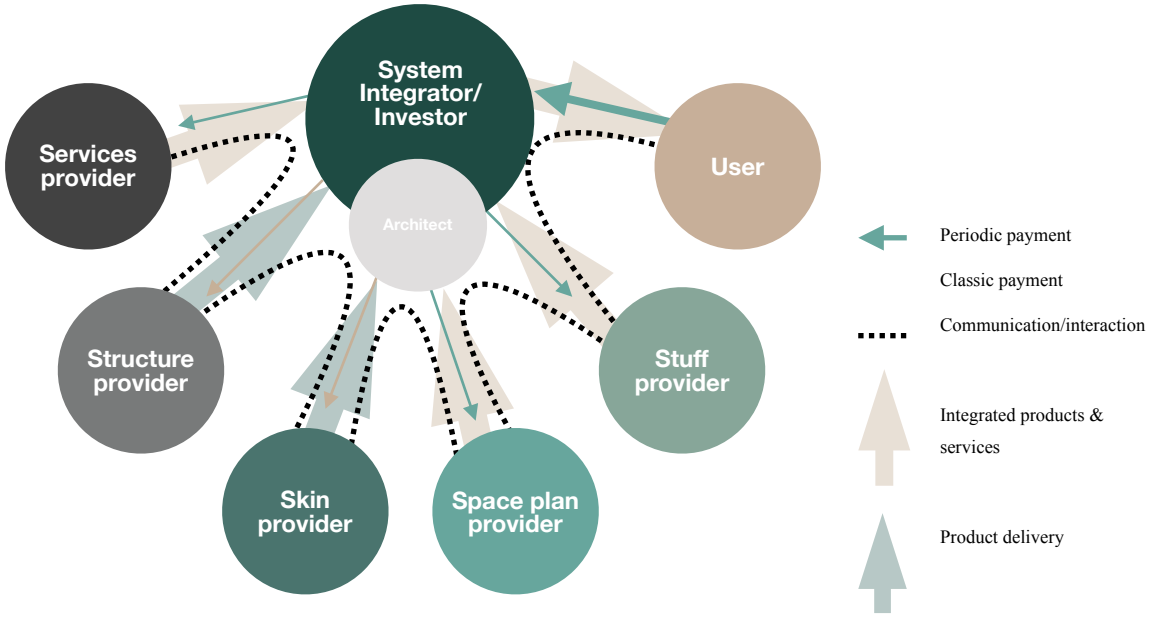

Figure 5: Realistic restructured stakeholder network for the construction project organisation

DISCUSSION AND CONCLUSION

The restructured stakeholder network of a construction project organisation will result in changes for the built environment from linear towards the circular economy. This report shows that the construction project organisation is able to increase value by implementing product-service systems. The shift in ownership from client to provider, gives a circular incentive to take back their products. Connecting product-service systems to building layers, based on their lifespan, will provide clear boundaries for the stakeholders and at the same time flexibility to the building. One is able to reuse their products or adjust and expand their product lifespan, which reduces waste and the depletion of the earth's resources. Due to the restructured stakeholder network of a construction project organisation, it is easier to implement product-service systems and contribute to a circular economy.

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1. INTRODUCTION

Due to urbanisation and the increasing world population, the construction industry has been growing for the past decades. To date, it is accountable for 13% of the global GDP and will continue to grow (McKinsey, 2018). This growth causes depletion of the earth's resources, because the current society is based on a linear economy ("take, make and dispose"), which is at the heart of industrial development (The Ellen MacArthur Foundation, 2015). In the Netherlands the construction industry alone is responsible for 40% of the waste disposal, 40% of the energy consumption and 35% of the CO2 emissions (MIE and ME, 2016) (figure 1.1).

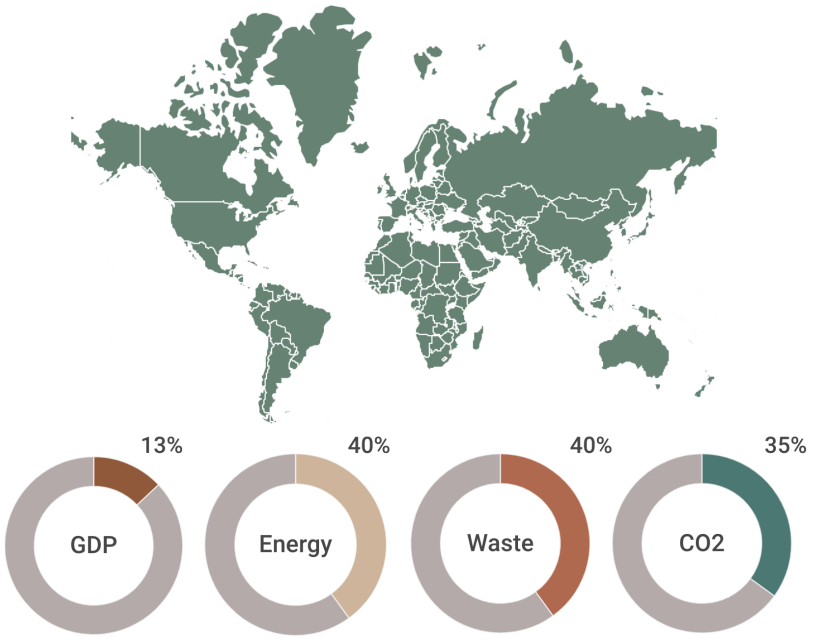


Figure 1.1: The impact of the construction industry on the world (own figure)

Today's society realises the importance of the shift from a linear model- towards a circular one (Upadhayay, 2019). The idea of a Circular Economy is to close material loops, decrease and eventually stop the depletion of the earth's resources (The Ellen MacArthur Foundation, 2015). To speed up the process, governments support different initiatives. For instance the Dutch government wants to become a Circular Economy by 2050 and implement 50% of circularity by 2030 (CB23, 2017). While other industries embrace circularity, the construction industry fails to implement it. The demand of circular projects is increasing and despite the increase in demand, the construction project organisations still approach new projects with their familiar way of working, partner networks and collaborations which can be described as their linear approach. One of the reasons is that the industry is still focused on delivering products instead of services. However the awareness in the built environment is slowly increasing, proved

by an article of Cobouw (2020), in which it was reported that a pilot of three facade contractors who are looking into the possibilities of facade-as-a-service.

The transition of delivering a service instead of a product could help the Construction Industry to decrease the use of the earth's resources. The United Nations Environment Programme (2015) sees the potential in product-service systems as a new business model, towards a Circular Economy. It will contribute to a green economy, lower carbon emissions and a resource efficient society. Product-Service Systems can be described as 'tangible products and intangible services designed and combined so that they jointly are capable of fulfilling specific customer needs' (Tukker, 2004, p. 1). This method focuses on the use, and not ownership of a product (Baines, 2007). Therefore the producer maintains ownership and is able to take responsibility for the whole lifecycle, and is able to extend product-life, reuse, recycle and re-manufacture its products (Chiaroni, 2016).

To deliver and increase value from circularity in the construction industry, organisations need to change their traditional structures and develop new partner networks (Nussholz, 2017). However, Yang (2018) states that the transition from a product- towards a service orientation is complex. To create structure, the theory of Brand (1994) could be used: "Building in layers." This theory with its origin in the early 1970s, by Frank Duffy, focuses on the different lifespan of elements in a building. Building in layers could help with the implementation of Product-Service Systems in the construction industry. Value creation within a circular economy is an inter-organisational responsibility, in which cooperation between different organisations and disciplines is necessary (CB23, 2017). On the other hand, the creation of financial value is no longer enough, as society also demands social and ecological improvements (CB23, 2017) .

A construction project organisation is a cooperative network of different stakeholders who are involved throughout the life-cycle of a project. Where a project should be seen as the collection of interrelated components, which together form a building. The outcome of a project is the result of the collaborations, interactions and partner networks within a construction project organisation. Could organising these interactions in another way result in a more effective approach towards the circular economy? This design-based research will contribute to a restructured stakeholder network for construction project organisations, to implement Product-Service Systems and promote the Circular Economy. The theoretical framework will define the research gap in the scientific domain which will be the point of departure for this empirical study. The methodology will describe how this design-based research will be conducted, how to gather and analyse the data. The data & analysis will give a better understanding of the practical problem. Two interviews and an ideation will provide an answer to this problem, in the form of a

restructured stakeholder network. The model will be validated with two interviews. The discussion will show the changes and impact of the model, with feedback from literature. Finally, the conclusion will answer the main question, recommendations and limitations will be given for the industry and further research.

1.1 PROBLEM DEFINITION

For decades the construction industry has been focused on the lowest price, however society is now asking for a better quality-of-life, and environmental improvements. Climate change and the depletion of the earth, is making us realise that our linear economy, of take, make and dispose, is not future proof. A circular economy contributes to an efficient (re)use of materials, sustainability and less carbon emissions.

If circularity is applied in the construction industry it is mainly focused on the design and (re)use of materials, and it is not economically attractive, compared to other projects. The construction project organisation could be an important vehicle to promote circularity in the built environment. However they don't have the right organisational instruments and structures in place to facilitate this change. The current structures are oriented in a linear way of working. So while the demand of circular projects is increasing, the construction project organisation still applies a linear approach. A construction project organisation are all actors who work together to realise a project and are able to influence the outcome. New structures and partner networks are needed to adapt the shift in ownership and responsibilities and make the implementation of product-service systems feasible. To address this problem the following problem is formulated:

Current construction project organisations have difficulties with implementing product-service systems, due to their current organisational approach.

This report will fill the organisational gap between circular buildings and the linear approach of construction project organisations.

1.2 OBJECTIVE

The purpose of this research is to restructure the stakeholder network of a construction project organisation, to meet the circular demand, by implementing the concept of product-service systems. The aim is to get a better understanding of the current state of construction project organisations and how they could implement product-service systems in an efficient way.

1.3 RESEARCH QUESTION

To fulfil the goal, objective, and answer the problem statement of this report, the following main question has been defined:

How can construction project organisations change towards the Circular Economy and add value by implementing Product-Service Systems?

To answer the main question, four sub-questions will divide the research into manageable steps:

1. What are the aspects of construction project organisation in the current state of knowledge, towards a Circular Economy?
2. How to gather and analyse the aspects of construction project organisations for the implementation of product-service systems?
3. What changes are needed to apply Product-Service Systems and add value within construction project organisations?
4. How should these changes be used in construction project organisations to embrace the concept of product-service systems?

1.4 SCOPE OF RESEARCH

This research has been executed for the TU Delft in collaboration with Drees&Sommer. They manage a wide range of projects for clients and contractors in the built environment, throughout all phases of a project life-cycle.

The topic of product-service systems is quite new and broad in the built environment, many topics can be addressed. Therefore a topic demarcation is needed to narrow the scope of this project. A project can be divided into technical, legal, financial and organisational aspects. This research will elaborate on the organisational aspects of a construction project organisation. It will focus on the collaboration and interaction of the internal stakeholders and partner networks.

1.5 RELEVANCE

The scientific, Practical and societal relevance of this problem are stated in this section, it will give an insight in the importance of the Circular Economy for the construction industry.

1.5.1 Scientific relevance

The demand for circularity is growing in the construction industry. Therefore more and more research has been done on this subject. However these researches are mainly focused on the theory and not the practical implementation. A good theory to meet this circular demand is the change from a product- towards a service orientated industry. For which others use Tukker's (2004) theory of Product-Service Systems. Ostaeyen (2011), however redefined Tukker's typology of Product-Service Systems, which is based on functional hierarchy modelling.

Little research has been done on the implementation of Product-Service Systems within the construction industry, towards a Circular Economy. Especially on how construction project organisations should use this theory and change towards a circular economy. A construction project organisation can be willing to build a circular project, but as long as they produce it with a linear mindset, it will not be efficient and effective.

1.5.2 Practical relevance

Construction projects are slowly changing towards circularity, because of the changing demand of clients, governments and public. Furthermore, the Dutch government urges projects to become Circular by 2050 (CB23), and therefore the construction industry has to pick up their pace. Not only the projects have to become circular but also the organisational structures, so that they can increase financial, social and sustainable value and meet this changing demand.

The Dutch government wants to increase circularity by 50% in 2030. By changing now, construction organisations can meet this demand and stay ahead of their competition.

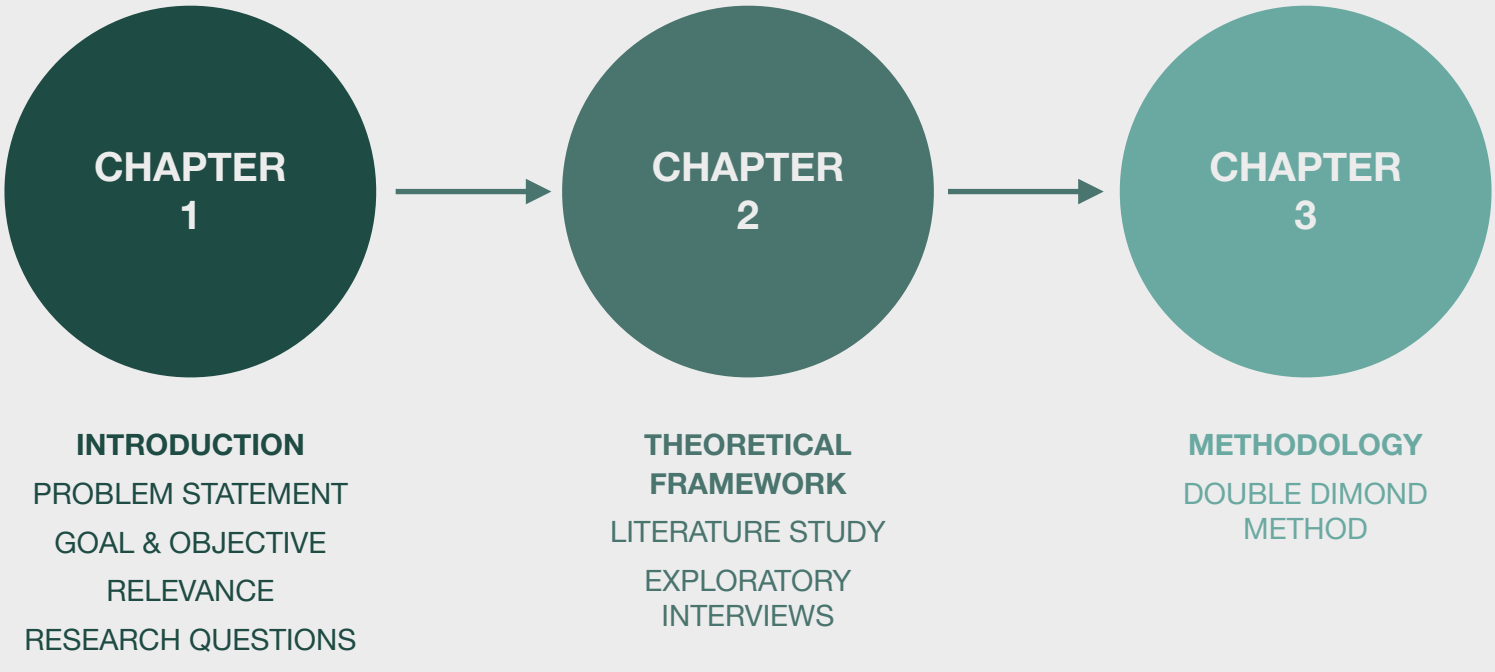
Other industries have proven that the implementation of Product-Service Systems closes material loops, therefore this could also be an interesting concept for the construction industry. This changing trend demands a shift in ownership, this will ask for a change in organisational structures.

1.5.3 Societal relevance

The call for sustainability is growing rapidly in our society. This is due to the multiple circumstances, but one of them is climate change. Carbon emission is one of the biggest causes of climate change and construction is responsible for 40% worldwide. The industry is able to make a huge positive impact if it is willing to change. The demand of the public is growing and causing a changing attitude from clients and governments. Another trend within today's society is that people no longer want to be the owner of a product but only want to use it when they need it.

1.6 THESIS OUTLINE

The thesis outline (figure 1.2), will contribute to a structured process in answering the research questions. The theoretical framework (chapter 2) will define the research gap in the scientific domain which will be the point of departure for the empirical study. The methodology (chapter 3) will describe how this design-based research will be conducted, how to gather and analyse the data. Chapter 4 (data & analysis) will give a better understanding of the practical problem and an ideation will provide possible changes and a restructured stakeholder network. The model will be validated with two interviews. The discussion (chapter 5) will show the changes and impact of the model, with feedback from literature. The conclusion, chapter 6, will answer the main question, limitations and recommendations will be given for the industry and further research.



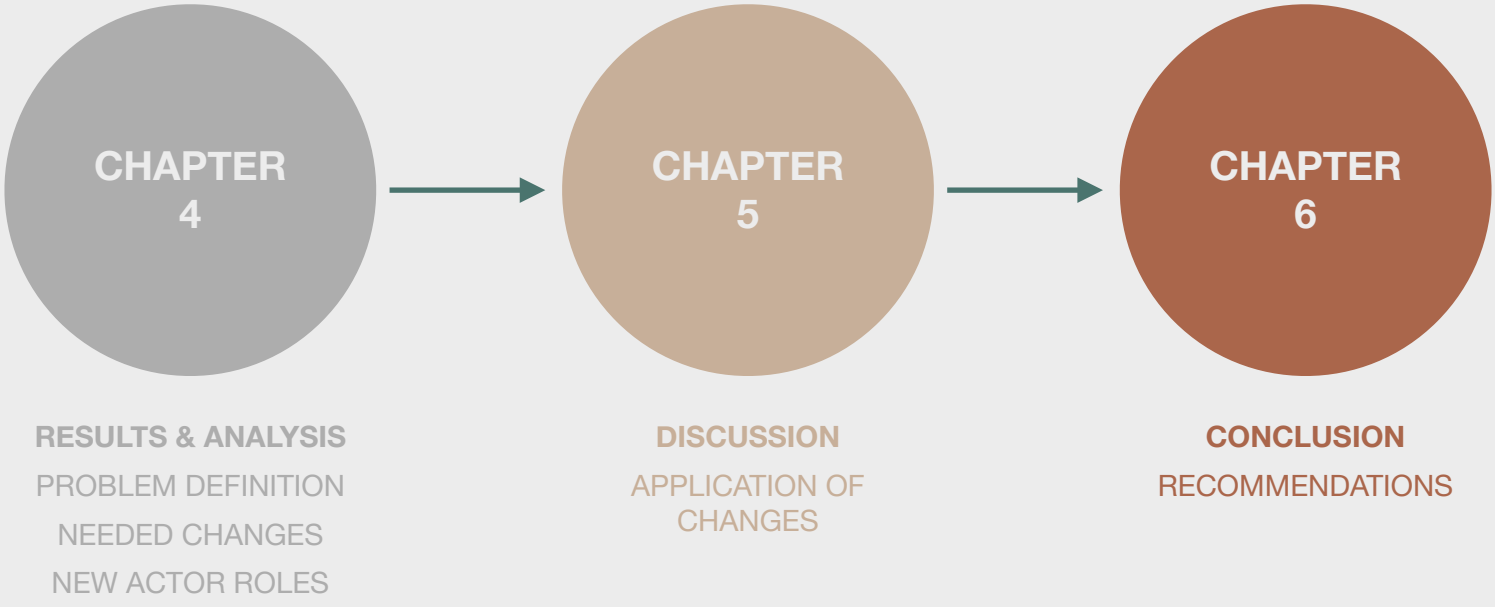


Figure 1.2: Thesis outline

2. THEORETICAL FRAMEWORK

This chapter shows the current state in literature for the need of circularity, service orientation and the aspects of a construction project organisation which are influenced by the implementation of product-service systems. The circular economy is the vision for a new economy to reduce the environmental impact and still benefit businesses. Service-orientated business models, such as product-service systems facilitate this vision and construction project organisations could play an important role in this transition in the built environment. This chapter will answer the first sub-question: What are the aspects of construction project organisation in the current state of knowledge, towards a Circular Economy? First will be explained why changing towards a circular economy is needed. Then, the circular economy, product-service systems, project value and the aspects of a construction project organisation will be discussed, according to a literature study and exploratory interviews. Finally the conclusion will define the research gap in the scientific domain which followed out of this theoretical framework and will be the point of departure for the empirical study.

2.1 ANOTHER ECONOMIC APPROACH

According to the Global Footprint Network (2018), who is monitoring the ecological footprint of the world, humanity is using earth's resources 1.7 times faster than can be regenerated by its ecosystems. In other words; humanity is consuming 1.7 earths. This is due to the world's linear economy of "take, make and dispose" (The Ellen MacArthur Foundation, 2015), which is not sustainable and future proof. According to Joensuu et al., (2020) and many others, the circular economy can be the answer to our sustainable problems. A circular economy reduces environmental resources and stimulates economic growth.

2.2 CIRCULAR ECONOMY

The circular economy is a growing subject among different industries, academia and policymakers. However different definitions for the circular economy are used, and this causes ambiguity (Geissdoerfer et al., 2017). For this reason there is a need for a clear definition before using it throughout this research. Kirchherr's (2017) findings show that reduce, reuse and recycle (3R's) is the most frequently used word combination when talking about the circular economy. Some scholars add a fourth R, referring to recovery (Kirchherr et al., 2017). The three elements that circular economy definitions focus on are, closing cycles, renewable energy, and systems thinking (Korhonen et al., 2018) (figure 2.1.).

"A circular economy is a systemic approach to economic development designed to benefit businesses, society, and the environment. In contrast to the 'take-make-waste' linear model, a circular economy is regenerative by design and aims to gradually decouple growth from the consumption of finite resources" (Ellen MacArthur Foundation, 2015).

In addition BPL (2017) states that it is the goal to optimal use of resources, generating the highest possible economic value and the smallest environmental damage. This is important since the emphasis is no longer only focused on the financial aspects, but also on the social and environmental elements (Johnson, 2016). One should see the circular economy as the means to achieve sustainability (Anastasiades et al., 2020).

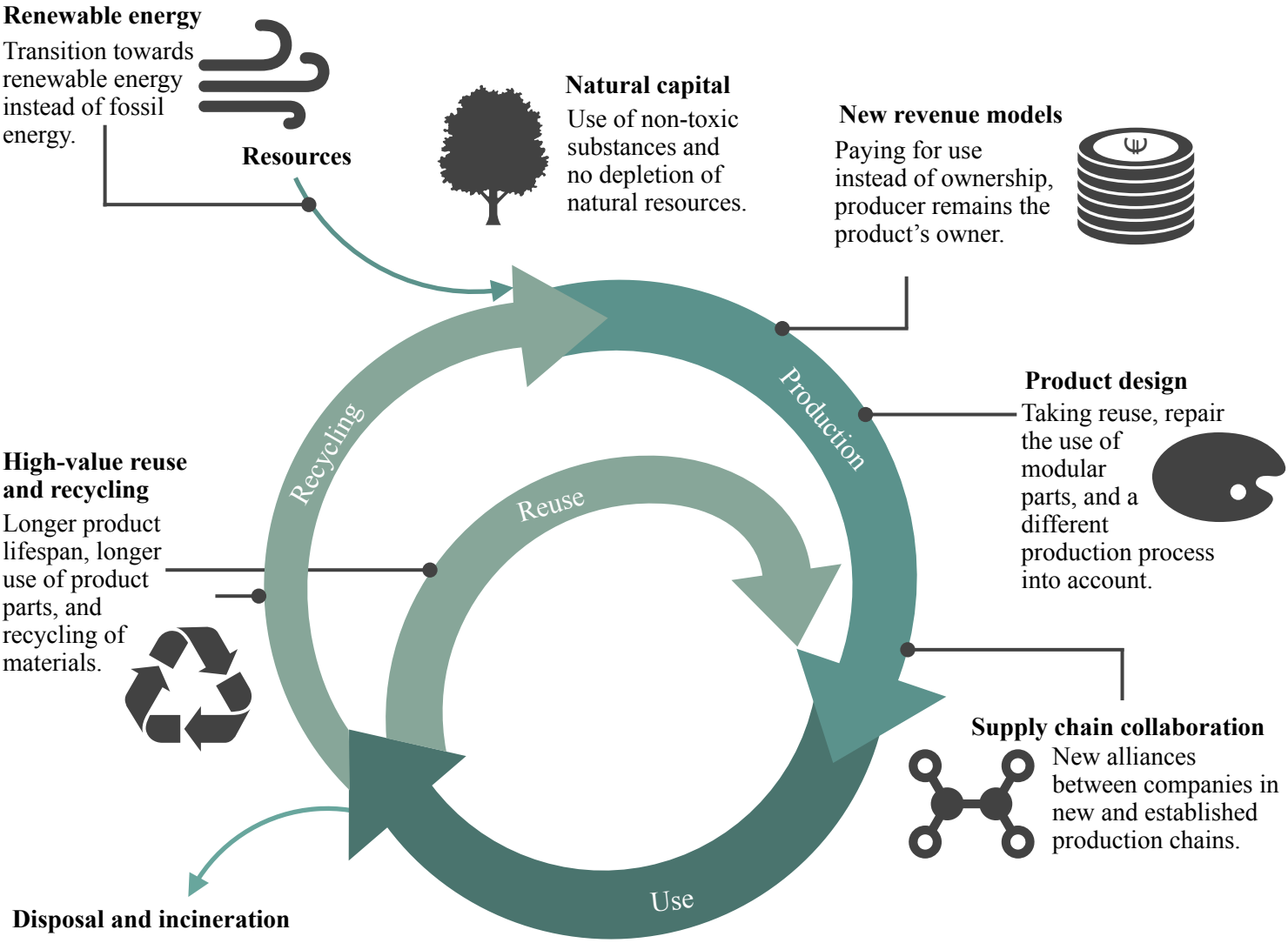


Figure 2.1: Elements of the circular economy (PBL, 2017)

2.2.1 Public Parties and Circular Economy

According to Huang et al. (2018), it is important that governments take a leading role with incentives for the private sector to stimulate circularity. Stahel (2013), suggests regulations like sustainable taxation, where polluters get higher taxes. Multiple governmental incentives stimulate the concept of a circular economy. The European Union created the European Green Deal providing a plan to become climate neutral in 2050 and create a sustainable economy. This growth strategy of the EU, will need cooperation of and in all sectors. The EU will invest in sustainability, mobility, innovation and help the different sectors with this transition towards a circular economy (European Commission, 2019). This deal is a framework of legislations and regulations setting clear goals, together with incentives to stimulate the private sector (The Guardian, 2020). Not only on European scale, but also at a national level there are more detailed plans to achieve these goals. The Dutch Government wants to become a circular economy by 2050, where the economy itself has to grow while waste production decreases. However PBL (2017) states that the idea of fully closed material loops is probably not feasible, because it's given that part of the resource use is linear. For instance Rijkswaterstaat, the Dutch party responsible for roads and waterways, will only launch circular projects by 2030 (MIE & ME, 2016). To stimulate innovative circular solutions in the construction industry, procurements should have border conditions and room for new inventions (Milios, 2018).

2.2.2 The Circular Construction Economy

The literature study of Benachio et al. (2020) on the circular economy in the construction industry looked into many articles concerning this subject. The circular economy in the construction industry is a "building which is designed, planned, built, operated, maintained and deconstructed in a manner consistent with circular economy principles" (Pomponi & Moncaster, 2017, p. 711). It is especially important to take the end-of-life (deconstruction) of buildings into consideration, since this phase is accountable for 50% of the total waste generation (Kibert, 2008). According to Leising et al. (2018) a shift in material and component ownership is an opportunity to close the material loops in the industry. The combination of "material banks" and "material passports" will contribute to reduction in waste, because of the temporary stock of materials in buildings (Benachio et al. 2020). Swift et al. (2017) states that new techniques like BIM are important for this transition. Another aspect is that data can be collected and saved, which helps manage the "material databank" over its life cycle. Which leads to financial opportunities, as the graph of shows, the value of building materials is increasing over time, this is predicted by Drees&Sommer (2020) (figure 2.2).

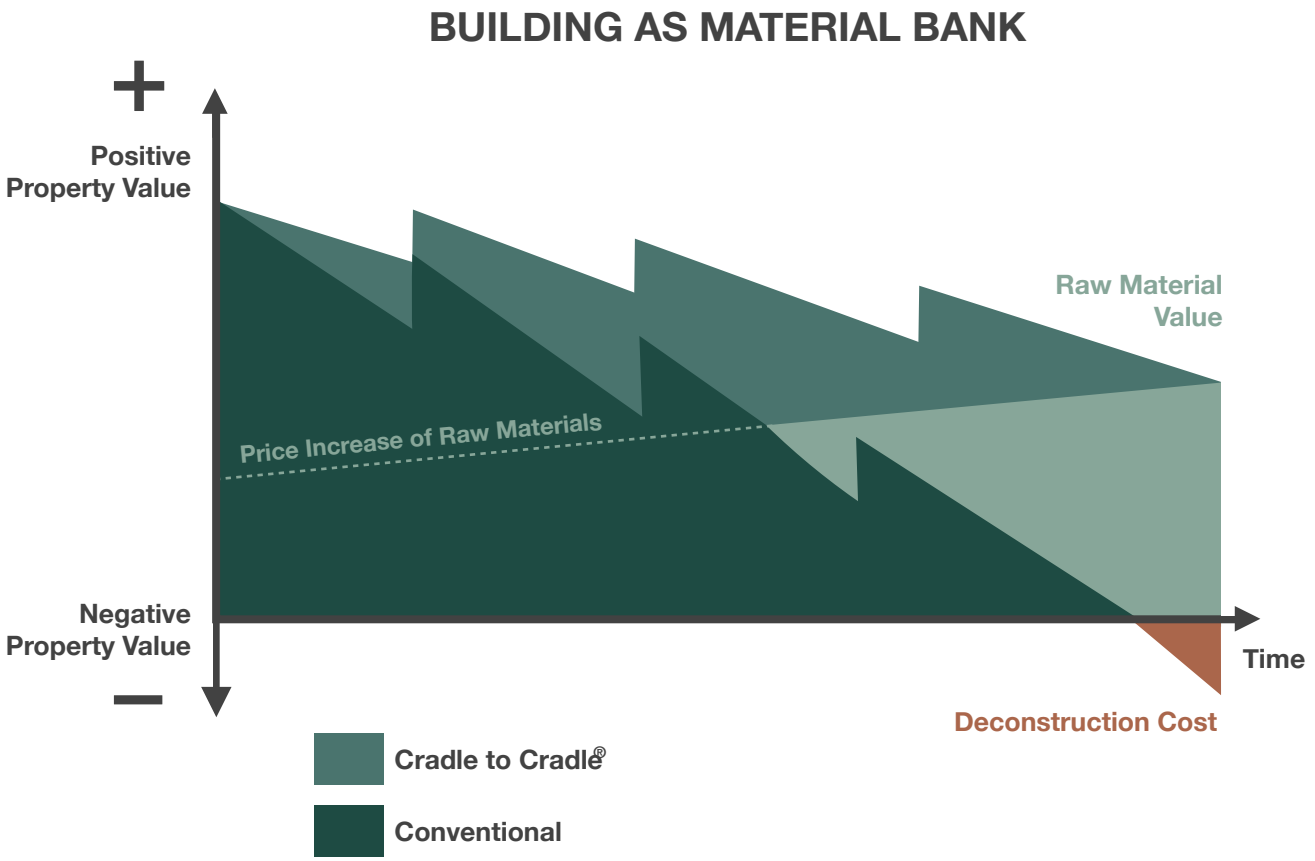


Figure 2.2: Buildings as material banks (Drees&Sommer, 2020)

Benachio et al. (2020) also defined the different stages of a circular construction project, which are: "project design, material manufacture, construction, operation and end-of-life". Adams et al. (2017) states that standard practices are missing for the implementation of circular concepts in the construction industry. Besides that the implementation of circularity is a slow process, because stakeholders don't understand the application of circular aspects in the construction sector (Adams et al., 2017). Some of the reasons for this lack of knowledge are a complex supply chain, short-term company goals and little attention for end-of-life (Eberhardt et al. 2019). To stimulate a better transition, the concepts of the circular economy should be taken into account in the early phases of a project (Benachio et al., 2020). According to Joensuu (2020), cross-discipline interaction, knowledge sharing, network platforms will benefit the circular economy in the construction industry. Additionally, the Ellen MacArthur (2020) foundation addresses the need for new business models that add value for circular construction projects.

2.2.3 Conclusion of the Circular Economy

Closing material loop, using renewable energy and applying system thinking are the elements which will lead to a circular economy. In which the focus is on generating the highest possible economic value and the smallest environmental and social damage. Governments have to play a major role towards circularity and provide incentives to stimulate it. Characteristics which will lead to a better implementation of circularity in the construction industry are: the need for more standardised practices, integrate circular concepts (such as the end-of-life) in an early phase of the project life-cycle, building as a material bank, cross-discipline interaction, knowledge sharing and the need for a shift in material and component ownership.

2.3 PRODUCT-SERVICE SYSTEMS

This shift in ownership, where the producer is the legal owner of the product and provides services accordingly, is a trend which contributes to a circular economy (Baines, 2007). In our globalised world, companies transform to service-oriented business models to stay ahead of competition (Buschmeyer et al., 2016). Product-service systems is a growing concept in literature, because it combines "sustainable resource management" and economic growth (Reim et al.,2014). Product-Service Systems is a framework which enables the reduction of waste (Joensuu et al., 2020). Also institutions as the UN and the EU see the potential of product-service systems as a new business model, towards a circular economy (UN, 2015). Tukker (2004), describes a product-service system as:

> *"Tangible products and intangible services designed and combined so that they jointly are capable of fulfilling specific customer needs" (Tukker, 2004, p. 1)*

Tukker (2004) characterised three different types of services. Firstly the product-oriented services, which are mainly focused on a product with some extra service futures. Secondly, use-oriented services, the product still has a central role, however the provider stays the owner, and the product can be shared with different consumers. Finally, result-oriented services, there is no product involved and the provider is focused on a result for the consumer. However, Ostaeyen (2013) revised this typology based on the following aspects, performance orientation and the level of integration between the different product-service types (figure 2.3). This integration level is defined as the amount of combined product-service system elements (segregated, semi-integrated & integrated). He divided the use-oriented services into two sub-groups: availability- and usage- based, and he divided the result-oriented services into: solution-,

effect, and demand- oriented types (figure 2.4.). The level of performance orientations gives a complete distinction of performance groups, which will align with the demand of client and consumer.

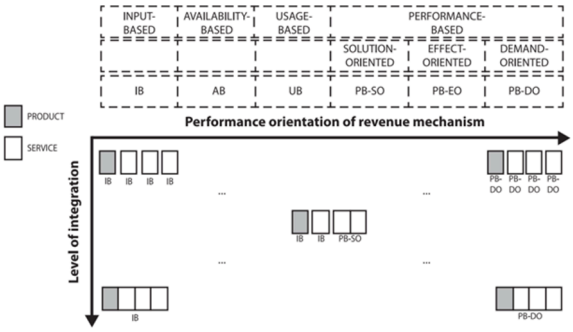


Figure 2.3: Level of integration vs. Performance orientation (Ostaeyen, 2013)

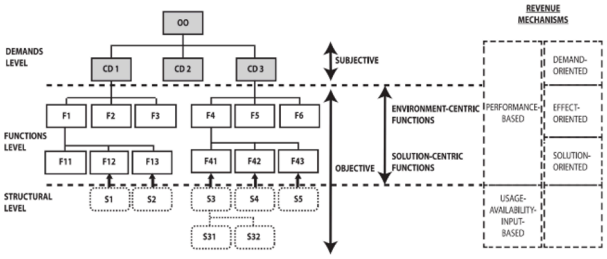


Figure 2.4: Level of performance orientation (Ostaeyen, 2013)

Input-based products are the least sustainable, the more one goes towards demand-oriented services the more potential for sustainable impact (Ostaeyen, 2013). For the reason that the revenue streams of the providers will disjoint from material goods, also the provider has more freedom for new incentives to meet consumer/client demand. In Ostaeyen's typology the most sustainable is a service which is fully-integrated and performance-based.

The main characteristic of product-service systems is the shift in legal ownership, which benefits sustainability. However, this can also lead to consumer carelessness, since it's not their product, this could be an unwanted side effect. This shift in legal ownership also means a shift in responsibility (Demyttenaere et al., 2016). Etzioni (1991), therefore makes a distinction in symbolic (mind) and legal (real) ownership. A consumer will take better care of a product when it is legally his or when he thinks the product is his. Pierce et al. (2002) states that this mental ownership can be accomplished by; controlling-, intimately knowing- and self-investing the object. Another reason for carelessness is that different consumers may have a different level of attachment towards a product (Schifferstein et al. (2008). If a consumer feels more attached to a product, because of an emotional bond it will postpone the replacement, which promotes sustainability (Demyttenaere et al., 2016). Since the producer will be the owner of the product, it is beneficial to take the end-of-life and maintenance into the design process. For this reason the concept of product-service systems will contribute towards the circular economy. In Appendix 2, Moro et al. (2020) indicates, with his literature review, the barriers and benefits of product-service systems. The most important barriers and benefits are shown in table 2.1, they are divided in internal and external aspects.

Where internal aspects refer to the design, economics and operations of the product/company. The external aspects refer to the social, environmental and customer effects of the product.

Table 2.1: Benefits and boundaries for implementing product-service systems (own figure)

Internal benefits	External benefits	Internal barriers	External Barriers
Customer loyalty	Shift in ownership and responsibilities	Lack of experience, information and knowledge	Rebound effect
Competitive advantage	Reduction of costs	High risk	Lack of legal support
Efficient use of products and equipment	Customized solutions	Long term contract	Cultural acceptance
Constant cash flow (seasonality elimination)	Reducing environmental impact and waste reduction	Organisational change is needed	
	Dematerialization	Careless use	
	Stimulates innovation	High initial investment	

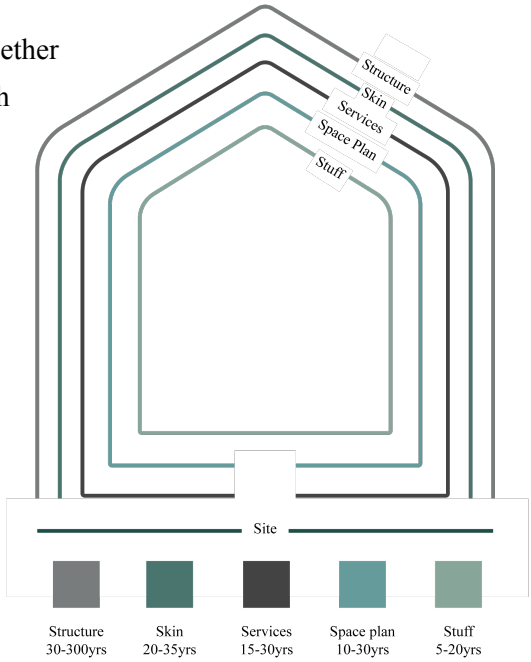
2.3.1 Conclusion of product-service systems

Product-service systems provide an integrated solution of services and products to customer demand. The provider stays the owner of the product and the consumer only uses the product. This means a shift in legal ownership and responsibility. This theory stimulates sustainability, because the producer is responsible in all life-cycle phases, including the end-of-life. Products will be (re)used more efficiently and become adaptive to changing demand. This will result in a decrease of the depletion of earth's resources. This business model combines sustainability and economic growth. The revised typology of Ostaeyen (2013) stimulates the integration and performance orientation of product-service systems. With a higher level of integration and performance orientation, the product-service system has a higher possibility of being sustainable.

2.4 CONSTRUCTION PROJECT ORGANISATION

A construction project organisation consists of stakeholders, who together have to find the right balance between cost, quality and time, for each individual project. This section will focus on the different aspects of a construction project organisation and the relations between the different stakeholders.

"A construction project organisation is a cooperative network of stakeholders who are involved throughout the life-cycle of a project. Where a project should be seen as the collection of interrelated components, which together form a building."



Site is the fixed location of the building
Structure is the building's skeleton including the foundation and load-bearing elements
Skin is the façade and exterior
Services are the pipes, wires, energy and heating systems
Space Plan is the solid internal fit-out including walls and floors
Stuff is the rest of the internet fit our including the furniture, lighting and ICT.

Figure 2.5: Building in layers (Brand, 1994)

In traditional construction projects the clients are primarily concerned about the cost, time and quality of a project, and procurement is focused on the lowest price (Bennet et al, 1990). Currently, more often clients ask for sustainable solutions, like the reduction of CO2. According to Tan et al. (2010), sustainable procurement results in competitive advantage and the reduction of environmental impacts. However, so far the investment is higher for the client, because he has to award sustainable solutions. The build environment is a product-based industry, which is mainly driven by the incentive of clients (Vrijhoef, 2011). A product-based industry is focused on one-of-a-kind processes, one of the reasons is the design approach which is unique for every project. Another aspect that contributes to this uniqueness, is that it is depending on local conditions, such as weather and soil conditions. The construction industry is highly fragmented due to controversial goals and objectives of the different stakeholders involved (Turin, 2003).

Product-service systems provide a mixture between products and services, therefore it is important to have a good understanding of the demarcation of different components of a building. Building in layers could provide a characterisation of these building components and a systematic approach. In 1994 Stewart Brand developed the concept of "Building in layers". His theory defines different layers, which are interlinked and separated, based on their lifespan. The layers of a building are: "site, structure, skin, services, space plan and stuff", shown and explained in figure 2.5. This allows elements with a long lifespan to stay, while elements with a shorter lifespan can be adapted, replaced or repaired, without

interfering with other layers. This concept contributes to the decrease of waste and resource depletion. At the same time these buildings are easier to adjust for new purposes, so the demolition can be postponed (Ellen MacArthur Foundation, 2020). NL-SfB divided a building in different components, which can be allocated to the layers of Brand's model (appendix 1). The transition towards integrated product-service systems, will result in fundamental changes in organisations (Buschmeyer et al., 2016) and they will need to change their structures and partner networks (Nussholz, 2017).

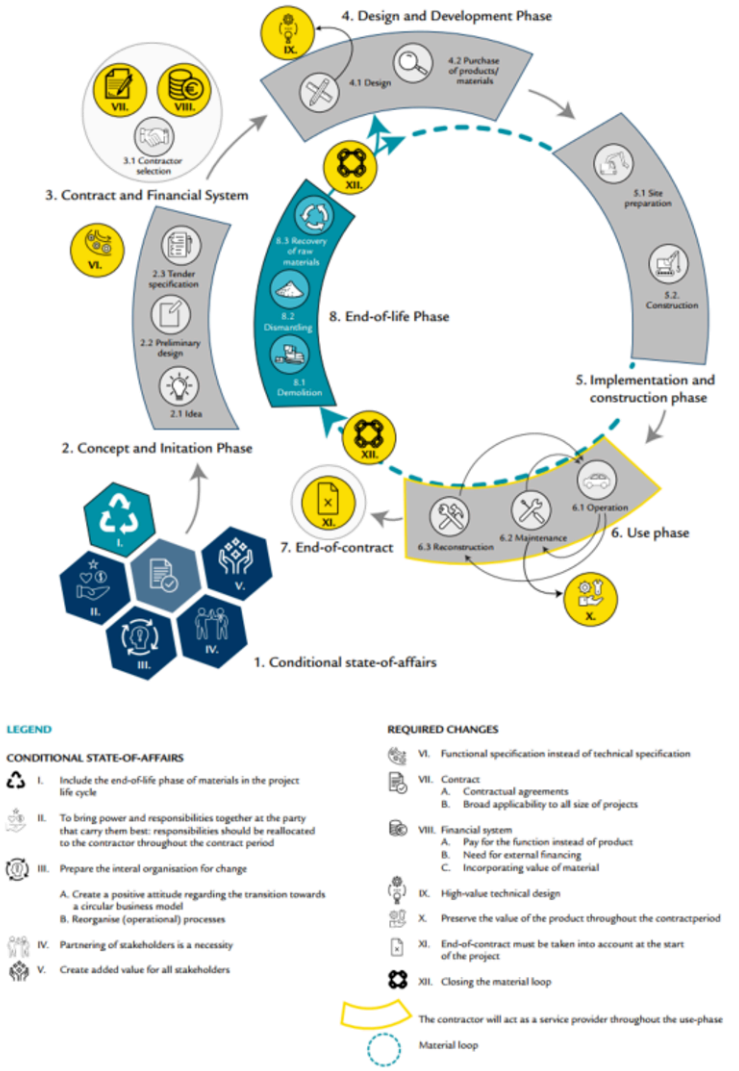


Figure 2.6: Project life-cycle (Huizing, 2018)

A construction project consists of different phases, Huizing (2019) designed a life-cycle for construction projects Figure 2.6. This life-cycle takes the concepts of product-service systems and circular economy into consideration. The different phases that Huizing identified are: Concept and Initiation, Contract and Finance, Design and Development, Implementation and construction, Use, End-of-contract and End-of-life phase. Product-service systems ask for longer cooperation (contracting) periods, including all phases of the product life-cycle. One party will be responsible for this life-cycle of a building component in return for a periodical payment. A longer contracting period will result in more interpretation freedom, which could result in more sustainable solutions.

2.4.1 Stakeholders of a construction project organisation

Product-service systems organise the relations between stakeholders in a different way and provide a mix of products and services. This section will show the current situation between different stakeholders of a construction project organisation. While most of the time one party is the owner of a building (client), on the supply side different parties are involved throughout a project, with changing objectives, responsibilities, demands, interests and needs over time. Projects exist of stakeholder networks, which are

interlinked with each other. A construction project organisation consists of internal- and external-stakeholders. Internal stakeholders have influence on the project and have an interest in its succession. External stakeholders are affected by the project, but have no influence or control (Jergeas et al., 2000). The building industry is fragmented because of its (unique) project-based approach, different sectors, disciplines and businesses are involved in the process.

Buildings are investments and therefore the client has a big influence on the demand side of a project, this causes a short-term mindset in the whole project organisation (Wamelink, 1998). Although the ownership of a project is in the hands of one party, there are multiple stakeholders with demands on the outcome of the project. On the supply side, stakeholders try to meet this demand with their products and services (Vrijhoef, 2011). The composition of stakeholders differ per project and change over the life-cycle of a project as well (O'Brien et al., 1995). This changing composition, in combination with the low level of project repetition (compared to other industries), is causing a higher level of unpredictability (Vrijhoef, 2011). To avoid risk main contractors usually outsource most of their work, to subcontractors which have more knowhow of a particular component. To overcome short-term personal focus and a fragmented organisation Jergeas et al. (2000) emphasises on the creation of common project goals and objectives and although the difficulties, good communication is key. The high level of fragmentation and lack of repetition, causes a low level of innovation and progress in the build environment (Vrijhoef, 2011). In addition the findings of Schraven et al. (2019) show that the implementation of the circular economy is difficult in the supply chain. Because of different goals, low incentive for circularity, high risks and different perceptions. Due to these causes and many stakeholders in the supply chain, problems occur easily (Vrijhoef, 1998), between different actors (figure 2.7.).

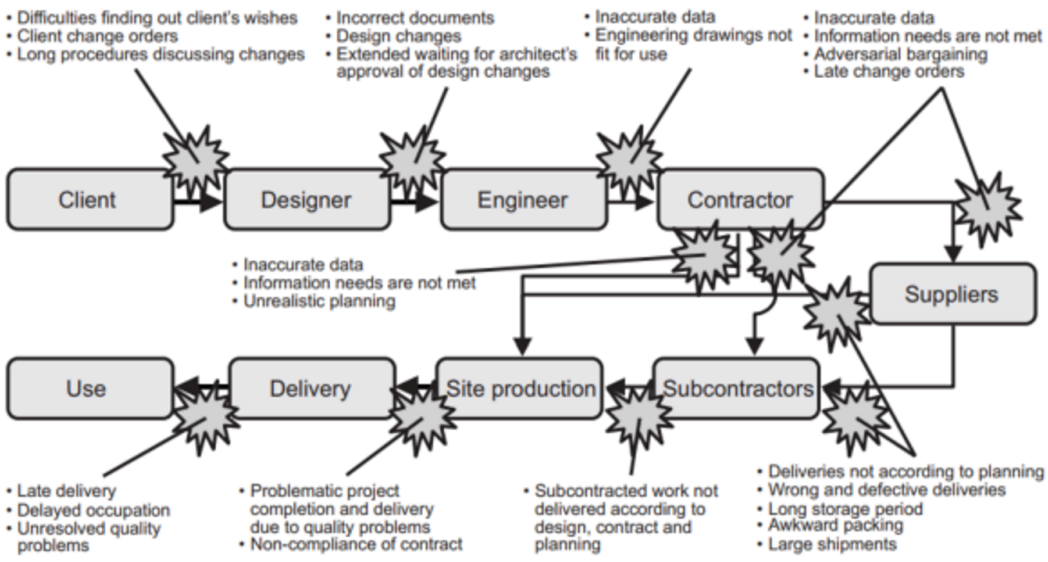


Figure 2.7: Problems progressing through the building supply chain (Vrijhoef, 1998)

As Klein (2013) indicates different stakeholders are sporadically involved during the whole life-cycle of a project, which causes fragmentation. His research focuses on facades, and illustrates (Figure 2.8.) this process for just that component. This research is relevant because it can function as an example for all components who together form a building. This means that the more components a building consists of, the more complex the interactions become. According to this research, stakeholders prefer existing relations, therefore it is important to create trust and long term partnerships. Figure 2.9. Shows the relations between different stakeholders involved in the process of a facade. An investor prefers one actor to deal with, because he wants to focus on his core business. The engineer and architect determine the primary design and integrate the different components. However he notes that it is strange that architects decide about almost all components while they don't have detailed knowledge and knowhow. Also the facility manager is not involved in the early phases, which could be beneficial. His most important finding is that most system suppliers are mainly involved early in the process, which makes information sharing hard. To overcome this problem a more integrated approach and other partner networks are needed for the implementation of product-service systems.

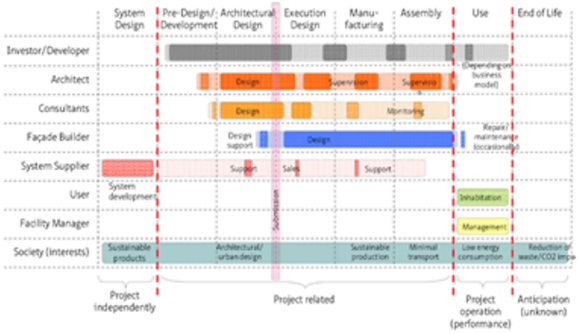


Figure 2.8: Involvement of stakeholders in the different phases of the façade design and construction phase (Klein, 2013)

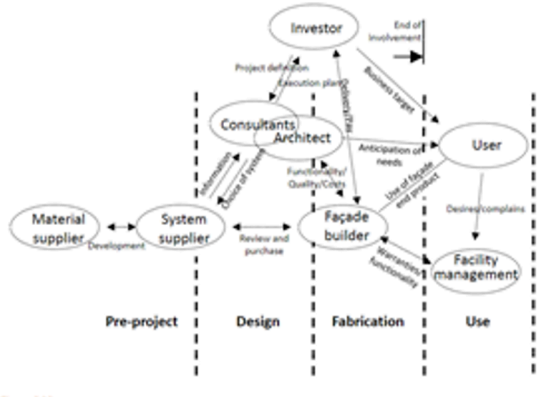


Figure 2.9: Scheme of the relationships of stakeholders (Klein, 2013)

While contractors are more willing to execute integrated projects with their client, they lack integration with their subcontractors and suppliers (Bygballe et al.,2010). This lack of integration is due to mistrust and different goals and objectives from the contractor towards the supplying parties (Vrijhoef, 2011). However more integration in the supply chain will lead to effective-, efficient- solutions, commercial successes and better product quality (Vrijhoef, 2011). Sharing information and open communication will lead to more trust in a construction project organisation. As mentioned before, to promote innovation and circularity, suppliers (experts) should be involved early in the project (Benachio et al., 2020). There is more room for innovation lower in the supply chain, because of expert knowledge (Bygballe et al., 2010).

As Benacchio et al. (2020) indicated a shift in ownership and responsibilities, from the client to the supplier, will result in more innovation as well.

2.4.2 Conclusion of construction project organisations

The change towards product-service systems will result in new organisational structures and partner networks. A construction project organisation is a cooperative network of stakeholders who are involved during the whole life-cycle of a project. Where a project should be seen as the collection of interrelated components, which together form a building. In the build environment, projects are “one of a kind”, however the theory building in layers, shows the different components which are the same for every project. This theory allows components with a long lifespan to stay, while elements with a shorter lifespan can be adapted, replaced or repaired.

A project consists of partner networks, which are interlinked with each other. Different stakeholders have their own objectives, responsibilities, demands, interests and needs over time. The composition of stakeholders differs over the life-cycle of a project. Integration, common goals and perceptions, information sharing and open communication will lead to a better end-result. To promote innovation and circularity, expert knowledge has to be involved early in the project. A shift in ownership and responsibilities, from client to supplier, could be beneficial.

2.5 PROJECT VALUE

As the definition of the circular economy (used for this research) states, the circular economy should benefit society, environment and businesses (Ellen MacArthur Foundation, 2015). Also product-service systems, as a business model, pursues this ideology. Value is no longer only related to finance alone, in 1997 Elkington introduced his theory, the triple bottom line (Figure 2.10.). He argues that added value should not only be focused on finance alone, and that sustainability should not primarily focus on the environment. Added value should be a balance between, planet, people and profit. As already stated before the environmental (planet) aspect in this theory focuses on the use reduction of resources and creating a future proof world. The social aspect (people) of the triple bottom line argues that a business should give back to its community, it is the social indicator between an organisation and community related issues, the increase of quality of life (Goel, 2010). The economic aspect (profit) is focusing on

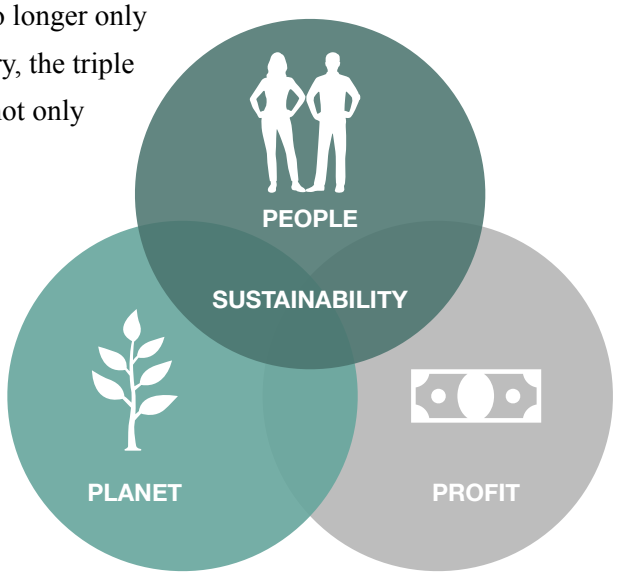


Figure 2.10: Sustainability; people, planet and profit

financial growth of an organisation, and how the organisation contributes to the surrounding system (Spangenberg, 2005). Unfortunately big companies are still mainly focused on increasing financial value, and less on the other aspects. For this reason solutions are needed which are increasing environmental and social value, which are financially more interesting (Alhaddi, 2015), product-service systems could provide this solution.

2.6 CONCLUSION

This chapter showed that there is a need for change towards the circular economy and helped establish the theoretical framework (figure 2.11.). For this research product-service system is chosen to be the business model who could facilitate this change. Product-service systems integrates products and services to meet customer demand, and is able to reduce environmental impact. With a higher level of service-orientation, the opportunities for circularity increases. Construction project organisations could be an important vehicle to promote and implement product-service systems and the circular economy within the built environment. A construction project organisation is a cooperative network of different stakeholders who are involved throughout the life-cycle of a project. Where a project should be seen as the collection of interrelated components, which together form a building. Aspects of the current construction project organisations that are influenced by the circular economy are the building components, project life-cycle phases and stakeholders. While most literature concerning the circular economy and product-service systems is about the first two aspects, there is little about stakeholder interaction and collaboration. Literature refers to the need of changing partner networks, different interactions and standardised processes to be able to implement product-service systems and increase project value. This chapter showed the research gap in the scientific domain and will be the point of departure for this empirical study.

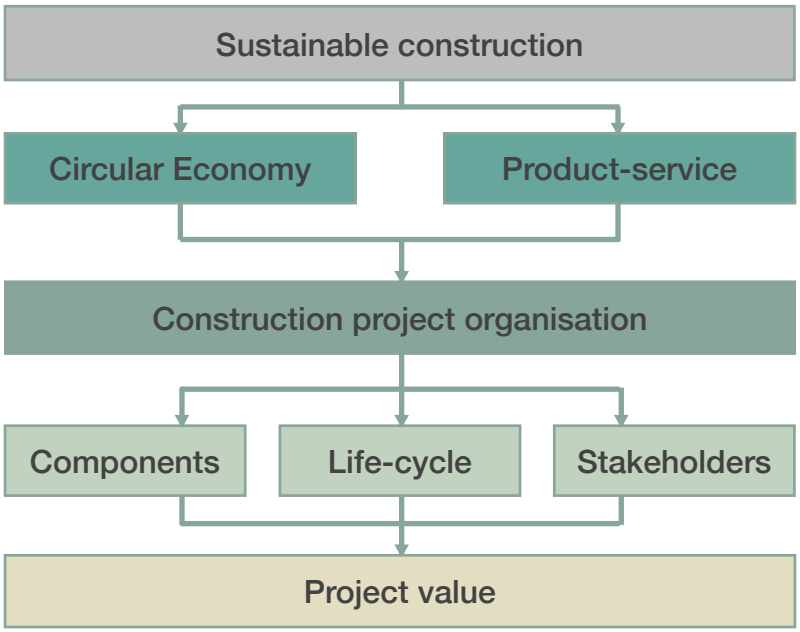


Figure 2.11: Theoretical framework

3. METHODOLOGY

This chapter will explain the method used for this research. The theoretical framework of the previous chapter gave a better understanding of the scientific problem, which will be used as a starting point for this empirical research. First, the characteristics of a design-based research will be described and explain why it fits this research best. Secondly, the double diamond method will provide guidance through the process of defining the practical problem and providing possible solutions for a restructured stakeholder network. The process of each phase will be explained and finally a conclusion with a summarising graph (Figure 3.2.) will be presented. This section will answer the second sub-question: How to gather and analyse the aspects of construction project organisations for the implement product-service systems?

3.1 DESIGN-BASED RESEARCH

According to Reeves (2006), the approach of a design-based research consists of four iterative phases: collaboration between practitioners and researchers to analyse a practical problem, develop a solution which consists of technical innovations and existing design principles, persistent cycles of refinement and testing, and reflection to produce and implement the design principles. This approach is designed to implement innovation, which changes the way of working in practice. The aim is to gain insights through a desk study and semi structured interviews for the application of product-service systems within the built environment.

> *"Design Thinking is understood as a way of thinking which leads to transformation, evolution and innovation, to new forms of living and to new ways of managing business" (Tschimmel, 2012, p. 1)*

A design-based research consists of three phases: defining the problem, designing a solution, and evaluating. Within this process the different phases interact with each other (Levina et al., 2009). This interaction gives the design-based research a creative and open character. To accomplish this approach, Anderson (2012) suggests to involve the following components: design-based research is at its best in an educational environment, because it provides legitimacy and the findings can be used to inform and improve the practice. The use of different methods and techniques is advised where the focus should be on the design and testing of an intervention. Design-based research requires multiple repetitions, however this makes it difficult to know when a research is complete, since there is always room for improvement. The collaboration between practice and theory is the most important aspect of a design-based research. Finally the validation and implementation of the developed design principle in the real-life situation, is

an ongoing process and is key for a design-based research. This theory also has some negative aspects which one should take into account. Since the researcher is involved in all phases of the principle, there is a possibility that they will lose objectivity and develop a certain bias for the subject (Barab, 2004).

A design-based research is chosen, because of the six characteristics best described by Wang and Hannafin (2005): “pragmatic, grounded, interactive, iterate, flexible and contextual”. This method solves real world problems, fills the gap between theory and practice (Wang & Hannafin, 2005). This design-based research will contribute to a practical implementation of product-service systems theory in construction project organisations. It promotes organisations to manage business in a new way (Tschimmel, 2012).

3.2 DOUBLE DIAMOND METHOD

According to Tschimmel (2012), the double diamond method is the most complete method, when compared to other design thinking methods (figure 3.1.).

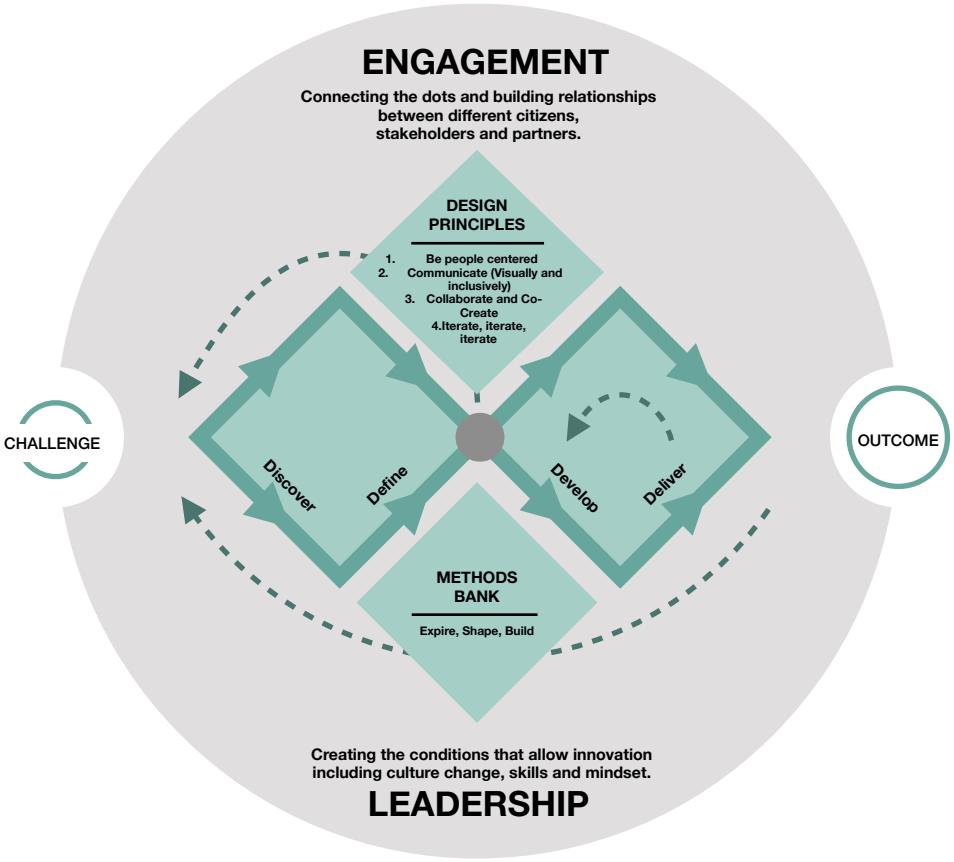


Figure 3.1: Double diamond method (Design council, 2019)

This is because it takes both the theoretical and practical aspects of research into consideration (Tschimmel, 2012). The double diamond method was designed by the British Design Council in 2004 and redefined in 2019, because of new insights (design council, 2019). The framework includes principles and methods that create a long lasting change. To be as effective as possible the design council indicates four characteristics: put people first, visualise, collaborate, and iterate. The process of the double diamond method consists of four parts: discover, define, develop, and deliver.

The double diamond method is known for its diverging and converging phase per diamond. Diverging to get broader insights or ideas and converging to analyse the data, draw conclusions and validation. The first diamond consists of two phases, discover and define, to get a better understanding of the practical problem. The second diamond will develop and deliver a model with solutions for this problem. This is a dynamic process, where information and findings interact between the different phases. This section will further elaborate on these four steps of the double diamond method, which are the backbone of this report.

3.2.1 Discover

This phase gives a better understanding of the problem and will deliver practical data relevant to the subject (Design council, 2019). This phase is characterised by primary research (Reeves, 2006), semi-structured interviews were conducted among different experts in the field (table 3.1.). How the semi-structured interviews were structured and conducted will be explained in section 3.3.

Table 3.1: Interviewees for the problem definition

Interview	Role	Description
1	Project Manager	Sustainability expert at Drees&Sommer, master on the subject of the circular economy and sees product-service systems as a possible solution for the sustainable demand.
2	Contractor	Head sustainability at a big Dutch contractor, responsible for eight pilots of product-as-a-service projects.
3	Supplier	Providing kitchen-as-a-service, awarded as the most circular start-up in 2020.
4	Project Developer	Responsible for project development, master on the subject of product-service systems and block chain.

Four semi-structured interviews provided a better understanding of the difficulties for construction project organisations to implement product-service systems. The experts were familiar with the concept of product-service systems. A contractor, project manager, project developer, and supplier were interviewed, to highlight the problem from different angles within a construction project organisation. A Stakeholder network consists of multiple actors, who all have other needs and goals. The diversity of actors gives a broader understanding of the practical problems.

The interviews were structured according to a presentation (appendix 3). The summaries of the interviews are shown in appendix 3. The interviews were focused on the problem, however the interviewer didn't interrupt when the interviewee came up with solutions. These solutions were taken into account in the ideation phase. The actors have different perspectives, due to their role/position in the construction project

organisation. So the gathered data is saturated when multiple interviewees are addressing the same problems, and giving overlapping answers.

3.2.2 Define

The definition phase analyses and converges the collected data of the previous phase. This phase will clearly define why current construction project organisations have difficulties with the implementation of product-service systems. The gathered information will be filtered according to the relevance for this research. The interviewees are all experts in their role within the network, sometimes they went into technical details, which is not relevant for the problem definition. The collected data is ordered in different categories which came up during the interviews. The focus of these categories is on the collaboration and interaction between the different stakeholders. The defined problem will be the point of departure for the ideation phase.

3.2.3 Develop

This phase will generate ideas (British Design Council, 2019) for the implementation of product-service systems in construction project organisations. The double diamond method is an iterative process, and so, ideas come up in all other phases. These ideas have been processed in this section. Other scholars also gave suggestions on how circularity and product-service systems could work in a more effective and efficient way. Possible solutions were suggested in the theoretical framework. These suggestions will be taken into consideration during the ideation of the author.

After problem definition, the author started an ideation for possible solutions. The ideation was based on the theoretical framework, combining theories from literature, interviews of the problem definition and own creativity. The ideas were visualised and put into a restructured stakeholder network. Due to this ideation, the author was able to push the interviews into a certain direction focusing on new partner networks. The interviews were more like a conversation about the possible solutions. The ideas were visualised and presented to two experts from the field, who were not familiar with this research or product-service systems. This will prevent the actors from bias for their own problems. The presentation was similar to a conversation, where new ideas are thought of along the way (appendix 4).

The two interviewees (table 3.2.) are both project managers who are responsible during the whole project life-cycle. They are familiar with the current actors within the construction project organisation. They provided new insights and ideas, which have been adopted into the restructured stakeholder network. Unfortunately these interviews had to be conducted online due to covid-19, this disrupted the creative process. Although the interviews were online they gave some relevant results.

Table 3.2: Interviewees for the needed changes

Interview	Role	Description
5	Project Manager	Senior project manager at Drees&Sommer, focused on sustainable innovation and operational excellence, main expertise on asset management.
6	Project Manager	Project leader at Drees&Sommer in infrastructure, who is focused on innovation, circularity and digitized processes.

3.2.4 Deliver

One validation interview will contribute to the feasibility and usefulness of the restructured stakeholder network. The interviewee was not involved in the research before. This is important to prevent bias towards the developed solutions in the previous phase. First, product-service systems were explained, then the different ideas and the restructured stakeholder network were presented. This was an iterative process where questions went back and forth. The interviewer asked about the feasibility of some elements and the interviewee asked questions if he didn't understand the solutions.

During the conversation different new ideas came up, which are implemented into the final stakeholder network which facilitates the implementation of product-service systems. This meeting was conducted in real life, which created a creative atmosphere. The presented concepts were also presented on paper, which gave the opportunity to put new ideas directly into the model.

3.3 SEMI-STRUCTURED INTERVIEWS

A semi-structured interview is a conversation with one interviewee, both closed and open questions can be asked, and followed up with how-or-why questions (Adams, 2015). Discussion points are not fixed and stimulate a flexible interview, focusing on the knowledge of the expert. The interviews will be 60 minutes maximum and they will be recorded, so that the interviewer can focus on the conversation, visualisation and subject. Afterwards a summary of the interview will be sent to the participant for confirmation on legitimacy (appendix 3).

Due to covid-19 the conducted interviews were all digital, this gave the option to record and later summarise the interviews. So that the interviewee could fully focus on the conversation with the different stakeholders. A presentation with different visualisations gave the interviewees a better understanding of the different aspects of the subject.

First both the interviewee and interviewer will introduce themselves, then the background information was presented to give the interviewee an understanding of the subject and it's different aspects, such as product-service systems, circular economy and construction project organisation. The focus will mainly be on the construction project organisation because all interviewees will know the concepts of circular economy and product-service systems. Then the focus of the interview will be explained, to push the interviewee in the right direction. The questions are divided into three subjects: general, ownership and collaboration. After the interview the interviewee is asked for a top three of difficulties concerning the implementation of product-service systems into the construction project organisation. Finally he is asked about his future perspective concerning this subject. The interview protocol can be found in appendix 3&4, as well as the presentation used during the interview.

3.4 SUMMARY

This chapter gave answers to the second sub-question: How to gather and analyse the aspects of construction project organisations for the implement product-service systems? It elaborated on the methodology of this design-based research, which is summarised in figure 3.2. The different phases of the double diamond method will provide guidance to this study. Experts were interviewed in the discovery phase, they gave a better understanding of the difficulties for construction project organisations to implement product-service systems. Semi-structured interviews were conducted with the guidance of an interview protocol. According to the knowledge of the expert, the interviewer was dwelling on some of the questions, to get more relevant data. The second phase clearly defined the current problem definition. The third phase restructured the stakeholder network of a construction project organisation with the help of two interviewees. Lastly one validation interview contributed to the feasibility and usefulness of the model and new insights will be implemented accordingly. The restructured stakeholder network will be discussed in chapter 5 with feedback from literature. The conclusion will give an answer to the research question.

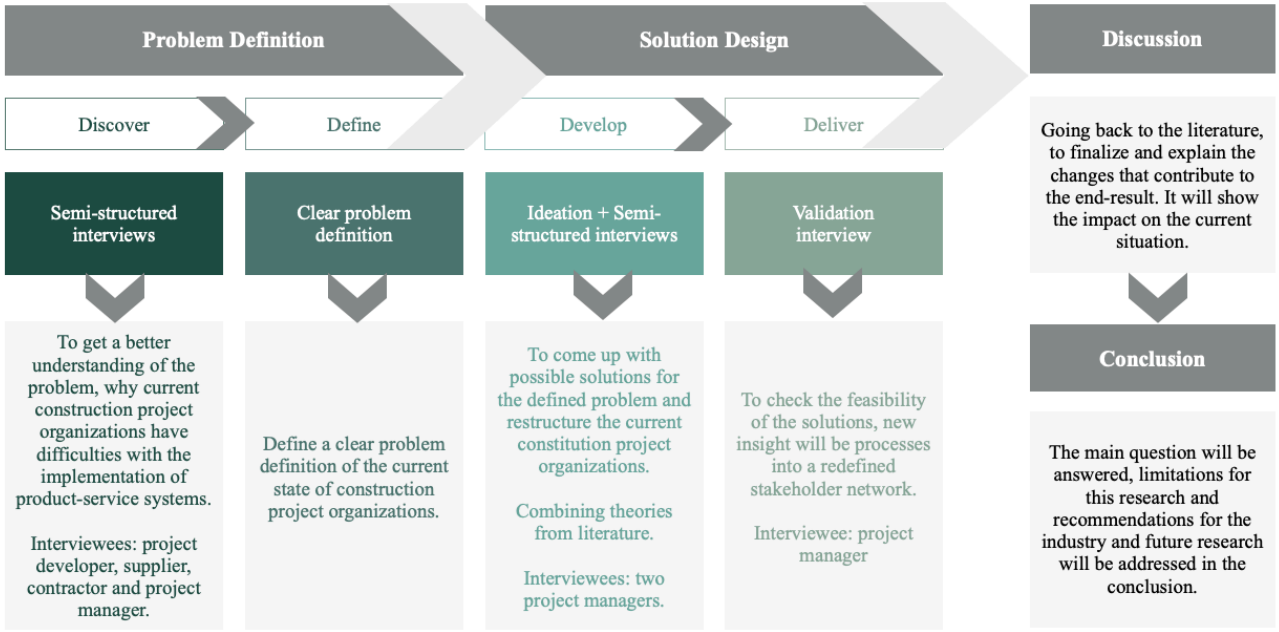


Figure 3.2 Methodology of design-based research

4. DATA AND ANALYSIS

The theoretical framework gave the research gap in the scientific domain and will be the point of departure for this empirical study, which is addressed in this chapter. The four phases of the double diamond method will provide structure. First four semi-structured interviews were conducted, according to the interview protocol. These interviews gave a better understanding of the practical problem, why construction project organisations have difficulties with the implementation of product-service systems. Secondly, a clear problem definition was defined. Thirdly, needed changes and a restructured stakeholder network was developed according to an ideation of the author and two semi-structured interviews, which gave possible solutions for the practical problem. Finally, the model was validated with one interviewee, to check the feasibility and new insights were implemented in the final model (figure 4.1). This chapter will answer the third sub-question: What changes are needed to apply Product-Service Systems and add value within construction project organisations?

Figure 4.1: Process of data and analysis

4.1. DISCOVER

This section will give a deeper understanding of the practical problem, why current construction project organisations have difficulties with the implementation of product-service systems. To get different viewpoints and perspectives, different actors of a stakeholder network in a construction project organisation were interviewed. The interviewees where, a contractor, project manager, supplier and project developer, they all knew or worked with the concept of product-service systems. The interviews were semi-structured, so that we could go deeper into a particular question, when the experts knowledge allowed that. The conducted interviews were 60 minutes long and all digital, this gave the option to record and later summarise the interviews. This section is known for its diverging character, all data gathered from the interviews is shown in table 4.1. The table shows the nine subjects that were addressed during the interviews, the numbers refer to the interviewee.

Table 4.1: Interview outcomes problem definition

General	All interviewees were very positive about this new concept within the built environment, however it has to be said that they see a lot of obstacles which have to be taken. Also it is a concept where just a few people are familiar with, it is a business model with many unknowns (2). A very interesting insight which all interviewees mentioned is that the linear model is a good business model, by which many companies make good money. They are not willing to shift and will just wait until they can implement this model, when others have figured everything out, and regulations are changed. Competence is one of the main difficulties (2&4), because stakeholders don't have the right knowledge in house. Legislations make this new model hard to implement. Actors are scared to lose work, so why would someone provide a product, which extends the guarantee period (2). One of the interviewees indicated that this business model could work for some components (4), but definitely not for all. More standardized processes, but also components to make product-service systems work (4). The short term mindset most actors have makes it hard to implement (2&#). A change, big as this one needs time and small steps to make it work (2). For now it is hard to tell if product-service systems contribute to circularity, they need more time to prove this (2). But all interviewees are confident that it will work and that it will benefit the environment and business in the future. Adopting now to this new model will give competitive advantage in the future (1&3).
Incentive	At the moment the incentive for product-service systems is bottom-up (2), mainly suppliers see the opportunity in this new business model. They see it as a solution for the growing demand for sustainability and circularity, which is asked at the top (1&2). It is a difficult process to convince this top of the opportunities, because they are not familiar with the possibilities of product-service systems (1). In the companies there is a huge generation gap, they see a growing awareness with the younger generation (1). But, the older generation on top are more conservative and are in the end the ones who make the decisions (1). So, incentive in the industry but also in the companies comes bottom-up.

Clients and ownership	If clients are aware of the possibilities of product-service systems, they are financially interested (2,3&4). Due to the periodic payment and low investment cost, they will be able to focus on their core business (3). Because they will be unburdened, all responsibilities are with the suppliers (2&3). It smooths out dips and tops, however the client wants to be flexible and on the other hand do funders want security (1). There is a need for a good balance between short and long term (4). This model is only interesting if the costs are lower than the current models (4). Clients need to know how they ask performance orientated- instead of function questions (3). A huge issue is that one is not able to measure circularity yet, like sustainability, once this is possible it will be more financially interesting (2). One of the interviewees showed that one should divide client ownership into risk, legal and financial ownership (2). It is depending per project what aspects are more relevant. Public parties are mainly concerned about the risks for their citizens, how to keep control when you give the ownership to a private party (2). Also why are clients not able to benefit from the new model? There is a lot unknown, and rules have to be made to make this work (2).
Suppliers and ownership	Suppliers will get a higher investment cost, however the periodic payment is interesting for the same reason as indicated above (3). Most of the time the incentive comes from the suppliers(3). They don't collaborate with each other, all suppliers are scared to lose work, when working together with others. Due to information sharing and mistrust, therefore innovation goes slow (2&3). They see it as a possible answer to the sustainable demand on top, however there is a lot of work to do to convince the deciding top in the chain (2&4).
Contractors and ownership	Currently contractors have two business models, or they own assets or they manage the project(2). Most of the time they do the latter, they unburden the client, construct the project and go on to the next one. There will always be the need for one party who brings together all the different components and stakeholders. But due to new techniques and ideas the role of a contractor is under pressure(2). They are still very traditional and their business model is making them money. Owning the asset is only interesting if they also own the material producer, like a concrete supplier. If not the incentive to reuse materials is low and financially unattractive (2). Also they are scared that it will look more like a DBFMO, which was not that beneficial over the last few years for contractors(1&2).

Collaboration	Concerning the concept of product-service systems, there is no collaboration between different actors (2&3). This is due to mistrust, they are not willing to share information, because they are scared to lose work. Every actor is working on their own product and although they have preferred partnerships, however they will go for the lowest price(1&4). All interviewees think that in the future, the actors will start working together. There is a lack of common goals within the industry and they miss a driving force who is enabling and promoting product-service systems(4). The construction industry is super fragmented overall, but for new ideas like product-service systems it is even more fragmented (2). There is not one party who is promoting the concept throughout the process and between the different stakeholders. While clients are not familiar with the possibilities, suppliers are not ready to take over the responsibilities to provide a whole integrated performance package (4).
Integration	Overall there is more integration in the construction industry, due to new techniques such as BIM. Different disciplines work together in the same model, also over the different phases there is more integration. Product-service systems give a stimulus throughout the process to promote circular concepts (2). However not enough is done about the end-of-life in other phases of the project. A good example one of the interviewees gave, is a material passport, which is increasing popularity (1). So many actors are willing to deliver a material passport, however they don't think about deconstruction, so that the materials can be reused in a good way. This is due to the linear mindset actors have in this industry. At the same time actors don't really know how to incorporate the residual value of materials at the start of the project (4). Also there is a need for expanding the lifespan of a product, because in the current situation this is not beneficial and will decrease extra work (2). During construction many changes come up due to new users, in the design phase there is no flexibility. One of the interviewees indicated that it would be helpful to implement the knowledge of a facility manager already in the design phase, in general, but especially for product-service systems. Due to their service orientation(1).

Boundaries	A project can be divided in different ways like products, components or materials (PCM) (1). This makes it hard for standardized processes and components, there is a need for clear boundaries. With a higher level of integration, the boundaries between different actors and their role becomes vague (3). Who is responsible for which component and what service should they provide accordingly. Not only technical concerns came up during the interviews but also the distribution of finance, legal and management becomes vague, when talking about product-service systems. Scope has always been a difficult subject in this fragmented industry, blaming and suing each other instead of collaboration has been the way. So boundaries between components and roles are unclear, when implementing product-service systems. When implementing services boundaries are becoming even less clear, therefore do actors who want to implement this new business model have to make new rules, and create boundaries for their scope.
Short term vs. Long term	Most actors have a short term mindset, while product-service systems are asking for long term collaborations. there is a need for flexibility at the bottom and security at the top(1). There is a need in balance between short- and long term collaborations, and possibilities to stop the collaboration as well(4). Besides that different components have different lifespan, therefore actors have a different mindset as well.

4.2 DEFINE

This section will define a clear problem definition, which will be used for the ideation phase, to come up with solutions and redevelop the stakeholder network of a construction project organisation. This section will filter the gathered information from the previous phase and show the relevant data for this research. The difficulties which came out of the interviews can be divided into five categories (figure 4.2): the overarching difficulty is the unfamiliarity with the concept of product-service systems, lack of collaboration and interaction between actors, the boundaries are unclear, there is a huge contrast in short- and long-term thinking, and finally a lack of phase integration.

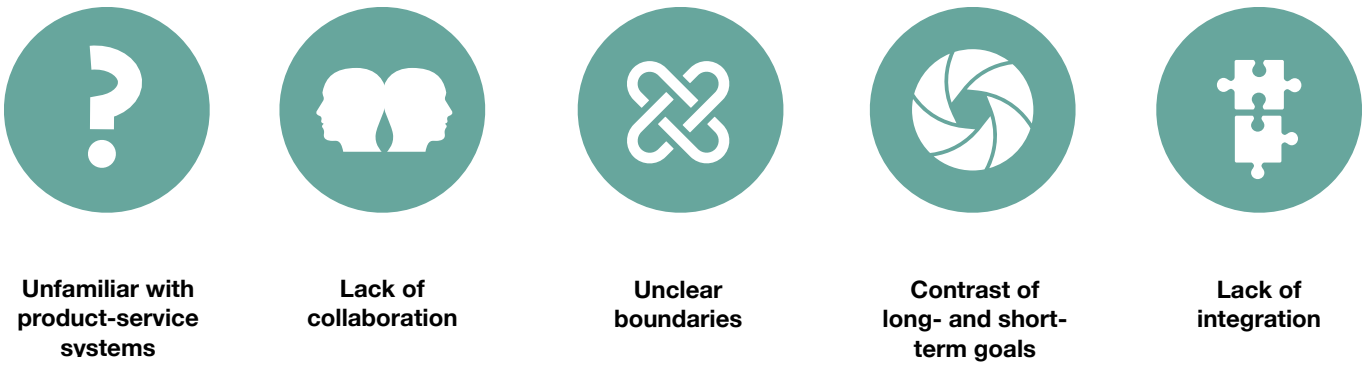


Figure 4.2: Difficulties for the implementation of product-service systems in the construction project organisation

4.2.1. Unfamiliar with product-service systems

This overarching difficulty was identified by all interviewees. Because this subject is relatively new, no one really knows how to deal with product-service systems in the built environment. Actors don't know about the possibilities and don't have the right competence for this transition (2&4). At the same time legislations are promoting the old way of working which still is financially more attractive (3). While more people are willing to change towards a circular economy, it is not measurable, like sustainability is (1). This holds back financial incentives from governments. In the supply chain the incentive for innovation and also product-services systems comes bottom-up, while the top has to decide (1). This is a slow process, because actors are not asking the right questions to each other (3).

There is much unknown about the shift in ownership, from client to supplier. As an example, one is not able to predict with certainty what the residual value of material will be in the future (4). One of the interviewees, who is working for a contractor says this could only be interesting if they have the production of materials in-house as well (2). On the other hand do clients want to profit from this new business model as well, so why hand-over the ownership? At this moment in time legislations are not making this transition easy, only with detours there are some possibilities (2&3). All actors are indicating the separation of legal and economic ownership, however there are no regulations in place to advocate this. With the shift in legal ownership, comes the shift in responsibilities, risks and finance. Most actors are not ready for this transition, mainly because they don't know how and are unfamiliar with the possibilities.

4.2.2 Lack of collaboration and interaction

While legislations are not promoting this transition, different actors are not working together either (3). A lack of collaboration and interaction between different actors is one of the main issues to implement product-service systems. Most actors don't want to share (new) information, due to mistrust and they are scared to lose their competitive advantage (2&3). All actors who are working with product-service systems are developing their own product, without any interaction. An interesting note is that actors have preferred partners to work with, however due lowest cost awards, they have to choose lower price competitors (1). The latter two are slowing down innovation and opportunities which may occur during this process (2). At the same time there is no driving force (4), who is promoting product-service systems. It is not quite sure how this driving force should look like and what his role within the construction

project organisation should be. one thing is for sure, clients want to focus on their core business and want minimal interactions with actors, also they are not familiar with this new business model and therefore are not the designated person for this role (4). While clients are not familiar with the possibilities, suppliers are not ready to take over the responsibilities to provide a whole integrated performance package.

4.2.3 Unclear Boundaries

With a higher level of integration, the boundaries between different actors and their role becomes vague (3). Who is responsible for which component and what service should they provide accordingly. Not only technical concerns came up during the interviews but also the distribution of finance, legal and management becomes vague, when talking about product-service systems. Scope has always been a difficult subject in this fragmented industry (4), blaming and suing each other instead of collaboration has been the way. So boundaries between components and roles are unclear, with a higher level of integration.

4.2.4 Contrast in short and long term goals

Another aspect which complicates this implementation, is the difference in short and long term goals of stakeholders (1&4). Most actors on the bottom of the current construction project organisation have short term mindsets. Which are focused on delivering their product and on to the next project (2). On the other hand do components have different lifespans, which have to be adjusted or replaced over time. At the moment there is no incentive for a long term mindset, one of the interviewees gave the example of guarantee period. If this period is five years, why would one produce products which last longer (2)? So actors are scared to increase the lifespan of their products, because probably they will have less work in the future (3). On the other hand on the top, do investors and clients want security and are therefore focused on the long term (1).

4.2.5 Lack of phase integration

This short term mindset also causes a lack of integration between different stakeholders and project phases over time. There is a need for more integration and communication between different parties (1&3). One of the interviewees gave a good example, that the facility manager is not involved in the design process, while he has all the knowledge about usage (1). There is a need for flexibility during construction, because most users are not known during design (4). So during construction a lot of waste is generated, due to changing demand of new users. Besides that the end-of-life is not taken into consideration, because one doesn't see the benefits in the short term. While the design and construction phase are more and more integrated due to new techniques, the other phases lack integration.

4.3 DEVELOP

The previous two phases gave a better understanding of the practical problem, why construction project organisations have difficulties with the implementation of product-service systems. This phase is known for its diverging character, ideation will contribute to the design of a restructured stakeholder network. The findings in this section are based on the outcomes in the theoretical framework, the authors own ideation and two semi-structured interviews. This section will elaborate on the needed changes to implement product-service systems in a construction project organisation. These changes will result in new stakeholder roles and different interactions over time.

Before we start some things have to be said about the other elements (finance, law, technology and organisational) of a project (table 4.2.). All components are interlinked and without one the others don't exist. As mentioned in the scope only the organisational aspects will be addressed, however finance, law and technology are interrelated and with the organisational elements of a project. This section will indicate some needed changes for these elements but won't go deep into the matter, due to time limitations.

Table 4.2: The elements of a project (finance, law, technology and organizational)

Finance	Technology
The financial system has to change, due to the shift in ownership. The producer will stay the owner of his product and will need an investor to be able to produce his product and services. The client and users will pay the producer periodically, based on his performance. If the producer is underperforming he will be paid less, and vica versa. At the end of the life-cycle the producer is able to take his product back or adapt it to new demand. When he takes it back he is able to use the residual value of his products for other projects	Standardized techniques and designs are needed, who are focused on circularity. Not only the materials but also the design, development, construction and deconstruction of the products have to be circular. Circularity needs to become measurable, like sustainability already is. Integrated packages of products and services are needed to meet the demand of product-service systems.
Law	**Organizational**
The current legislations do not promote the shift in ownership, a solution could be to divide ownership, into legal and economic ownership. The client is the legal owner of the product and decides what happens, the provider stays the economic owner, provides services and takes it back at the end of life. To ease the implementation of product-service systems, new regulations are needed, which for instance facilitate shared ownership of buildings.	**Scope of Report**

4.3.1 Needed Changes

The needed changes to implement product-service systems in the construction project organisation will be addressed. The changes (figure 4.3.) are the need for promotion, scope boundaries, central organised services, early expert involvement and in-house knowledge. These changes form a possible solution for the earlier described difficulties. To show the chain of evidence the needed changes will refer to the difficulties of previous section (table 4.3). These changes are an answer to the difficulties for the implementation of product-service systems. With these changes product-service systems are easier to implement.

Figure 4.3: Needed changes in the construction project organisation to implement product-service systems

#	Name difficulty
4.2.1	Unfamiliar with product-service systems
4.2.2	Lack of collaboration and interaction
4.2.3	Unclear boundaries
4.2.4	Contrast in short and long term goals
4.2.5	Lack of phase integration

4.3.2 Driving force for product-service systems

As mentioned in the previous section, there are many unknowns about this relative new subject. There is a need for a party who promotes product-service systems and knows about its possibilities (4). It is a party who knows how to answer the sustainable demand and how to ask for products and services who can meet that demand (4.2.1). This will result in solutions for the unfamiliar character of product-service systems. There should be a platform where actors can share their experience and find new ways to approach their problems (5), this will result in better collaborations (4.2.2). This driving force has to find out which regulations should be changed by politics and should promote this as well. The driving force takes a leading role in the stakeholder network, facilitates cross-discipline and -industry interaction (4.2.2) (Joensuu, 2020) to promote collaboration and interactions and makes clients aware of the possibilities (4.2.1). The driving force facilitates the process of the right questions from top to bottom and the right solutions from bottom to top (1).

"A lot of times, people don't know what they want until you show it to them." - Steve Jobs

The driving force will focus on a common and long term goal within the construction project organisation (4.2.4). This will result in less contrast between short and long term goals. He will be involved throughout all phases of the project and stimulate phase integration (4.2.5).

4.2.1 **4.2.2** **4.2.4** **4.2.5**

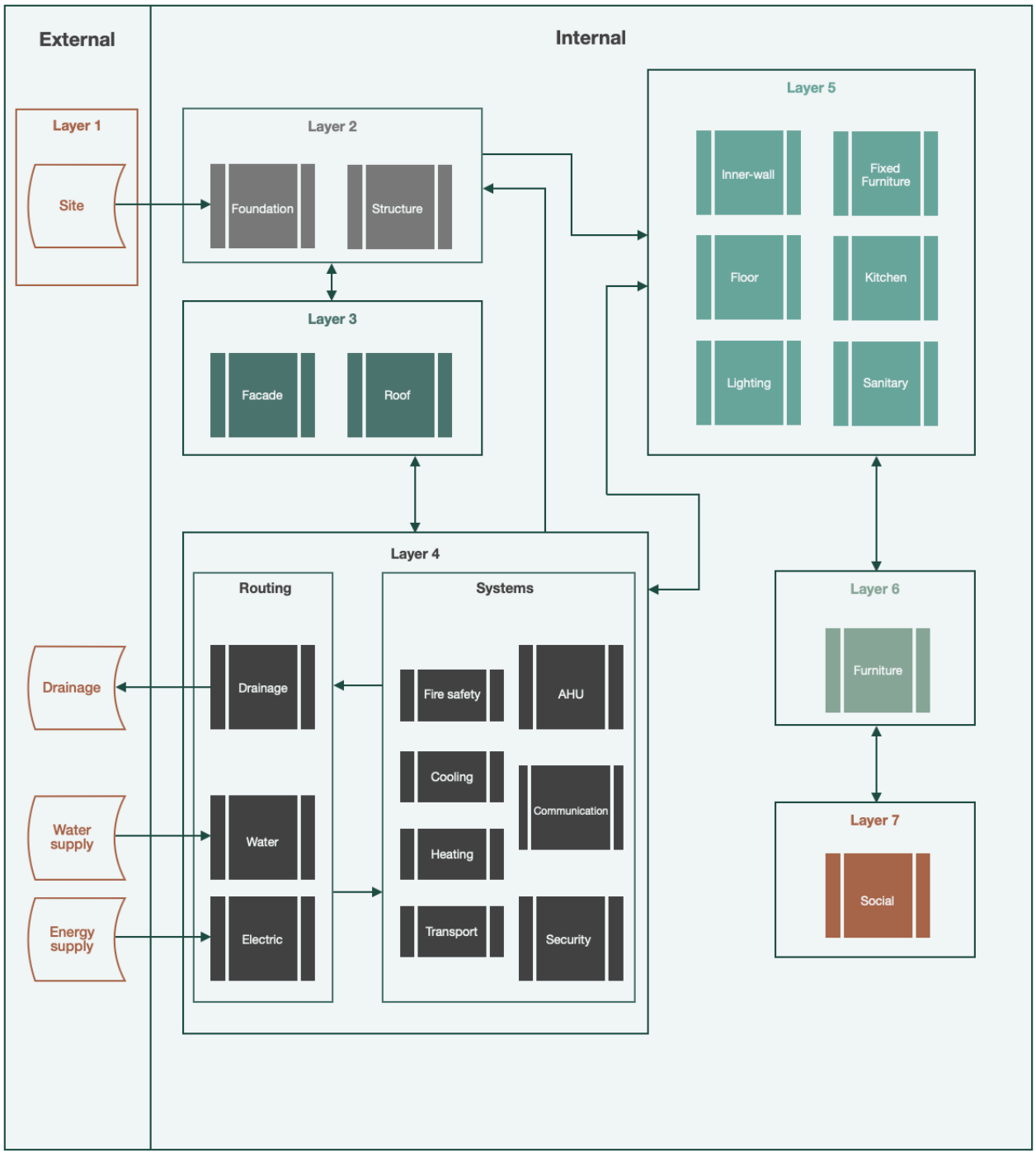


Figure 4.4: Components of SfB connected to building in layers and their interactions (own figure)

4.3.3 Clear boundaries

To provide structure and support to actors, there is a need for clear boundaries (4.3.2). Within these boundaries there has to be room for innovation and new solutions. Literature indicated that Building in layers of Stewart Brand (1994) could be a good solution. This model divides a building in layers based on the lifespan of the component. This aspect is interesting for product-service systems, because it makes it possible to take back or change components without touching or damaging others.

4.2.3

A building will be divided into smaller projects, based on the building layers. The boundaries and points of interactions between the layers, have to be clear before the project starts. This creates design security for all layers, a good example is the connection between the structure and facade, the specifications should be known to each party, so that this will be their point of departure for the design (3). Not only the technical elements are important but also when and how the actors interact with each other. Some ways of communication can be one way, just providing information to another layer as shown in figure 4.4.

The components within a layer, have the same lifespan and therefore could have the same rules/ boundaries. Figure 4.4. is based on the components described by SfB and it shows the interactions between the different layers. Design interaction like connection and penetrations, but also information or specifications based on the performance the project requires. Projects become smaller and actors are able to focus on their core business, which reduces project complexity (Klein, 2013).

4.3.4. In-house knowledge and component production

Two interviewees indicated that there is a need for in-house knowledge and production, when implementing product-service systems (2&3). There are two ways to increase in-house knowledge and component production. Get all actors under one roof, by taking over companies in the supply chain or long-term contracts with preferred partners, to stimulate long term collaborations (4.2.4), this will result in a common goal. This will lead to cross-discipline interaction and less fragmentation in the built environment (4.2.2), better collaboration and interaction between the actors.

The producer will be the owner of his product and he will be responsible over the whole product life-cycle. In-house knowledge, products, production and services will lead to quick adaptation, easy changes and one is able to learn from their mistakes (3). The producer should be involved in all phases of their product life-cycle (concept, design, development, construction, use and end-of-life) (4.2.5), this will result in more phase integration. They also need to have all types of management in-house and tools to facilitate this. More in-house production will lead to less fragmentation in the industry, higher level of trust, short communication lines and better information sharing, which will lead to more innovation, better solutions and a common goal (4.2.2 & 4.2.4). More in-house knowledge or long term collaborations, will result in information sharing, trust and will create a common goal for everyone involved (4.2.2), more collaboration and interaction between stakeholders. The focus should be on long term collaborations (4.2.4), to reduce the contrast between short and long term goals. Due to the characteristics of product-service systems, producers are responsible for the whole life-cycle of their product. Phase integration will benefit the quality of their products and reduce the amount of services they need to deliver (4.2.5).

4.2.2 4.2.4 4.2.5

4.3.5. Early expert involvement

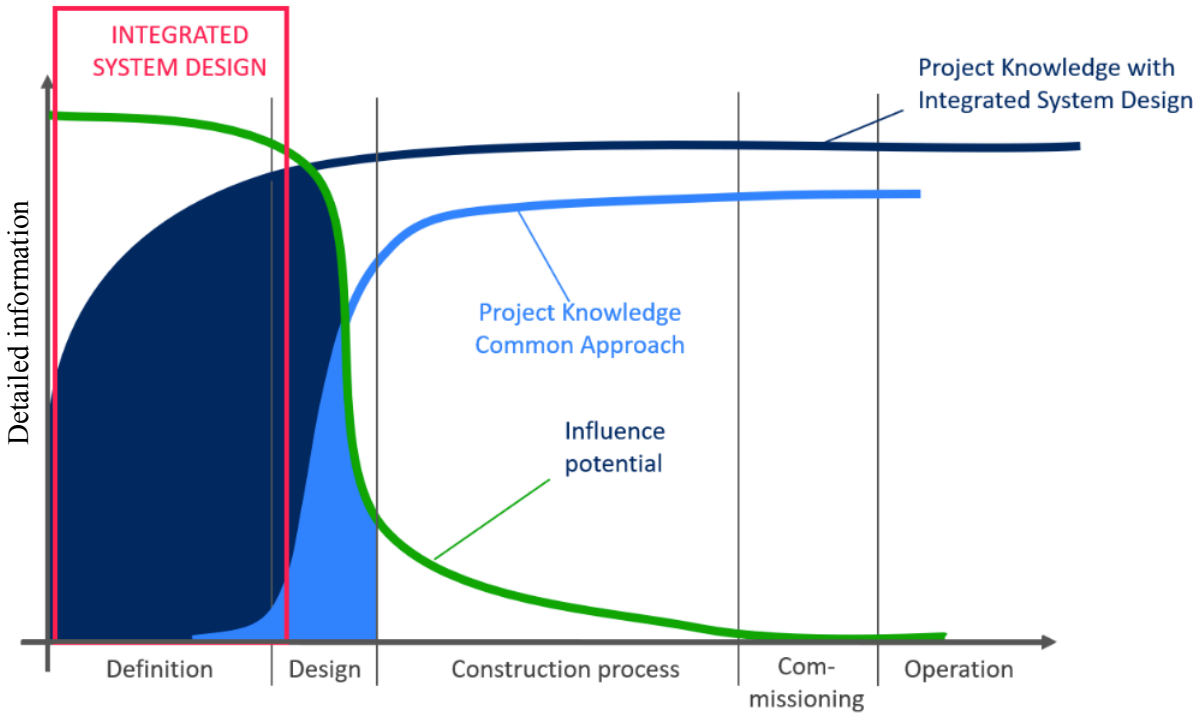
In the discovery phase multiple interviewees indicated that there is an increased integration between the design and construction phase. However the other phases (concept, use and end-of-life) are not integrated or addressed in this process. There is a need for more phase integration and expert knowledge at the start of a project, also indicated by literature (Bygballe et al., 2010)(4.2.5). This will prevent unnecessary changes and cost overruns, later in the project. At the same time the experts are able to come up with sustainable and circular solutions which will benefit project value.

As figure 4.5. shows, in current projects the project knowledge increases in the design phase when experts get involved. Project knowledge is all the information of a project, like design, production, assembly, etc. But at that same time the influence potential decreases. This means that changes will be harder and more expensive to apply. Another negative effect is that design and cost estimates are inaccurate at the start of the project. Which is awkward, because decisions based on costs are made at the start of the project. Before expert knowledge comes in, important design decisions have been made by the architect and project manager (klein,2013). However most of the time they do not have the right knowledge to make these decisions. The right questions should be asked to the person who knows the right answer, to create clear boundaries between the different actors (4.2.3).

4.2.3 **4.2.5**

Involving experts at the start of the project will cause more room for innovation and cost certainty at the start of the project (Bygballe et al., 2010). It will save time, clashes occur early in the project when the influence potential is still high and changes are easily adapted. Involving experts from all phases of a project early on will stimulate a common project goal (4.2.4), and phase integration (4.2.5).

Figure 4.5: Early expert involvement; detailed information vs. influence



A good example of expert knowledge at the start of a project is the facility manager or asset manager, who has the responsibility over assets after construction is done. He takes care of the maintenance and repair, however his expertise is not considered in the design. This could save a lot of service and repair costs, if his knowledge was considered at the start of the project (5).

An example for phase integration are material passports, they enable buildings to function as a material bank. It is important not only to provide the passports but also techniques to deconstruct the buildings and reuse the components and materials. To facilitate this it is important to make an actor responsible for the decommissioning of his components, by extending the contract to after end-of-life. Also give the actor the possibility to adjust his component to changing demand, this will benefit sustainability and reduce waste. Multiple life-cycles of one component can be integrated into one contract as well. The actor will know exactly when he gets back his products/materials and is able to use it for other projects (1).

4.3.6. Central organised services

Since the origin of building in layers by Stewart Brand (1994), things have changed, we live in the digital era now. Therefore a digital layer should be added to this model, the social layer (figure 4.6). This layer connects the users of a building, by organising social events, common groceries, rent, cleaning, etc. Instead that everyone is organising this for themselves there should be a platform who provides this. This will improve the quality-of-life within the building and increase project value. It is all about unburdening and connecting people.

But the main reason for this layer is that actors are able to provide central organised and therefore cheaper services, to all users. Due to the social layer one is able to monitor the building and act if needed (5). Central organised services will prevent all providers to execute on their own behalf and burden the users (4.2.2), this will result in clear boundaries, everyone will know clearly what his tasks are. This is organised by one party, he will call for help to the providers when repairs on their components are needed, as referred in section 4.4.2, the driving force. This layer is combining the technical and social processes during the project life-cycle. Central organised services is a result of the previous solution and more in-house knowledge.

The actors will be responsible over the whole life-cycle of their product, also in the user phase. If all actors would act on their own behalf, with maintenance for instance, then it would be chaos within the building. For this reason there is a need for central organised services. This will also result in more collaboration to come up with the most efficient service solutions, it will create clear tasks for every actor and therefore clear boundaries (4.2.3).

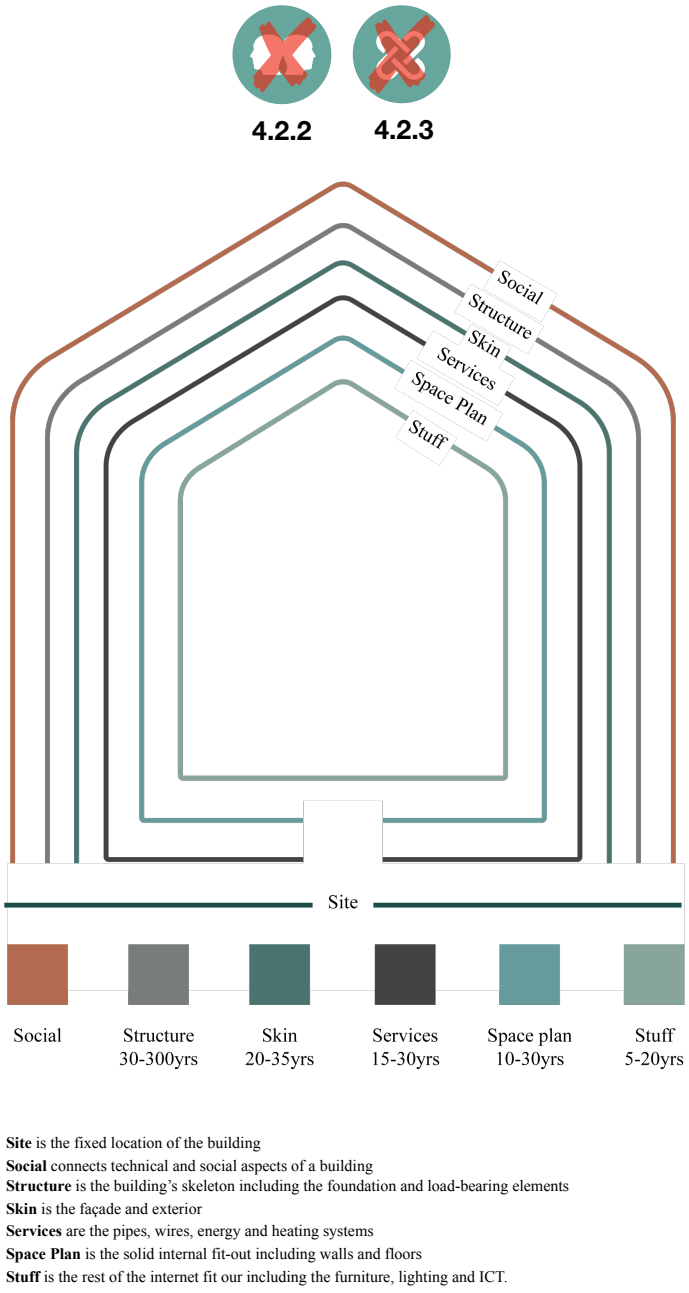


Figure 4.6: New building layer: Social (own figure)

4.4 NEW ACTOR ROLES

Based on the changes of the previous section, new actor roles will be introduced (figure 4.7), which contribute to a restructured stakeholder network. The implementation of product-service systems in the construction project organisation will result in new partner networks. The changes will result in new actor roles and current actors have to adapt to the new situation, the focus will be on long term collaborations. New actor roles (figure 4.7), resulted from the changes indicated in previous section.

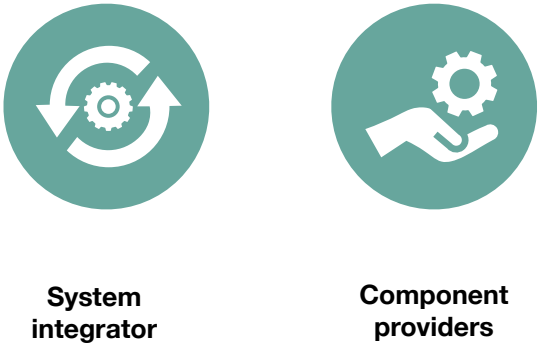
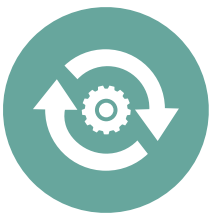


Figure 4.7: New actor roles for a construction project organisation

To show the chain of evidence, the following numbers will refer to the needed change.

#	Name change
4.3.2	Driving force for product-service systems
4.3.3	Clear boundaries
4.3.4	In-house knowledge
4.3.5	Early expert involvement
4.3.6	Central organised services

4.4.1. System integrator



The system integrator will be the driving force for product-service systems (4.3.2). He was introduced by interviewee 4 and other scholars are also addressing this role. The task of the system integrator is “a system integrator sets up a network of various organisations and coordinates the activities within. For individual clients, the system is developed by a network of various organisations. The system integrator chooses the organisations involved in the network and organises the activities of the network

members to guarantee the coherence of the network output" (Renier & Volker, 2008, p. 126). The main task of the system integrator is to bring the different components together which form a building and create clear boundaries between the providers (4.3.3), over the whole life-cycle of a project (figure 4.8). Ideally all providers will stay the owner of their product and the system integrator will be paid according to his service of bringing the components together. The system integrator will be involved from the start until the decommissioning (4.3.4), this will result in more phase integration.

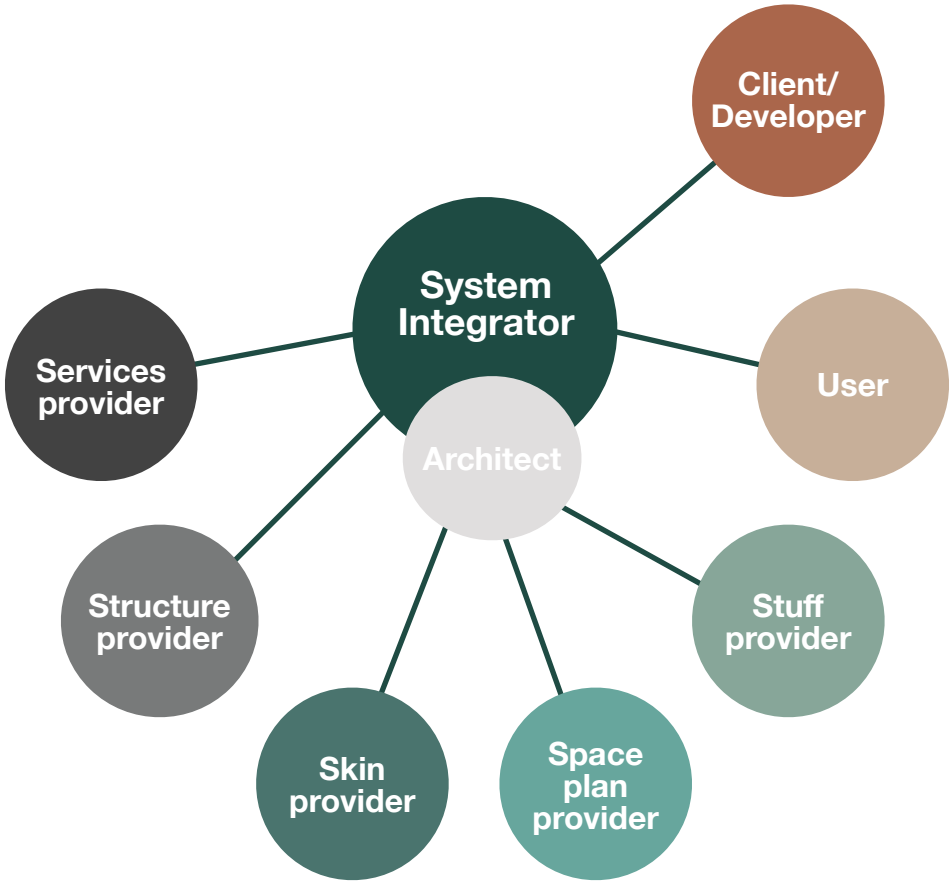


Figure 4.8: Restructured stakeholder network for the construction project organisation with client involved (own

The system integrator is the spider in the web, he connects all actors and steers on performance instead of functionality. He is the driving force for product-service systems within the construction project organisation (4.3.2). To facilitate the interactions and collaborations in the network, he has in-house management to guide the actors through all phases (4.3.4). Information management will be one of the main tasks for the system integrator, digitalising expert knowledge and lessons learned, so that it can be used in other projects. Collection data and monitor the building during all phases, to learn and act if needed, therefore the project knowledge increases over time (4.3.6), which is a result of the monitoring

discussed at central organised services. Programmers are needed to collect and analyse the right data and to design tools, which can be used by all users. The tools should be connected to real time data, such as weather, changing costs and time. Due to information management and the digitalisation of expert knowledge, the role of some experts (cost consultant, planner, etc.) will change from advising too controlling.

Renier et al. (2008), argues that this role could be fulfilled best by the architect, since he is a generalist and does not have a “tunnel vision” like other actors. However as discussed earlier the architect makes important decisions at the start of a project while he doesn’t have the right knowledge (Klein, 2013). At the same time the detailed design is the responsibility of the providers, when implementing product-service systems. This new role asks for a new actor, current actors are not capable to fulfil the role of a system integrator. Decisions should be made by the expert and the actors who have the right information/ knowledge, for this reason the architect is not the right actor. As mentioned before, actors should focus on their core business (4.3.3), within the boundaries of the their component. As discussed earlier experts have to be involved early in the project when the influence potential is still high. The system integrator is a new role who knows how to find the right expert for the correct answer. He brings together expert knowledge and makes well-considered choses based on a balance between all elements. While an architect is focused on the design and an engineer is focused on the construction, the system integrator tries to find the right balance with the highest profit margins.

The concept design will be done by the system integrator in collaboration with an architect, they will provide guidance through all project phases. The system integrator will monitor the project and make sure every actor is working conform their contract and concept design. To facilitate this integration, he will need in-house engineering and design knowledge, to detect clashes and check the detailed designs of the providers, this is due to the clear boundaries between the components (4.3.4). The System integrator is responsible for two building layers; site and social. He brings all the components together and will facilitate the general site logistics, this is mainly needed during the construction phase. The social layer will be used to monitor the building and provide central organised services (4.3.6). Section 4.5, will elaborate on the interaction of actors per phase. To summarise the system integrator is the driving force and promotes product-service systems bottom-up and top down. He guides the other actors and makes sure everyone stays within their boundaries. To facilitate this he will need more in-house knowledge, for all phases of a project. He will provide central organised services to prevent chaos between all component providers.

4.4.2. Component providers

The producers will be the owner of their product, due to the shift in ownership provided by product-service systems (Tukker, 2004). Ideally all providers together will be the shared owner of a building. Connecting product-service systems to the building layers will provide flexibility and adaptivity based on product lifespan. The providers are able to adjust and replace their product, based on changing demand. The separation based on building in layers (Stewart Brand, 1994) will provide clear boundaries for the different actors (4.3.3). This also means boundaries in communication, the communication between different layers should go through the system integrator. The system integrator will be able to detect clashes between the providers. However clear project rules have been provided at the start of the project, these rules will create a clear point of departure for the providers.

Each provider is able to focus on his core business and due to more in-house knowledge and production, he is able to change easily (4.3.4). This will result in a higher level of innovation, Volker and Wamelink (2009) showed that retaining experience and knowledge within the company will be beneficial in other projects. The provider is able to solve problems and adapt to changing demand both bottom-up or top-down. In combination with more freedom within the boundaries will result in better solutions and more innovation. The providers are responsible for the design, production, assembly, construction, maintenance and deconstruction of their product. They are able to learn how their products and services will react in real-life and if needed they are able to adjust, also they can use this knowledge in new projects. A small remark, Volker and Wamelink (2009) referring to the system integrator, however by implementing product-service systems these tasks should be allocated to the providers, since they stay the owner of their product. Focusing on their core business and dividing the project into smaller sub-projects will result in less project complexity, due to clear boundaries (4.3.3). The right question should be ask to the right person therefore experts need to be involve early and throughout the process (4.3.5).

As mentioned in the section about needed changes section, long-term collaborations like joint ventures or takeovers are needed to be able to change and adapt easily. Also after the end-of-life the providers will be able to take back their products and reuse or adjust them in other projects.

Each provider is responsible for their own design, however they have to comply with the concept design of the system integrator and architect, so their is a need for more in-house knowledge (4.3.4). During the design they should implement expert knowledge of other phases, like an asset-manager, this will result in less cost overruns and changes later in the project. Thinking of other phases at the start of the project will

result in less services needed during the user phase, which will result in lower costs and higher profits, due to early expert involvement (4.3.5). As mentioned in the changes the services need to be centrally organised, which means that providers have to educate the system integrator how they should provide some services to their products. If big repairs, adjustments or replacements are needed the providers will be notified and are responsible to react accordingly.

To summarise the component providers have clear boundaries due to the building in layers. They need more in-house knowledge and production to be able to implement product-service systems in an efficient way. Early expert involvement will result in better products and more innovation.

4.3.3 4.3.4 4.3.5

4.4.3. Client/Developer

He will start the project process together with the system integrator. The client/developer will be the owner of the contracts between him and the different providers. He will be paid by the users and he will pay the providers periodically. His business model is the difference between the income from the users and the providers payment. It could be a long term investor who likes a steady income for a longer period of time. He will be the owner of the site and initiate the project, a good example could be governmental organisation, think of "erfpacht" in the Netherlands.

4.4.4 User

Currently the user is switching to a newer building every 10 to 15 years, because his needs, wishes and demands change over time. With product-service systems there is no need to move to another building, because the components and actors are able to adapt to this changing demand. New techniques will be implemented over time. The user will be totally unburdened and quality-of-life is central. Their point of contact is the system integrator, who will provide centralised services as discussed previously.

4.4.5 Architect

The architect will be in close contact with the system integrator, he has to guide the design with some providers. He will provide a concept design together with the system integrator, with design specification and aesthetics. However the provider is responsible for the detailed design of his component. This could also be a new role for the architect, they could collaborate and assist the providers with their detailed

design. This will mean just focus on that one component, the structure, skin and space plan could be of interest for the architect. The other layers are less focusing on design and more on performance.

4.4.6 Investor

The role of the investor will change slightly, instead of funding the client/developer he will fund the different providers. For the reason that the providers stay the owner of their products.

4.4.7 Material supplier

It could be interesting for the material supplier to have a long-term contract, with the providers. So that he is able to take back the materials after the end-of-life for the residual value. However just providing the material would be beneficial for the providers, since they are the owner and can adapt or reuse these materials in other projects.

4.5. STAKEHOLDER NETWORK PER BUILDING LAYER

The previous figure 4.8, showed the interaction between the different providers and the system integrator. The figures in in this section zoom in on this network per provider. These stakeholder networks are based on the lifespan of the components (Brand, 1994). In this section the providers will be connected to a product-service system (Ostaeyen, 2013). Due to the different lifespans, one performance orientation will be more attractive than the other. The connection is based on a balance of interest of the different stakeholders involved. Allocating the performance orientation to the layers provides building flexibility and increases adaptivity over time (5). Take into consideration that each layer consists of multiple components, however due to their lifespan, they are considered as one. The interactions between the actors is explained per layer. For this research the lifespans of Stewart Brand are used, it could be interesting to use other (shorter) lifespans. This will result in a higher performance of the different components, because they get replaced or adjusted more often in the same period of time. Also multiple life-cycles can be included into one contract.

Availability based - Structure (30-300y)

Due to the long lifespan and high investment costs of the structure, it is of no interest for the provider to have a long term contract, which will outlive the provider (figure 4.9) (5).

So for this type of product-service systems the client will be the owner of the structure, like it is in a current situation. The client will need the investor to provide for the structure, or the client has the money himself, that would ease the process.

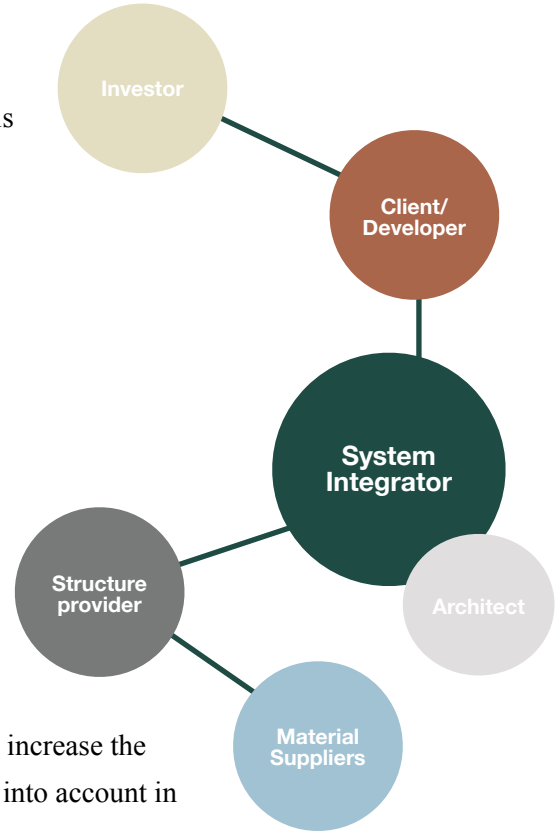


Figure 4.9: Availability based – Structure (30-300y)

The contract of the provider will end after he completes the structure. He will be responsible for maintenance and repairs when needed for some years after the contract, as the current situation is. To increase the sustainable characteristics of this layer, the end-of-life has to be taken into account in the design, early expert involvement will result in more phase integration (4.3.5). This means material passports and a deconstruction manual. The provider is still responsible for all phases, but will hand over the ownership after the construction phase.

The architect is involved in combination with the system integrator to guide the design principles and detect clashes with other layers, because of clear boundaries (4.3.3). It would be interesting for the provider to take an architect in-house, collaborate on the structure, although it is mainly engineering (4.3.4). The system integrator is the point of contact, the driving force within the stakeholder network, unburdened the client and guides the provider through the processes (4.3.2). Due to the long lifespan, it would not be interesting for the material supplier to take back his materials after end-of-life, therefore no long-term contracts.

Solution based - Skin (20-35y)

Due to a shorter lifespan the skin provider could stay the owner of his product. He will need an investment upfront, to design, produce and install the skin. The provider will get paid periodically by the client (figure 4.10).

The architect and system integrator will provide the skin provider with a concept design. The skin provider will get the specification from the connections and interactions of other layers, due to the clear boundaries, agreed upon at the start of the project (4.3.3). With this package he will be able to start designing the skin. The architect will keep track of the design, in a controlling role, to avoid clashes with other layers.

The skin provider will need the production of his products and more knowledge in house. The detailed design will be done by the provider, it would be interesting to take an architect in-house (4.3.4).

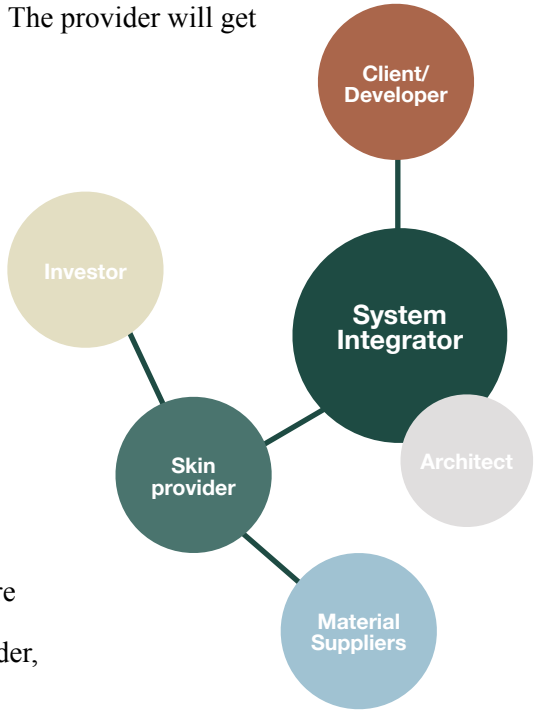


Figure 4.10: Solution based – Skin (20-35y)

The provider has to educate the system integrator to maintain the skin and to carry out small repairs. The skin provider will be contacted if the repairs are out of scope for the system integrator, who will execute the central organised services (4.3.6). The skin provider and material supplier could have a long term contract to take back the materials. Or the skin provider will rescue his components into other projects (2). After the lifespan the provider could adjust or take back his product. However it would be more profitable to just adjust to new demand and expand the lifespan with more life-cycles. Multiple life-cycles could be integrated into one contract, also shorter life-cycles could be interesting if one will only adjust the skin to new demands.

Effect oriented - Services (15-30y)

Services will have a lifespan of 15 to 30 years. Multiple life-cycles can be included into one contract (figure 4.11). This will promote adaptive design and innovations can be implemented to meet new demands. This product-service system should focus on performance orientation, and being paid accordingly. If The services don't perform as they should, they should be paid less. However when they outperform they should be paid more. Since the providers will stay the owner of their products, the investor is directly involved to facilitate design, development and installation costs, due to to more in-house knowledge (4.3.4). The provider will get paid periodically by the client. Since the provider will adjust or reuse his products, there is no need for a long-term contract.

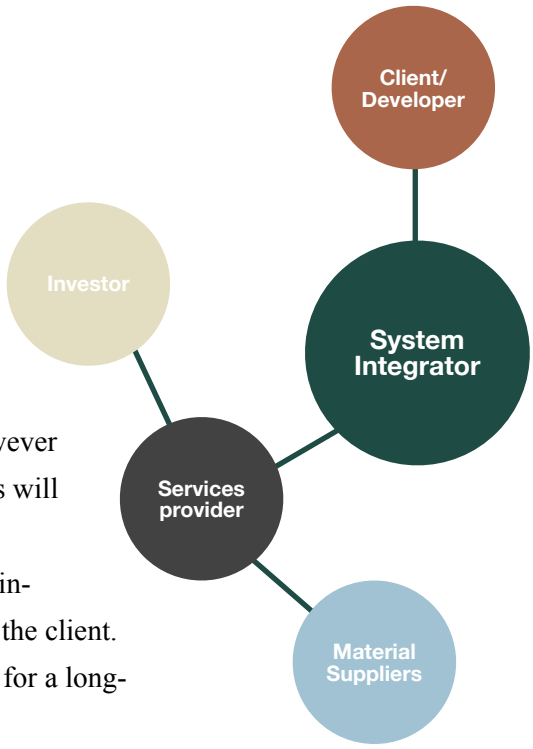


Figure 4.11: Effect oriented – Services (15-30y)

Services are most of the time not visible in a building and therefore the architect is not involved. The system integrator has engineering skills in-house (4.3.4) and is able to check the designs of the service providers. The system integrator is responsible for the interactions between the different services. It is important for the provider to show his boundaries to other layers as a point of departure for the design (clear boundaries, 4.3.3).

Especially for the service providers it would be interesting to buy the materials and reuse their product components, this will benefit the in-house production (4.3.4). They will be able to reuse these products into new projects, to close material loops. This layer could focus on demand orientation and focus on the behaviour of clients and adapt real time. But for now this step is too big, it could be super interesting for the future.

Effect oriented - Space plan (10-30y)

For the first time the user will be involved. They will use the building or a part of the building and will have demands for their use (figure 4.12). Their wishes and needs will be implemented in the design and execution. This will probably change with every new user or in a few years.

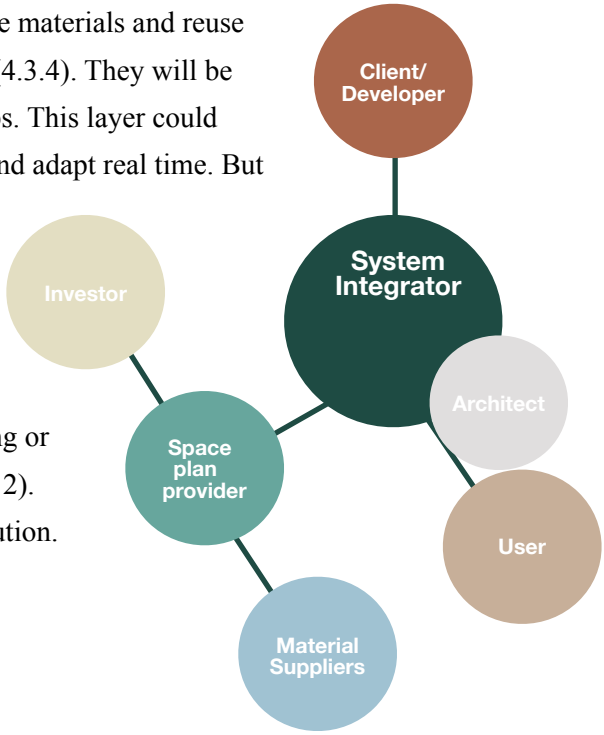


Figure 4.12: Effect oriented – Space plan (10-30y)

The space plan provider is able to execute the first part of his design and execution before the user comes in. However the finishing is user specific and needs to be adapted to their demand and wishes. This design will be done in consultation with the architect and system integrator, the detailed design will be done by the provider, within the boundaries (4.3.3). This will be checked by the system integrator and architect, which is a task of the driving force (4.3.2). The client is not really involved in this layer, since it is user specific. The investor is involved directly with the provider for a short term investment.

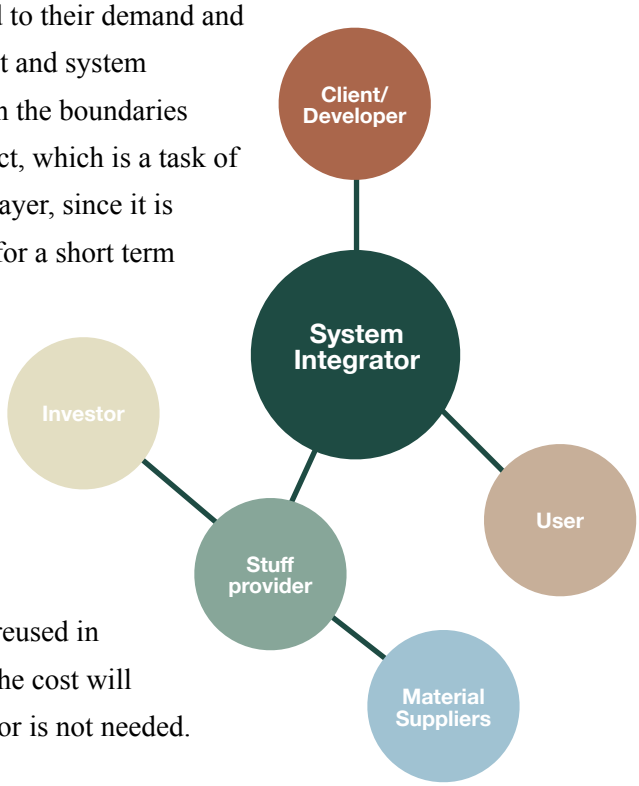


Figure 4.13: Demand oriented – Stuff (5-20y)

Demand oriented - Stuff (5-20y)

The stuff layer is almost the same as the space plan layer, only for a shorter period of time and the demand of the user will get a more prominent role (figure 4.13). The lifespan of furniture is depending on user demand, it will switch more often and can be reused in other projects, this will benefit the in-house production (4.3.4). The cost will be smaller than other layers, so it could be possible that an investor is not needed.

Demand oriented - Social (1-2y)

The system integrator will be responsible for the social layer (figure 4.14), who facilitates the central organised services (4.3.6). This layer connects the residents and users of the building, by organising social events, common groceries, rent, cleaning, etc. Instead that everyone is organising this for themselves there should be a platform who provides this, the social layer, due to clear boundaries (4.3.4). This will improve the quality of life within the building and increase project value. It is all about unburdening and connecting people.

But the main reason for this layer is that actors are able to provide central organised and therefore cheaper services, to all users. Due to the social layer one is able to monitor the building and act if needed. This layer combines the social and technical aspects of a building, it connects people and monitors the building, which are the characteristics of central organised services (4.3.6).

The most important actor will be the programmer, who will provide the user and system integrator with tools to facilitate this interaction. Programmers will become more important since the role of a project manager will shift to an information manager. Collecting data and using it in the right way will be of most importance.

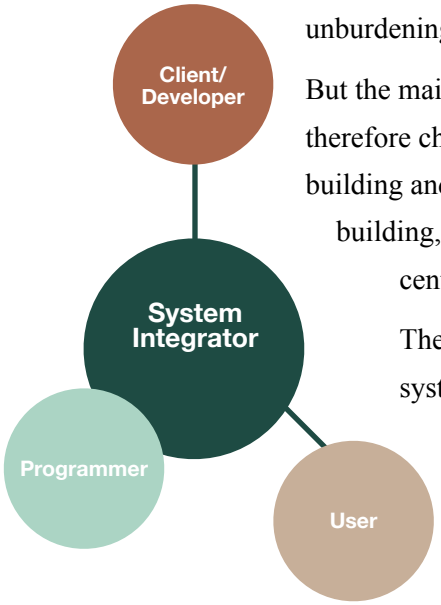


Figure 4.14: Demand oriented – Social (1-2y)

4.6. PROCESS TIMELINE

Now that we know the new roles of each stakeholder, we will now discuss how these actors could interact over time. The combination of product-services systems and building in layers, provides separate components with different lifespans. Figure 4.15 shows a possibility of different lifespans per stakeholder. For example, while the life-cycle of the facade could be 30 years, the services could have 2 life-cycles in that same period of time. The services can be replaced or adapted to changing demand, while the facade stays intact. Multiple life-cycles can be included into one contract, this will promote the producer to use sustainable products who will last for a long period of time. The red highlighted sections will be explained in more detail, highlight one is the start of the project and highlight two is after 15 years when some components have to be adjusted, repaired and/or replaced.

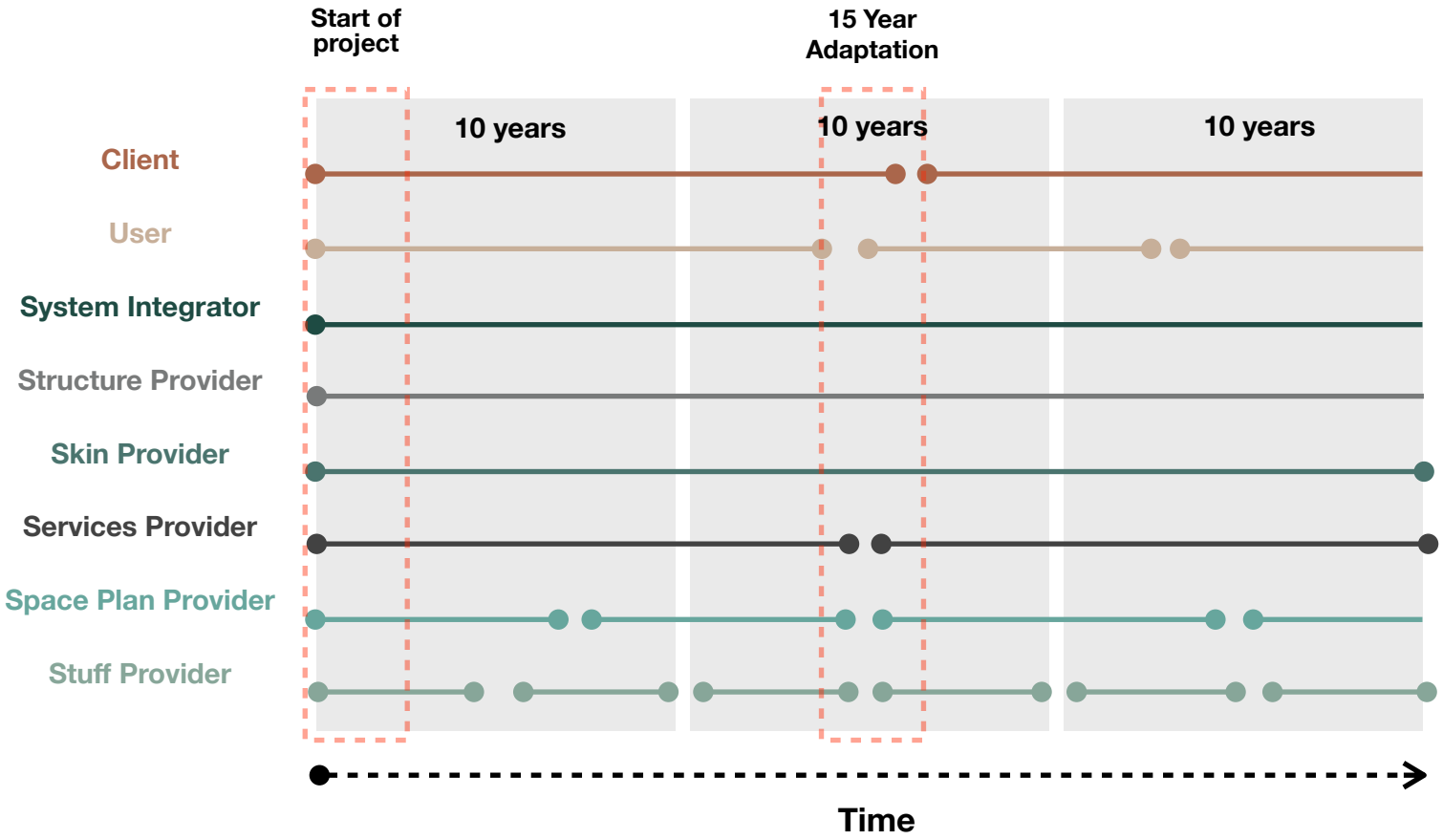


Figure 4.15: The interaction of actors over time based on their product lifespan (own figure)

The separation and different lifespans of the layers, creates more flexibility for the building and increases expert knowledge over time (5) (figure 4.16). Users want flexibility and change to their current circumstances, these users grow and shrink and the building is able to change accordingly (4). The

influence potential increases when components have to be replaced or adjusted. At the same time, since all knowledge is in house, the expert knowledge keeps growing over time. During all phases the social layer is monitoring and learning, this also increases the knowledge in the project, due to the monitor characteristic of the central organised services (4.3.6), while in current projects the knowledge stagnates over time.

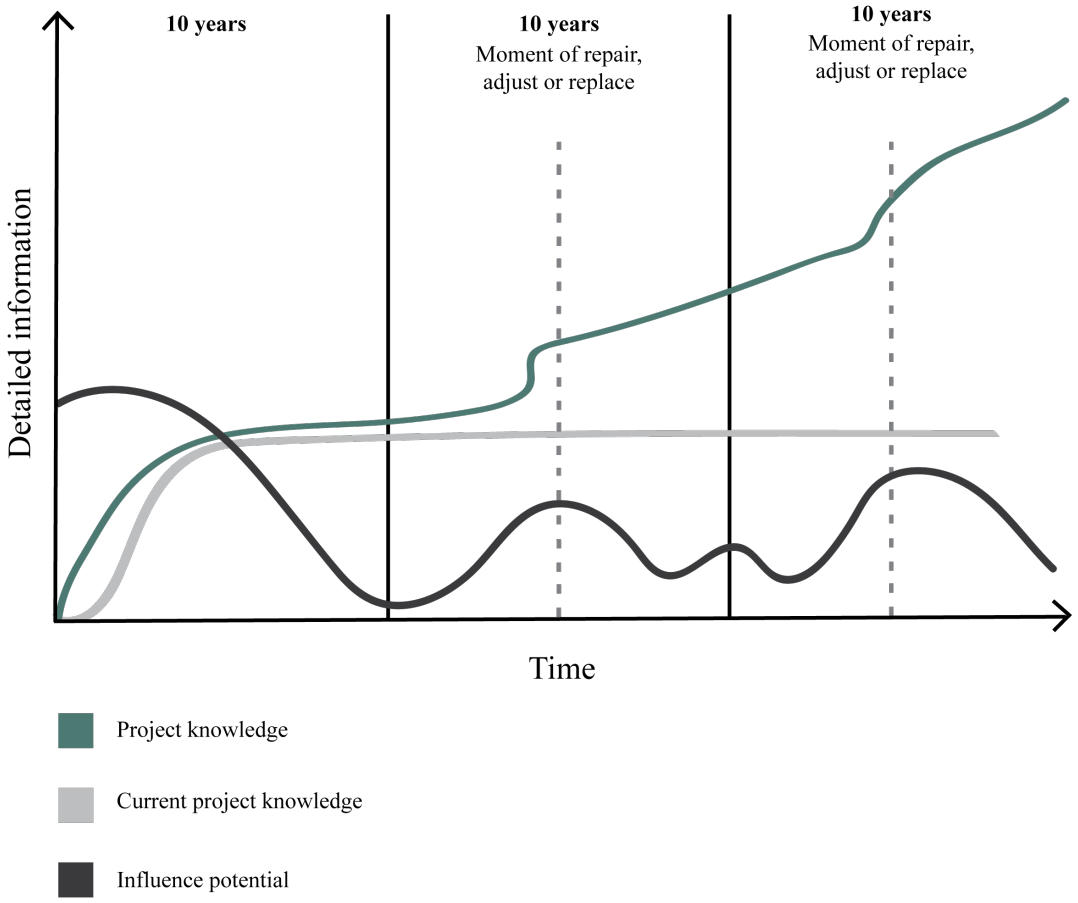


Figure 4.16: Increasing building flexibility and project knowledge over time (own figure)

In this section the interactions between the producers will be explained per phase according to the project life-cycle of Denise Huizing (2018). Since a project is divided into sub-projects, the life-cycles for each layer are different and are executed in parallel. Her phases will be used to explain the interaction between actors over time.

4.7. START OF PROJECT

This figure zooms in on the possible interactions between the different stakeholders at the start of a project (figure 4.17.). This figure is based on the previous discussed stakeholder network per layer. If a layer is connected to another product-service system these interactions will be different as well.

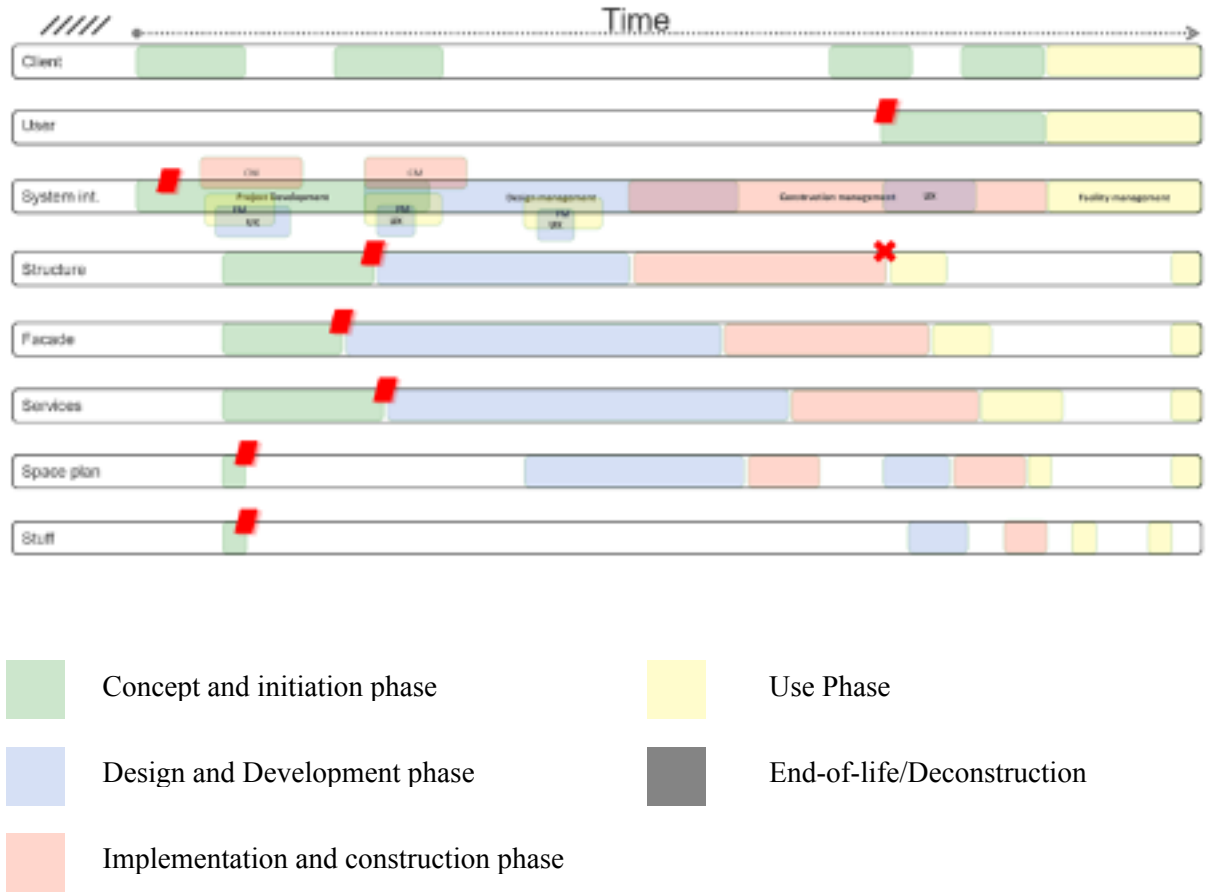


Figure 4.17: Interaction of actors at the start of project (own figure)

4.7.1. Concept and initiation phase

First the client will ask a system integrator to join him and to manage the project. They will create a concept design which has to be approved by the client. The system integrator will contract the providers, in this phase they have to agree about the scope boundaries (4.3.3), this results in early expert involvement (4.3.5). All providers need to join in the concept design to make sure their requirements, needs and wishes are heard. Layers such as structure, facade and services will need more time together to set clear boundaries. Early expert involvement is important in this phase, to increase phase integration and

provide accurate cost estimates. The system integrator has to coordinate the “rules of the game”, he has tools to guide this process.

4.7.2. Contract and financial system

Except for structural layers, all contracts are at least one life-cycle and the provider will get paid periodically. The contracts will be signed after the concept and initiation phase, when the high over boundaries are clear (4.3.3). All contracts are with the client, he will be the owner of the contracts who together form a building. During this phase the providers have to find an investor for an upfront payment, to facilitate their in-house knowledge and production (4.3.4).

4.7.3. Design and Development phase

Most interactions are between the structure, skin and services, therefore they will need more time for the design. The design boundaries, principles and connections, will create room for innovation within these boundaries (4.3.3). The designs are performance orientated. The space plan is separated into two design phases, the first phase is needed for general space planning and the second phase is needed for user physic design. The system integrator will keep the overview and facilitate the interaction between the actors, and make sure everyone is keeping their promises, this is a task of the driving force (4.3.2).

4.7.4. Implementation and construction phase

The only differences during this phase are the use of circular elements and some parts of the construction will be executed after the user comes in to avoid unnecessary waste. The system integrator is responsible for construction management and for the general site activities, he will need more in-house knowledge (4.3.4). Due to the long lifespan of the structure their contract will end after this phase.

4.7.5. Use phase

During the use phase the system integrator is responsible for central organised services (maintenance and small repairs) (4.3.6). He is able to monitor the building with the seventh layer, explained earlier. The system integrator is the point of contact and will execute small repairs, maintenance and cleaning. However if the repair is too big they will call in the providers. The providers stay the owner of their products and will be responsible and liable for the performance. If the product doesn’t perform in the right way the provider will get paid less. He has to educate the system integrator how to provide the small services for his product, so that the system integrator is able to execute central organised services (4.3.6).

4.7.6. End-of-life

This phase is not shown in the figure, due to the different lifespans per layer. There are multiple possibilities for the end-of-life, replacement, repair and adjustments can be executed. Depending on the demand this could change, as mentioned before, multiple life-cycles can be included in one contract. Providing sustainable and adaptable products will benefit the providers.

4.8. INTERACTIONS AFTER 15 YEARS

Figure 4.18, zooms in on the timeline after 15 years. Some of the producers have to adjust or replace their components while others are maintaining their contract.

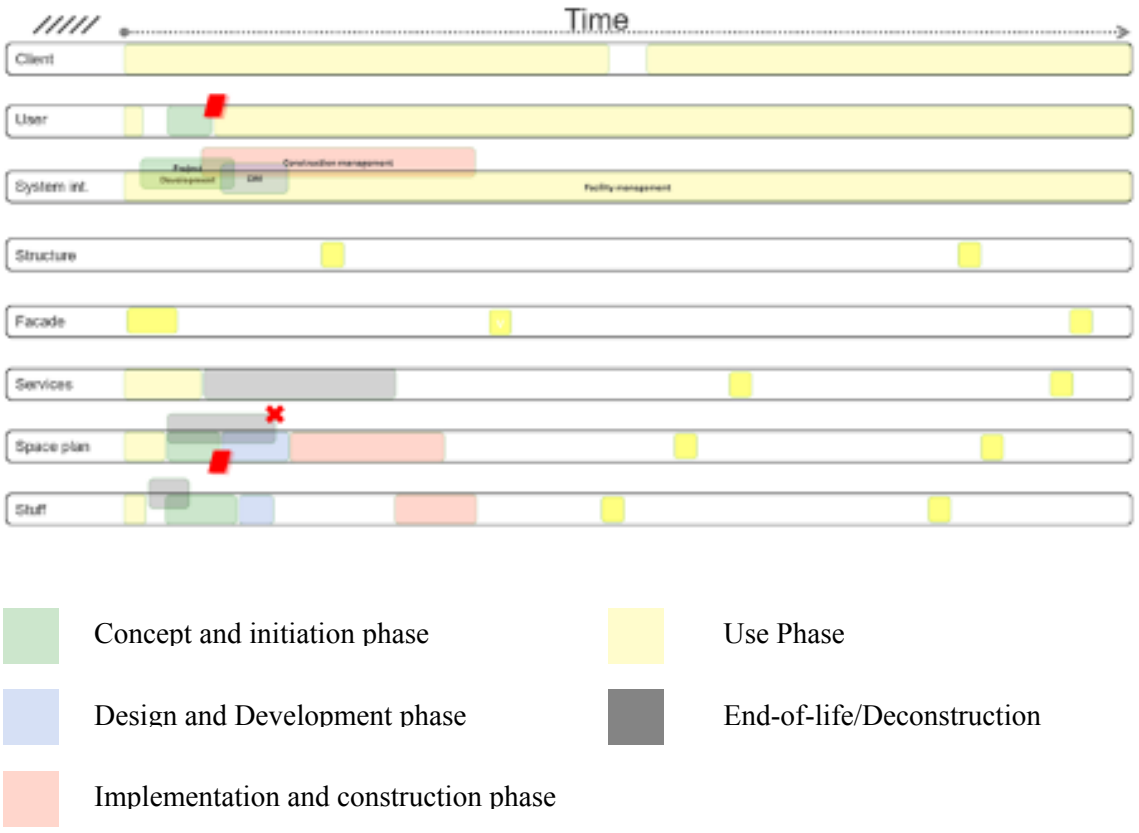


Figure 4.18: Interaction of actors after 15 years (own figure)

4.8.1. Use phase

Due to the lifespan of a component some have to be replaced, repaired or adjusted more often than others, this is due to clear boundaries (4.3.3). In this example the layers stuff and space plan will be replaced, due to a new user. For layer space plan the first contract is ended and a new contract is signed. The services

have to be adjusted to new demand and will keep the same provider. All other providers will stay the same and will when needed execute repairs, however as mentioned before the system integrator is responsible for maintenance and cleaning. He is able to monitor the building of a digital tool, which is also connecting users, this is a characteristic of central organised services (4.3.6).

4.8.2. End-of-life/Deconstruction

A new user will take over the building, this user has new demands to the building and therefore some elements have to be replaced to meet this demand. As per the contract the producer is able to take back his components and use it in other projects, which is a nice aspect of in-house production (4.3.4), the contract of the space plan ends after this phase. Taking back their products will reduce waste. The system integrator will supervise this process as a driving force for product-service systems (4.3.2).

4.8.3. Concept and initiation phase

From the moment the new client comes in the providers are able to start their concept phase and this can go in parallel with the end-of-life phase, because of their in-house knowledge and production (4.3.4). Again the concept design will be supervised by the system integrator, which is the task of the driving force (4.3.2).

4.8.4. Contract and financial system

All providers except for the space plan provider have ongoing contracts which include multiple life-cycles. For the first space plan provider the contract ended after he took back his components. However he could sell some or all to the new space plan provider who could be able to reuse these components. The new user will be guided in the concept process by the systems integrator.

4.8.5. Design and Development phase

For this example the design and development phase is focused on the fit-out which focuses on the new demand of the client. This phase can be done in parallel with the deconstruction of the same components.

4.8.6. Implementation and construction phase

The system integrator is responsible for the interaction between the different components, the services have to be adjusted to the new standard and wishes of the users, this is a result of central organised services by the driving force (4.3.2) (4.3.6).

4.9. COMPARING THE CURRENT SUPPLY PERSPECTIVE

First a comparison from the supply perspective will be made, in the next section a comparison from a demand perspective will be made. From a supply perspective this model can best be compared with a DBFMO. The comparison with the DBFMO has been chosen because they are the longest integrated contracts (Huizing, 2018), the contractor will be responsible for the design, construction, maintenance and operation phases. The periodic payment also has some similarities in both situations. The third similarity is the early expert involvement, since the main contractor is involved from the start of the design. However he does not involve sub-contractors at the start which results in a lower level of early expert involvement.

The system integrator can best be compared with the main contractor of a DBFMO (table 4.43). The main contractor has to bring all components together, he divides the projects over different sub-contractors, which can best be compared to the providers (table 4.4). The next table compares the actors of a DBFMO with the new situation.

Table 4.3: Comparison main-contractor and system integrator (own figure)

Main-contractor	System Integrator
Integration: Design, Construction, Maintenance Operation	All (including deconstruction)
Responsible, but not the owner	Owner of the contracts
Responsible for the building during maintenance and operation	Not responsible for the building components
Client involved with demands	No client
Not responsible for concept design	Responsible for concept design
Needs investors	No investors needed
Outsourcing	In-house knowledge

Table 4.4: Comparison sub-contractor and provider (own figure)

Sub-contractor	Provider
Integration: design and construction	All (including deconstruction)
Product delivery	Owner of his product (responsible for the whole life-cycle)
Outsourcing	In-house production
Short-term mindset	Long-term mindset
Focused on functionality	Focused on performance
Partnership based on cheapest product	Preferred partnership based on trust and long term collaboration

4.10. COMPARING THE CURRENT DEMAND PERSPECTIVE

Both new actor roles were first described from a supply perspective. However due to the new characteristics the system integrator could also be compared from a demand perspective. The findings in the section followed from an interview with Juan Azcarate Aguerre (2021). From a demand perspective the system integrator can best be compared to a developer. There are two types of developers, one who develops to resell to an investor, and a developer who owns the property and rents it out (commercial sector) or uses it for own primary activities (corporate and public sector). The main difference is a short and long term mindset. Table 4.5 compares the tasks of the two type developers with the tasks of a system integrator based on the four aspects of a project. The legal aspect is an overarching aspect which is involved in all tasks. The new role of the system integrator could result in conflicts with the current developers. The table shows if they execute the task (V), possibly execute (V/X) or do not execute (X).

Table 4.5: Comparison developer/owner and system integrator (own figure)

Task	Developer	Developer/owner	System integrator
Organise project finance	V	V	V
Project cash flow	V	V	V
Explotation cash flow	X	V	V
Technical concept	V	V	V
Technical execution	V/X	V/X	V
Technical management	X	V/X	V
Technical commissioning	V	V	V
Service commissioning	X	V	V
Contract management	X	V/X	V
Information management	X	X	V

As table 4.5 indicates the developer/owner has many tasks in common with the system integrator. This overlap exists due to the knowledge and network characteristics of the actors. This is due to the long term investment goal of both actors. Since they are still the owner of the building, they will have more possible tasks to fulfil. The developer/owner, most of the time, outsources some of his tasks, however is able to execute them.

Another difference is that the system integrator connects product-service systems, and needs to interact with these actors, over the whole project life-cycle. Where actors who interact with the developer/owner, deliver their product and leave to the next project. The focus for the system integrator has to be on long term collaborations and create preferred partnerships. This is important since the actors will be involved for many years. The developer/owner is the owner of only hard assets, while the system integrator is the owner of partly hard assets and contracts of integrated product/service packages. This will result in more interactions with the actors involved.

To conclude, the system integrator is, from a supply perspective, moving towards the demand perspective and vice versa. This means that he will execute both the supply and demand tasks, as mentioned before the system integrator will need more in-house knowledge and management tools to facilitate this (figure 4.19). The system integrator could also facilitate in some of the tasks, for a contractor or developer/owner, in the recommendations this will be explained. He is able to replace both sides, then he will become a huge horizontally integrated company, as we have seen in other industries (Apple, Microsoft, etc.).

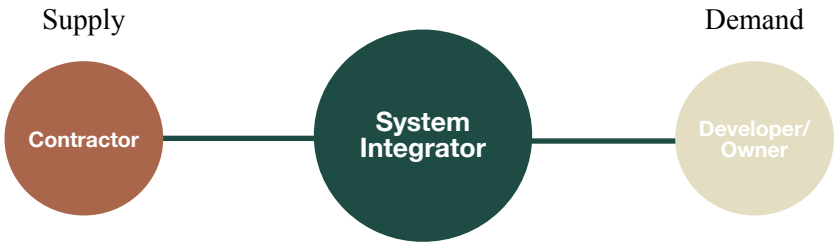


Figure 4.19: Supply and demand perspective tasks for the system integrator (own figure)

4.11. DELIVER

To validate the findings of the previous section, one experienced project manager was interviewed. He has been involved in all phases of a project life-cycle. The interviewee was not familiar with the subject of product-service systems and was not involved with my research before, to avoid bias. The interview was an iterative process, where questions went back and forth while the finding where explained. After explaining the findings, the interviewee was positively surprised about the possibilities. He underscored that a lot has to be done, if one would like to implement product-service systems in the built environment.

4.11.1. Ideal situation

The interviewee indicated that in an ideal product-service system situation, there is no need for clients who own the building. Clients become users who only use the facilities of a building, this is what you see in other industries as well. This new situation creates flexibility for the users and they are fully able to focus on their core business. In an ideal world all providers stay the owner of their products, the system integrator will be the owner of all contracts who together form the building. The system integrator will be paid by the users and pays the providers periodically, the difference between these two payments is his turnover. His business model is providing the service to connect all components, if he does this efficiently, his margins will be higher as well.

The new role of a system integrator could be a new role for an investor, however their mindset has to change completely. Instead of just putting money on the table, they will need to take more knowledge in-house which is able to bring all components together. The investor could invest in the different providers, and get paid periodically for a long period of time. This could be a very interesting business model for an investor, since he will be the owner of all the contracts, he has the security of owning the building itself.

The revenue model of the providers is to take care of their products over the whole lifespan, the better the product the less services needed. So his margins will be higher by delivering better products.

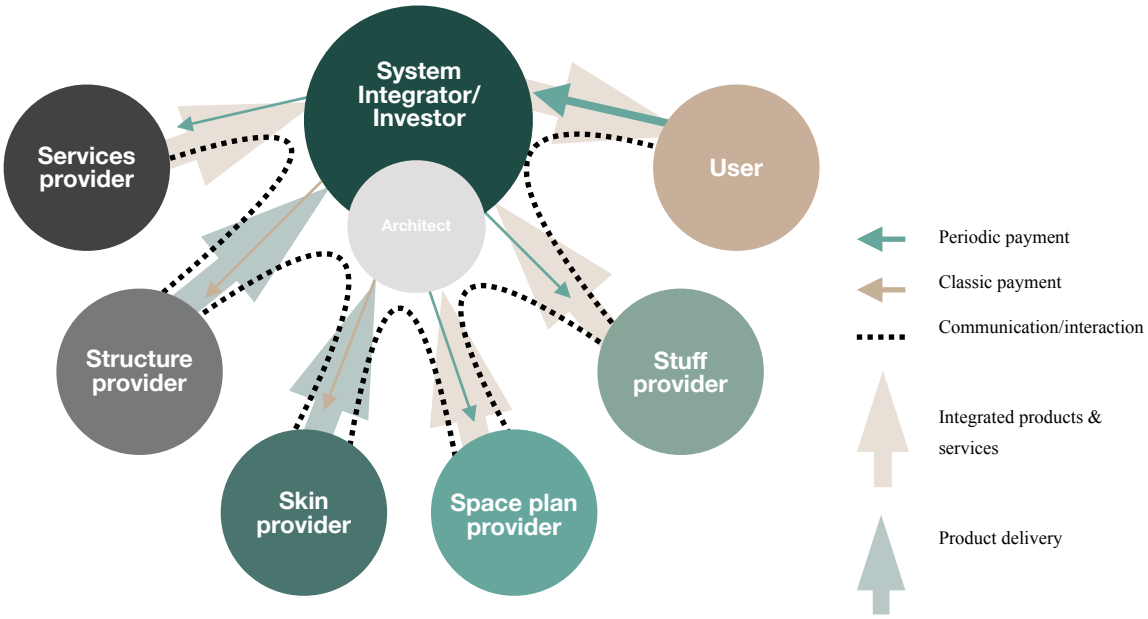


Figure 4.20: Realistic restructured stakeholder network for the construction project organisation (own figure)

4.11.2. Realistic situation

For the ideal situation much has to change therefore a more realistic step was described by the interviewee. To provide security the system integrator could stay the owner of the site, structure and skin, and the other layers could be done as described in the previous section, due to lower costs and shorter lifespan (figure 4.20). The product delivery will be paid as it is done most of the times, based on the products and time needed to create these products. This will provide more circularity and flexibility to the building, than what they are now. This investment is interesting for long term investors, or governmental agencies. A good example is “erfpacht” in the Netherlands, the municipality stays the owner of the site and the residents have to pay monthly to live on that site. This could be interesting for the structure and skin as well. Another reason is that the shift in ownership for services, space plan and stuff is easier and the risk is lower. It could be a nice step towards 50% circular in 2030, where half of all materials used in a building needs to be circular. However one of the interviewees indicated that if the whole life-cycle was shorter, like 40-50 years it would be interesting to implement product-service systems for all layers. One would be able to break down the building and build it somewhere else. Another issue is that the breach of contract has to be possible, and that rules to facilitate this have to be drawn up. The contracts have a long lifespan, but if one of the actors is not happy with the performance of the other he should be able to stop the contract in some way.

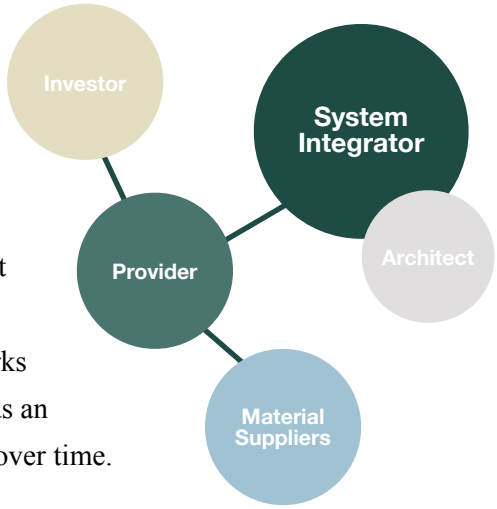
4.11.3. How to use the restructured stakeholder network

This section will elaborate on the realistic approach for the construction project organisation. In 2030 the built environment should be circular for 50%, so the realistic situation could be a good step in achieving this. It will be explained according to revised stakeholder network, shown in figure 4.19. This stakeholder network was created because of new actor roles, which are based on the needed changes.

To provide security the system integrator/investor will be the owner of the site, structure and skin layer. Also he will be responsible for the social layer during the use phase to increase the quality of life for the users. Owning these layers will provide the system integrator/investor with more security on his investment. The other layers (services, space plan and stuff) can implement the shift in ownership. The system integrator/investor will pay these providers confirm their performance.

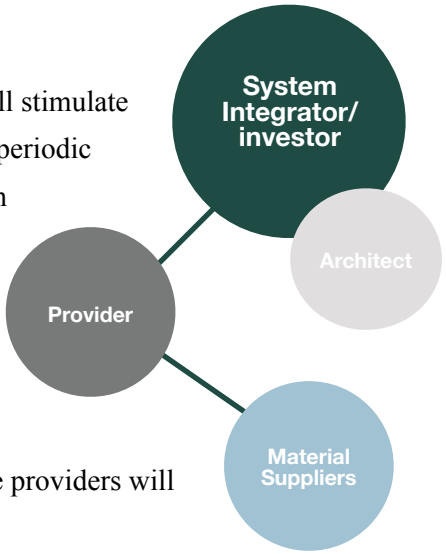
Structure and skin provider

The system integrator will take over the role of a long term investor for these layers. The system integrator/ investor will stay the owner of the structure and skin layer, due to their lifespan and his security on investment. The providers are still responsible for the design and construction, like they are now. Also they could have maintenance contract for some years after execution. The system integrator/ investor is able to monitor the building and when needed ask for repair and maintenance works from the providers. For these layers the systems integrator also functions as an investor. The building will function as a material bank and increase value over time.



The providers have to focus on circular solutions and implement this in their designs. Think of material chose, adaptable and flexible solutions. They must think of the end-of-life/deconstruction so that the materials can be used for other projects after the buildings life-cycle. The designs have to be future proof, since the other layers can change over time.

Service, space plan & stuff provider



For these layers the providers will stay the owner of their products. This will stimulate a circular incentive and is financially interesting, due to residual value and periodic payments. They will provide integrated product and service packages which are adaptable to changing demand. Their lifespans are much shorter than the other layers and are easier to change. The providers will need an investor for an incentive, so that they are able to design, develop, construct and maintain their products. After end-of-life these providers are able to take back their products and use it for other projects, this will close material loops. This could contribute to the 50% circular need by 2030. The providers will be paid according to their product performance.

The system integrator will bring all components together to one building. It has to be mentioned that for some layers the user will play a role as well, since they have demands for their facilities. The communication will go through the systems integrator, who guides this process. Because he knows how to ask and answer performance based questions.

4.12. CONCLUSION

This chapter answered the third sub-questions: What changes are needed to apply Product-Service Systems and add value within construction project organisations? The first diamond gave clarity of why current construction project organisations have difficulties with the implementation of product-service systems. The most important reason is that actors are unfamiliar with this new theory and many factors are unknown. There is a lack of collaboration and interaction between different stakeholders, due to mistrust and competitive advantage. Boundaries between the different components become vague, when integrating more products and services. There is a contrast between short- and long- term goals among the stakeholders and finally there is a lack of phase integration.

Unfamiliar with product-service systems

Lack of collaboration

Unclear boundaries

Contrast of long- and short-term goals

Lack of integration

The second diamond contributed to needed changes for a construction project organisation, which will facilitate the implementation of product-service systems. There is a need for one party who promotes product-service systems and knows about its possibilities. The theory of Stewart Brand was chosen to provide structure and clear boundaries for a project. This model divides a building in layers based on the lifespan of the component. The social layer was introduced to provide centrally organised and therefore cheaper services, to all users. Due to the social layer connecting the technical and social aspects of a building, one is able to monitor the building and act if needed. Involving experts at the start of the project will cause more room for innovation and cost certainty at the start of the project. It will save time, as clashes occur early in the project when the influence potential is still high and changes are easily adapted. More in-house production will lead to less fragmentation in the industry, higher level of trust, short communication lines and better information sharing, which will lead to more innovation, better solutions and a common goal.

Driving force

Clear boundaries

Central organised services

In-house

Early expert involvement

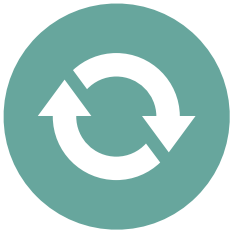
These changes resulted in two new actors roles, the system integrator and component providers. The system integrator facilitates all interactions between the actors in a construction project organisation. He is the owner of the contracts, which together form a building. It could be an interesting role for an investor, the investor will need more in-house knowledge to guide the process and focus on long-term collaborations. The role of the system integrator is horizontally integrated, he fulfils both tasks of the demand as well as the supply side of a project. The component providers remain the owner of their product, this will result in shared ownership of the building. The more in-house knowledge and production they have the better they are able to implement product-service systems. These new actor roles lead to new partner networks, collaborations and interactions between stakeholders. A realistic approach provides on the one hand security on investment and on the other hand flexibility and circularity to the building.

System integrator

Component providers

5. Discussion

This chapter will answer the last sub-question: How should these changes be used in construction project organisations to embrace the concept of product-service systems? It will look back at the literature and indicate what, according to the scholars, is needed concerning this subject. Then it will explain how the findings can be an answer to these needs and finally the added value to society will be discussed. This section will discuss five main topics, which are of importance for the implementation of product-service systems in a construction project organisation.



5.1. FROM LINEAR TO CIRCULAR

Literature indicates that there is a need for change towards a circular economy, to reduce the earth's depletion and increase economic value. Our current linear approach of “take, make and dispose” is not future-proof and will result in many ecological problems. However, this linear business model is well known and still a profitable way of working. Implementing a new business model like product-service systems, brings many uncertainties and is much more expensive than this linear approach. As two interviewees indicated, why would we change now if we can copy it from others in a few years? They won’t have any investment costs for research and innovation and will be able to provide cheaper products than their competitors for the next few years.

Changing now will give a competitive advantage in the long run. While you know all the ins and outs of this model, the competitors still have to figure out how to implement it. Besides that, literature indicates that product-service systems and the circular economy could be an answer to the growing sustainable demand. Construction project organisations try to meet this demand with conservative and linear approaches. Circular projects are asking for new structures and different types of organisations.

The outcomes of this research gave possible changes for construction project organisations and how they could implement product-service systems. It narrows the gap for the change from a linear to a circular economy and gives suggestions on how to form a construction project organisation which is able to increase project value by restructuring its stakeholder network. The focus should be on long-term collaborations, interactions and common goals, instead of competing for the lowest price. A lot has to be

figured out for the implementation of product-service systems. Think of other elements a project consists of: technology, finance, law and organisation.

This research is a first step in how one could organise a project and bring the different components together, by collaborating in a different way. Actors are currently developing their own product-service system, and don't want to share their knowledge. This research gives suggestions on how they can collaborate, won't lose any competitive advantage, and together, can increase project value. It provides a circular organisation for a circular construction project.

5.2. SHIFT IN OWNERSHIP

The shift in ownership is seen as an opportunity to close material loops and reduce waste. The provider will maintain ownership of his products, is responsible for the services and is able to execute adjustments to meet new demands and expand the lifespan. This is a growing trend in all industries, users want to use the product, but don't want to own it. The users are fully unburdened and can focus on their core business. In return they pay periodically and don't have any investment costs.

To facilitate this in the construction industry, the system integrator is introduced, who will bring all components of a building together. The system integrator is responsible for the interactions between the providers over the whole project life-cycle. Bringing all components together to serve the users in their needs. A building is a one of a kind and complex project, the system integrator is able to give structure and guide the actors in their process. Dividing a project into sub-projects based on building in layers will provide clear boundaries for each provider. However the system integrator is able to facilitate cross-discipline interaction and knowledge sharing between the separate layers.

The new building layer (Social) introduced in this report will increase project knowledge over time and provide central organised services. It is needed to organise this centrally because otherwise all stakeholders will act on their own behalf and will be unclear for the users. The system integrator is able to monitor the building and learn during the user phase, and ,if needed, implement adjustments that will benefit the overall project.

In an ideal situation the system integrator is the owner of all the contracts who together form the building, they won't own any assets like a developer does now. A good example from another industry is Uber, the

biggest taxi company in the world. However they don't own any cars, they provide the connection between the taxi driver and users. A first step to this future perspective could be the separation of economic and legal ownership. To speed up the process, governments should change regulations, which promote the use of product-service systems and shared ownership.

5.3. PROJECT FLEXIBILITY

In current projects the influence potential decreases at the same time that project knowledge increases. This means the more we start to know about the project the less we are able to implement changes. Literature suggests to involve experts early on in the project, to increase project knowledge while the influence potential is still high. This should result in early clash detection, accurate cost estimations and time efficiency.

The restructured stakeholder network in this research brings the component providers (experts) up front in the project. They are the owner of their own products and will be responsible for all phases of their component life-cycle. The components are connected to product-service systems based on their lifespan. This enables the providers to adjust, change or replace a component without touching or damaging others. Early expert involvement gives flexibility at the start of a project. The connection between building in layers and product-service systems provides flexibility to a building over its life-cycle. This is interesting because normally the influence potential only decreases and stops after completion, but now the influence potential increases over time (figure 4.16).

To make this possible the actors should focus on performance instead of functional requirements. The system integrator needs to ask the right questions (performance based) and at the same time needs to give the providers room for innovation. The providers will be able to provide new ideas and cheaper solutions, while still meeting the performance required.

5.4 INFORMATION MANAGEMENT

Multiple scholars showed that information sharing and cross-discipline interaction will lead to more innovation. While this is beneficial for everyone in practice this does not happen, because parties are scared to lose their competitive advantage. Concerning the subject of product-service systems and circularity, every actor is working on their own island and re-inventing the wheel without interacting with others who preceded them.

Which is strange because why would a skin provider not share his information and knowledge with a service provider? They are not competitors and could learn from each other concerning the legal, financial, technical and organisational aspects of a project. Information sharing is also important when it comes to designing and bringing the components together. To facilitate this information and knowledge sharing, the system integrator is introduced. The system integrator will manage all interactions and monitor how things are going during the project life-cycle. Learning from mistakes, digitising information and expert knowledge will be a key role for the system integrator.

The role of the system integrator will move from project management to information management. Collecting the right data and using this knowledge in other projects. Experts will get a controlling role instead of advising. Good examples are, for example, a cost consultant and planner, who take data from known databases, filter the data and connect them to certain materials and processes. A computer is able to do this faster, more accurately and up to date. To facilitate this the system integrator will need tools to execute these tasks. Therefore I predict that a programmer will become more important than a cost or planning consultant in the future.

Information management will become the most important task of the system integrator. Actors won't need to re-invent the wheel. Not only in the design and construction phase real time data could help, also in the user phase the system integrator will be able to collect data and act accordingly.

5.5 MORE IN-HOUSE KNOWLEDGE AND PRODUCTION

With a higher level of integration and performance orientation, the product-service system has a higher possibility of being sustainable. Besides that, product-service systems have the possibility of becoming circular if all stakeholders in the supply chain participate. For these two reasons the change to more in-house knowledge and production is suggested. More in-house management for the system integrator to guide the process, and more in-house for the providers for less fragmentation, higher level of trust, short communication lines and better information sharing, which will lead to more innovation, better solutions and a common goal.

This report suggested two options; long-term collaborations or taking over other actors of the supply chain. More in-house knowledge and production will lead to bigger companies and less competitors on the market. One could say positive and negative things about this change. When looking to other

industries this already happened decades ago, think of a Microsoft or Apple. The more products one owns, the more one is able to apply product-service systems to their components. The provider will maintain ownership of his components and will be able to take them back after the contracting period, which will lead to residual value. He is able to use them for other projects or adjust them to expand its lifespan.

6. Conclusion

This research gives a better understanding of the transition for a construction project organisation towards the circular economy, by implementing product-service systems. It addresses the possibilities of a restructured stakeholder network, which increases project value. This chapter will answer both the sub- and main- questions, it will elaborate on the limitations of this research and finally it will give recommendations for the future research and the industry.

6.1.1. What are the aspects of construction project organisation in the current state of knowledge, towards a Circular Economy?

There is a need for change towards the circular economy. In this study, the product-service system is chosen to be the business model that can facilitate this change. Construction project organisations could be an important vehicle to promote and implement product-service systems and the circular economy within the built environment.

Aspects of the current construction project organisations that are influenced by the circular economy are the building components, project life-cycle phases and stakeholders. While most literature concerning the circular economy and product-service systems is about the first two aspects, there is little known about stakeholder interaction. Literature refers to the need of changing partner networks, different interactions and standardised processes to be able to implement product-service systems and increase project value.

6.1.2. How to gather and analyse the aspects of construction project organisations for the implement product-service systems?

The methodology used for this thesis is a design-based research. The different phases of the double diamond method will provide guidance to this study. Experts were interviewed in the discovery phase, they gave a better understanding of the difficulties for construction project organisations to implement product-service systems. Semi-structured interviews were conducted with the guidance of an interview protocol. According to the knowledge of the expert, the interviewer will dwell on some of the questions, to get more relevant data. The second phase will clearly define the current problem definition. The third phase will contribute to needed changes and to restructure the stakeholder network of a construction project organisation with the help of two interviewees. Lastly, one validation interview will contribute to the feasibility and usefulness of the model and new insights will be implemented accordingly.

6.1.3. What changes are needed to apply Product-Service Systems and add value within construction project organisations?

The first diamond gave clarity as to why current construction project organisations have difficulties with the implementation of product-service systems. The most important reason is that actors are unfamiliar with this new theory and many factors are unknown. There is a lack of collaboration and interaction between different stakeholders, due to mistrust and competitive advantage. Boundaries between the different components become vague, when integrating more products and services. There is a contrast between short- and long- term goals among the stakeholders and finally there is a lack of phase integration.

Driving force | **Clear boundaries** | **Central organised Services** | **In-house** | **Early expert involvement**

The second diamond contributed to needed changes for a construction project organisation, which will facilitate the implementation of product-service systems. There is a need for one party who promotes product-service systems and knows about its possibilities. The theory of Stewart Brand was chosen to provide structure and clear boundaries for a project. This model divides a building in layers based on the lifespan of the component. The social layer was introduced to provide central organised and therefore cheaper services, to all users. Due to the social layer connecting the technical and social aspects of a building, one is able to monitor the building and act if needed. Involving experts at the start of the project will cause more room for innovation and cost certainty at the start of the project. It will save time, clashes occur early in the project when the influence potential is still high and changes are easily adapted. More in-house production will lead to less fragmentation in the industry, higher level of trust, short communication lines and better information sharing, which will lead to more innovation, better solutions and a common goal.

Unfamiliar with product-service systems

Lack of collaboration

Unclear boundaries

Contrast of long- and short-term goals

Lack of integration

These changes resulted in two new actors roles, the system integrator and component providers. The system integrator facilitates all interactions between the actors in a construction project organisation. He is the owner of the contracts, which together form a building. It could be an interesting role for an investor, the investor will need more in-house knowledge to guide the process and focus on long-term collaborations. The component providers own the product, this will result in a shared ownership of the building. The more in-house knowledge and production they have the better they are able to implement product-service systems. These new actor roles lead to new partner networks, collaborations and interactions between stakeholders.

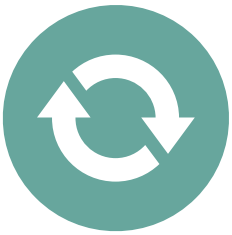
System integrator

Component providers

6.1.4. How should these changes be used in construction project organisations to embrace the concept of product-service systems?

The discussion elaborated on five subjects concerning the implementation of product-service systems in a construction project organisation. The change from the linear- to circular economy, the shift in ownership, project flexibility, information management and in-house knowledge/production were discussed in this section.

Linear to circular



This research is an organisational step closer to change from a linear- towards a circular economy, by implementing product-service systems. It provided possible organisational changes with the focus on long-term collaboration and common goals. Without losing competitive advantage and increasing overall project value.

Shift in ownership

The shift in ownership can close material loops, the providers will own their products. The system integrator was introduced and will be the owner of all the contracts, which together form the building. The system integrator connects the social and technical aspects of a building. A first step could be the separation of legal and economic ownership.

Flexibility

Early expert involvement, together with clear boundaries based on the building layers will provide flexibility to the building and adapt to new demands. The focus has to be on performance instead of functional requirements. The right questions have to be asked and the providers need room to provide solutions and innovations while answering these questions.

Information management

The role of the system integrator will move from project management to information management. Collecting the right data and using this knowledge in other projects. Experts will get a controlling role instead of advising, during the user phase the system integrator will be able to collect data and act accordingly.

In house

More in-house knowledge and production will lead to bigger companies and less competitors on the market. The more products one owns, the more one is able to apply product-service systems to their components. The provider will maintain ownership of his components and will be able to take them back after the contracting period, which will lead to residual value. He is able to use them for other projects or adjust them to expand its lifespan.

It has to be mentioned that a lot has to be figured out, but this research is a nice step in the right direction. The implementation of product-service systems in a construction project organisation, is a promising move towards the circular economy.

6.1.5. Answering the main research question

The previous answers contribute to the conclusion which answers the main-question: *How can construction project organisations change towards the Circular Economy and add value by implementing Product-Service Systems?*

This report shows that the construction project organisation is able to increase value by implementing product-service systems. The shift in ownership from client to provider, gives a circular incentive to take back their products. Connecting product-service systems to building layers, based on their lifespan, will provide clear boundaries for the stakeholders and at the same time flexibility to the building. One is able to reuse their products or adjust and expand their product lifespan, which reduces waste and the depletion of the earth's resources.

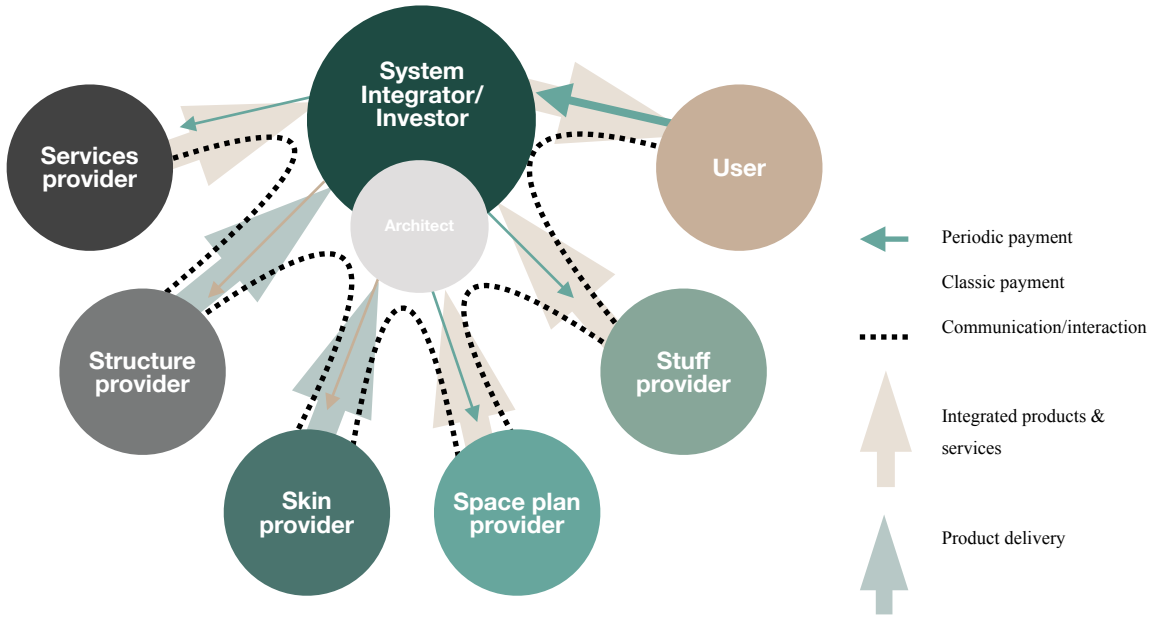


Figure 4.20: Realistic restructured stakeholder network for the construction project organisation

The changes needed for the implementation of product-service systems in the construction organisation are; One party who promotes product-service systems and brings all actors together. The concept of building in layers should be connected to the product-service systems based on the component lifespan. This provides clear boundaries for the different stakeholders in the stakeholder network. A seventh layer is introduced to connect the social and technical aspects of a building, this increases the quality-of-life and one is able to monitor a building and provide central organised services. To increase project knowledge and flexibility it is important to involve experts early in the project and focus on preferred partnerships. Finally, long term collaborations and in-house knowledge/production is important to increase trust and circularity.

These changes resulted in two new actor roles (figure 4.19): the system integrator and component providers based on the building layers. The system integrator is the owner of all the contracts which together form a building. He facilitates the interaction between all actors over the whole life-cycle of a project. The role of the system integrator is horizontally integrated, he fulfils both tasks of the demand as well as the supply side of a project. In this new situation there are no clients, but just users of the building. These users pay the system integrator periodically and he pays the providers based on their performance. This could be an interesting role for an investor, however they have to change their way of working.

On the other hand the providers maintain ownership of their products, which together form the building. They are responsible over the whole life-cycle of the project, after this period they are able to reuse, repair or adjust their products to new demand. The more production and knowledge the provider has in-house the better he is able to provide product-service systems. This will result in more circular solutions and less depletion of the earth's resources. This realistic approach provides on the one hand security on investment and on the other hand flexibility and circularity to the building.

These changes and new actor roles resulted in a restructured stakeholder network for a construction project organisation. This transition will result in a different way of working, new partner networks, other collaborations and interactions between stakeholders. The focus needs to be on long-term collaborations, performance orientation and quality-of-life. Due to the restructured stakeholder network of a construction project organisation, it is easier to implement product-service systems and contribute to a circular economy.

6.2. RESEARCH LIMITATIONS

Providing research limitations is needed to validate the findings and discussion of this report. These limitations will be used to give recommendations for future research and the industry. The limitations addressed are based on choices made while conducting this research.

Implementing product-service systems in the construction industry is a relative new subject. There are many unknowns and a lot has to be figured out. As mentioned in the report, actors are not willing to share information because they are scared of losing their competitive advantage. This limited the findings as well.

It is hard to compare these new interactions and collaborations with current delivery models. There is no standard delivery model to compare to, other delivery models have some elements which are discussed in this research. A comparison has been made with a DBFMO, but more comparisons should be made to better understand the situation. Besides that, implementing product-service systems on a big scale has not been done before.

The interview results already had some overlap in their answers, however the results for the problem definition and solutions were not saturated. More interviewees would benefit the outcomes and would lead to better answers. Multiple actors have been interviewed, however more diverse actors could have been interviewed, to get a more complete overview of the stakeholder network.

Interviews in real-life would be preferred but due to the COVID-19 circumstances this was not possible. Real-life is preferred because one is able to keep the tension high and visualise their ideas when talking about the subject. Interaction is totally different in real-life and one is able to react to body language.

The Scope of this research was the organisational aspects of a construction project organisation. However the legal, finance and technology aspects of a project are also very important for product-service systems. New findings concerning the other elements would influence the organisation as well.

6.3. RECOMMENDATIONS FOR FUTURE RESEARCH

It would be interesting to look into the other elements, finance, law and technology, which also have a huge influence on the organisational aspect of a project. New findings in the other elements will result in changes in the organisational aspects as well. It would be interesting for new research to go deeper into these elements.

A good subject could be the separation of ownership into legal- and economic ownership. The client will be the legal owner and is able to use the product how he wants to and the producer is the economic owner. A good example is erfpacht in the Netherlands, it would be interesting to implement this idea to other components as well, when implementing product-service systems.

This research connected product-service systems to the building layers of Stewart Brand. It would be interesting to look at this into more detail, try different options and compare them with each other. What is the best combination for which situation?

There is a lot not known about the residual value of products after the end-of-life and how to take this into consideration, when calculating a periodic payment strategy. This is of high importance for product-service systems, how to standardise this and how should it be considered?

It could be very interesting for an architecture student to create a “Fidic” design book. This book gives guidance for the design principles between the different layers, what are the connections and what are the rules of the game? Also what kind of information each layer needs from one and other.

There is a need for breach of contract in long-term collaboration, when one party is not happy about the other's performance. How should one integrate this? What happens when one party goes bankrupt, this has to be figured out and are interesting subjects for future research.

6.3.2. Recommendations for the industry

Organisations have to take information management into consideration and look at other industries and how they have managed data over the years. The construction industry could learn a lot from companies like Google and Amazon. Not only is the information interesting but also the organisation of their supply chains.

The construction industry has been conservative as long as we know it. While margins are small, they should invest much more into innovation and new techniques, this will benefit them in the long run. This possible change needs more time and research, but there is no time to lose. Governments are forcing industries to change their linear behaviour towards sustainable solutions. Adapting to change now will give your company competitive advantage in the future.

6.3.3. Recommendation for Drees&Sommer

Drees&Sommer has many clients who have an increasing demand for circularity, product-service systems could answer this demand. From the supply side many actors have already implemented product-service systems, while on the demand side, not many actors are familiar with the possibilities. For this reason Drees&Sommer should create awareness among their clients. Drees&Sommer has all types of management in-house to guide the client through the whole life-cycle of a project. Currently Drees&Sommer is service orientated and gets paid accordingly. They could in collaboration with an investor implement the realistic approach (section 4.11.2) and guide the long term investor through the project life-cycle. This first step is convenient, because they are familiar with the different these types of management.

While Drees&Sommer has different types of management in-house, they have to integrate them to make this work. When integrating all types of management they can provide the clients with integrated service packages over the whole project life-cycle. Besides that, they have to promote product-service systems as an answer on the circular demand, and raise awareness among their clients.

The system integrator will have tasks from both the supply and demand side of a project (figure 19). A realistic approach for Drees&Sommer could be that they help both parties with the tasks they are not familiar with. So for the developer they could take over supply tasks, and for the contractor they could take over demand side tasks.

The next step in research could be how Drees&Sommer should fulfil this role. What types of clients could be interested and which actors would like to collaborate. While some of the layers can be executed as they currently are, others can deliver integrated packages and therefore increase circularity and adaptability within the building.

6.3.4. Remarks on research

As mentioned in table 4.2. this research looked into the organisational aspects of a project. The gap in literature showed that there was a need for more information concerning interactions and collaborations between different actors when implementing product-service systems. However looking back on my research process, I think one is not able to dive into one aspect without involving the others, especially the legal and financial aspects.

The interviews were focused on the organisational aspects, however the other aspects have been discussed. These aspects came up in the interviews and these findings are described throughout the report. So the other elements are discussed, but due to time limitations and scope boundaries, they are not discussed in detail. In this section they will be discussed again as a clear remark on this research.

This research showed that there are changes needed in the organisational structures to ease the implementation of product-service systems. But to make this possible, regulations have to change. Which rules have to change so that producers can remain the owner of their products, but most of all, rules which promote new types of business models towards the circular economy. As an example, currently it is not possible to be a shared owner of a building due to regulations, however this is the essence of this research. If the regulations don't allow this new way of working, then this business model should adapt to these rules.

New business models like product-service systems, will result in another financial system. Currently, actors focus on product delivery, with products that outlive their guarantee period. In the new situation, the actors will need a long term focus and they will be paid based on their performance. So when their products don't work as they promised, the actors will be paid less. The payment will be periodically for the contract duration and how they should deal with the **r**esidual value. The increase of building flexibility and project knowledge will also increase the value of the building. Who will be the owner of this "extra" value, the providers, system integrator or both? While working together towards a common goal, how to split the increasing/decreasing value of a building?

Finally, the technical aspects of a building, some things have been said, but rules have to be made. What has to be standardised towards the circular economy. While technical boundaries for actors will result in more innovation, the rules for these boundaries have to created.

To conclude, the starting point, the research scope, was too narrow. I should have considered the other aspects as well, which maybe would result in other changes and different collaborations. However due to time limitations, I was not able to address these aspects fully as they should have been. This would have resulted in a more complete research, however focusing on the organisational aspects has resulted in relations with the other aspects as well. These relations are explained in the report, but more detail would benefit the transition towards the circular economy by implementing product service systems.

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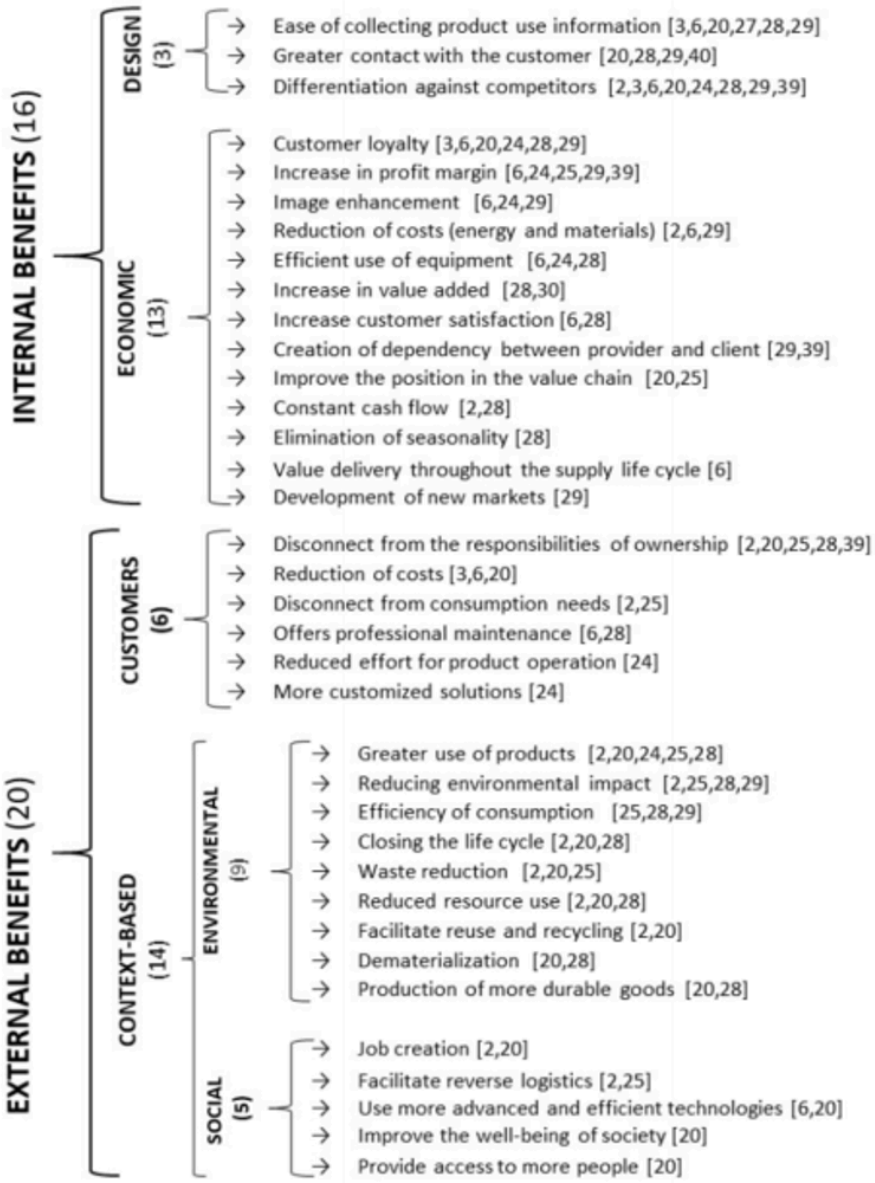
8. Appendix

Appendix 1: NL-SfB connected to building in layers

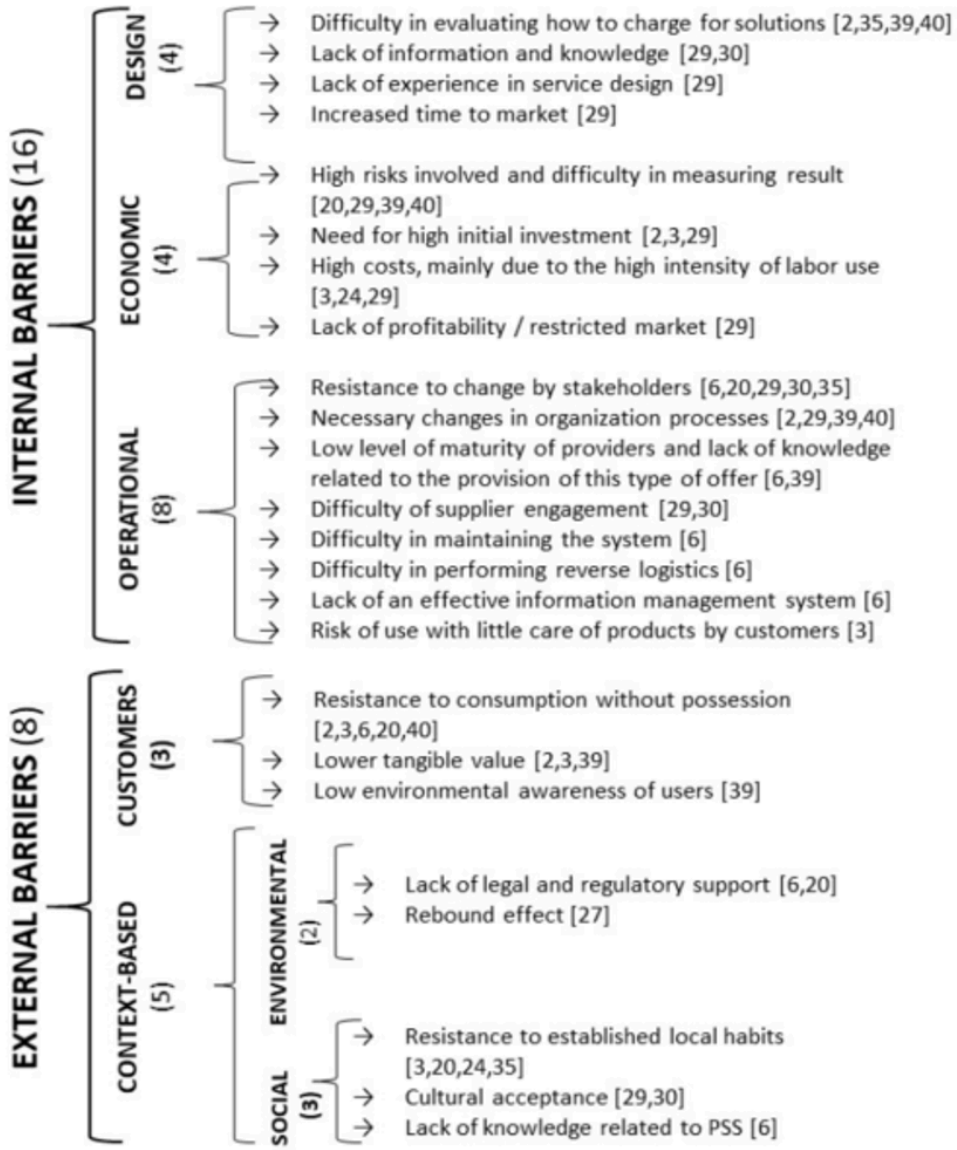
Site	Structure 30-300yrs	Skin 20-35yrs	Services 15-30yrs	Space Plan 10-30yrs	Stuff 5-20yrs
Terrain	Foundation	Facade	Drainage	Inner Wall	Lose Furniture
Project facilities	Structural	Roof	Water	Floor	Lose User Inventory
			Cooling	Finishing	Lose Kitchen Inventory
			Heating	Fixed Furniture	Lose Sanitary Inventory
			Air Handling	Fixed User Facilities	Lose Maintenance Inventory
			Control Systems	Fixed Kitchen Facilities	Lose Storage Inventory
			Fire Safety	Fixed Sanitary Facilities	
			Central Electricity	Fixed Maintenance Provisions	
			Energy Supply	Fixed Storage Facilities	
			Lighting		
			Communication		
			Security		
			Transport		
			Building Management System		

Appendix 2: Benefits and barriers for the implementation of product-service systems

Benefits



Barriers


INTERNAL BARRIERS (16)
DESIGN (4)
→ Difficulty in evaluating how to charge for solutions [2,35,39,40]
→ Lack of information and knowledge [29,30]
→ Lack of experience in service design [29]
→ Increased time to market [29]
ECONOMIC (4)
→ High risks involved and difficulty in measuring result [20,29,39,40]
→ Need for high initial investment [2,3,29]
→ High costs, mainly due to the high intensity of labor use [3,24,29]
→ Lack of profitability / restricted market [29]
OPERATIONAL (8)
→ Resistance to change by stakeholders [6,20,29,30,35]
→ Necessary changes in organization processes [2,29,39,40]
→ Low level of maturity of providers and lack of knowledge related to the provision of this type of offer [6,39]
→ Difficulty of supplier engagement [29,30]
→ Difficulty in maintaining the system [6]
→ Difficulty in performing reverse logistics [6]
→ Lack of an effective information management system [6]
→ Risk of use with little care of products by customers [3]
EXTERNAL BARRIERS (8)
CUSTOMERS (3)
→ Resistance to consumption without possession [2,3,6,20,40]
→ Lower tangible value [2,3,39]
→ Low environmental awareness of users [39]
CONTEXT-BASED (5)
ENVIRONMENTAL (2)
→ Lack of legal and regulatory support [6,20]
→ Rebound effect [27]
SOCIAL (3)
→ Resistance to established local habits [3,20,24,35]
→ Cultural acceptance [29,30]
→ Lack of knowledge related to PSS [6]

Appendix 3 Interview: Problem definition

Introduction

Interviewer:

- Background
- Study
- Company

Interviewee:

- Background
- Company
- Expertise

Interview Goal:

Getting a better understanding of the problem: Why do current construction project organisations have difficulties with the implementation of product-service systems?

Interview Structure:

Background information:

- Circular economy
- Product-service systems
- Construction project organisation

General questions:

- What do you think of the concept of pss in our industry?
- Does the incentive of pss go top-down or bottom-up?
- If pss is used do they take care of all phases of a life-cycle?

Questions about shift in ownership:

- Do clients know of the possibilities of pss and the shift in ownership?

○Are clients willing to handover their responsibilities and let suppliers decide?

○Do you think clients are willing to pay more for integrated products/services?

- Is the shift in ownership interesting for suppliers?
- Do contractors see this shift as a threat?

Questions about Collaboration:

- Do you think that fragmentation in construction holds back innovation?
- Do you see different interactions between stakeholders when they use pss?
- Do you think that boundaries between different disciplines are clear?
- Are different parties looking for integration with each other, or are they only concerned about their own product?
- How do different parties look at a long term collaboration period and periodic payment?

To conclude: Getting a better understanding of the problem: Why do current construction project organisations have difficulties with the implementation of product-service systems?

Future perspective about the subject

Presentation problem definition

1

2

3

4

5

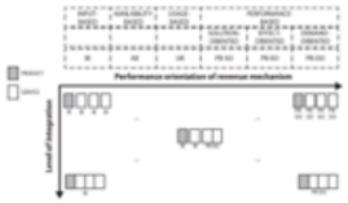
6

Product-Service Systems

- Shift in ownership and responsibilities
- Integration of products and services
- Waste reduction
- Adaptive to changing demand
- Long term contract and Periodic payment

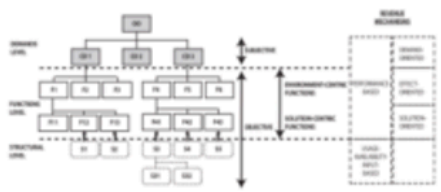
7

Product-Service Systems



8

Product-Service Systems



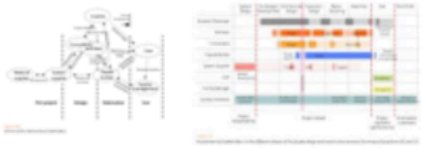
9

Construction Project Organization

"A construction project organization is a cooperative network of different stakeholders who are involved throughout the life-cycle of a project. Where a project should be seen as the collection of interrelated components, which together form a building."

10

Construction Project Organization



11

Interview goal

Getting a better understanding of the problem, why current construction project organizations have difficulties with the implementation of product-service systems?

12

Afstudeer interview 1 – PM project development – 15/12/2020

Demand orientation zie je steeds meer in gebouwen, onder te titel smart buildings. Bijvoorbeeld een medewerker die met zijn telefoon het licht of temperatuur kan instellen voor een bepaalde ruimten.

In de laatste maanden is er steeds meer bekend over het onderwerp pss, dgbc heeft een Paris proef commitment getekend en grote bedrijven zijn hier publiekelijk mee bezig. De Circulaire economie is sinds een paar maanden hot.

Wie is er verantwoordelijk als producten gelinkt zijn en er ontstaat een defect.

Martijn veerman vragen naar juridisch eigendom

Korte termijn gedachten bij de klant, maakt pss lastig in de bouw

General questions:

- **What do you think of the concept of pss in our industry?**

Het heeft een toekomst, maar er moeten veel grote obstakels overwonnen worden. Gebouwen bestaan uit honderden component die ook weer vast zitten aan elkaar. Na een gebouw te hebben gebouwd verkoop je hem, en daar zitten dan geen leasecontracten aan vast. Hierdoor heeft de financier of belegger een stuk zekerheid want hij heeft het gebouw als onderpand, iets tastbaars. Grootste uitdaging is, wie is er eigenaar van een pss, wie heeft er wat over te zeggen, welke afspraken moeten erover gemaakt worden. Financieel, juridisch en eigendom zitten er de grootste uitdagingen, ook omdat een gebouw heel complex is, weinig standaardisatie, standaardisatie is een must. Iedereen wil unieke gebouwen maar standaardisatie is nodig, dus waar trek je de lijn? Grote gebouwen zijn voor nu nog te complex, misschien klein beginnen. Maak standaard componenten die bekende interacties hebben.

Waarom het niet van de grond af komt is omdat een lineair model is nu nog een veel beter verdienmodel. Maar dat is nu ook een ding met garantie

- **Does the incentive of pss go top-down or bottom-up?**

Bereidwilligheid vanaf de top bepaald of iets doorgaat of niet. Maar jonge medewerkers beginnen zich te verenigen en willen dat er verandering plaatsvindt. Er is een enorme generatiekloof, maar bovenaan beginnen zich hier nu ook van bewust te worden. Dus het komt van onderaf maar vanaf bovenaf moeten ze dit opnemen, gebeurt dit niet dan komt het niet van de grond.

- **If pss is used do they take care of all phases of a life-cycle?**

Er wordt steeds meer geïntegreerd, met name door BIM, wel met een kleine volgorde. Deconstructie wordt veel te weinig aan gedaan, wel materiaal paspoorten maar niet hoe het demontabel zou moeten zijn. De manier van denken moet veranderen, misschien meer vanuit een tijdelijke behoefte, en vooral meer circulair.

Questions about shift in ownership:

- **Do clients know of the possibilities of pss and the shift in ownership?**

Grote bedrijven vinden het interessant, financieel gezien, periodiek betalen, geen kosten, geen grote investeringen. Lease is in deze onzekere tijden ook gunstiger. Je wilt een tijdelijke flexibiliteit bieden aan

de klant, maar vastigheid aan de financier. Dus hier moet een goed balans in gevonden worden. Balans tussen lange en korte termijn.

○**Are clients willing to handover their responsibilities and let suppliers decide?**

Ja want ontzorgen, geen omkijken naar, verantwoordelijkheid ligt bij iemand anders. Hierdoor kunnen zij zich gewoon focussen op hun core business!

○Do you think clients are willing to pay more for integrated products/services?

Zelfde antwoord

- **Is the shift in ownership interesting for suppliers?**

Nu juist een hoge investeringen kosten, maar wel periodiek betaald waardoor je pieken en dalen kan uitvlakken.

- **Do contractors see this shift as a threat?**

Sommige vinden het geen enkel probleem, andere kunnen hier niet mee overweg. Ze zijn traditioneel, willen vaak iets neerzetten en gelijk weer weg, dat kan nu niet. Bang dat pss steeds meer op dbfmo gaat lijken. Ondanks dat verschillende partijen een pss leveren is het toch beter om 1 facilitator te hebben, dan heb je 1 aanspreekpunt voor de klant. Het gaat erom dat de klant zijn core business kan blijven uitvoeren.

Questions about Collaboration:

- **Do you think that fragmentation in construction holds back innovation?**

Niet gevraagd…

- **Do you see different interactions between stakeholders when they use pss?**

Nu is iedere leverancier op zijn eigen eilandje bezig en is er weinig interactie. Op een gegeven moment zal dit wel gekoppeld worden, maar daar is het nu nog te vroeg voor. Kwestie van tijd.

- **Do you think that boundaries between different disciplines are clear?**

Producten – componenten – materialen (PCM) een manier van het opdelen van producten. Op elk niveau kun je afspraken maken, data wordt steeds belangrijker.

- **Are different parties looking for integration with each other, or are they only concerned about their own product?**
- **How do different parties look at a long term collaboration period and periodic payment?**

Je moet altijd een ontbindingsmogelijkheid hebben, dan zou het wel kunnen werken. Dan moet je vooral sturen op prestatie. Voor de producent is dit heel fijn, want je hebt duidelijkheid, zekerheid en inkomstenstroom, je weet dat je het product terug krijgt. Maar is de klant bereid zich zo lang hieraan te

committeren, dat is de hoofdvraag. Kortere contracten betekent ook duurdere contracten. Je moet naar maatwerk per klant.

Why do current construction project organisations have difficulties with the implementation of product-service systems?

3 punten: financierbaarheid (zekerheid voor de bank, van wie is het eigendom), Eigendom (wat heb ik nou gekocht en wat heb ik in bezit), manier van denken moet omschakelen, van korte termijn naar lange termijn. Klantvraag moet wel echt op gang komen, en dat is een kwestie van tijd.

Afstudeer interview 2 – Contractor – 04/01/2021

Het denken moet anders, nu is een garantie 5 jaar, waarom zou een aannemer de weg langer laten meegaan?

Verantwoordelijkheden en risicoverdeling moet je duidelijke afspraken over maken, maar hoe dat wordt ingevuld moet je vrij laten.

De drive moet juist zijn, dus de juiste vraag moet gesteld worden. Service gericht specificeren!

De visie moet omarmd worden om draagvlak te creëren. Zorg voor haalbare stapjes, naar het einddoel toe.

Binnen de bouw is competitie een belangrijke drijfveer

General questions:

- **What do you think of the concept of pss in our industry?**

heel erg onderontwikkeld en het komt weinig voor. Een veranderende dienst die eigenlijk nog niet bestaat.

- **Does the incentive of pss go top-down or bottom-up?**

De vraag is er nog niet in de markt, bij klanten in de infrastructuur. Het komt echt vanuit dura. Vanuit de suppliers is het ook nog niet bekend, zij kennen de mogelijkheden niet. Dit komt omdat dura nog niet met 100% zekerheid kan zeggen dat het ook echt daadwerkelijk werkt, en leidt tot meer circulariteit. Maar ze zien nu geen reden dat het daar niet toe zou leiden. Op het moment dat je prikkels anders legt, zijn er inderdaad andere keuzes gemaakt gaan worden die dan vervolgens leiden tot circulariteit.

- **If pss is used do they take care of all phases of a life-cycle?**

Pss geeft een prikkel die in alle onderdelen van het proces zorgt voor een incentive naar circulariteit. Aan de voorkant wordt zeker nagedacht om de rest waarde zo hoog mogelijk te houden aan het eind van het

project. Doe je dit niet dan is het interessanter om een weg zo kort mogelijk mee te laten gaan, want dat levert meer werk op, en je kan kosten rekenen voor onderhoud. En die prikkel moet eruit.

Questions about shift in ownership:

- **Do clients know of the possibilities of pss and the shift in ownership? (responsibilities, periodic payment, integrated**

product/services)

daar zijn de klanten niet happig op, want risico's voor de burgers, hoe hou je daar controle over terwijl je ownership over geeft aan een particulier. En het verdienmodel is een eng woord (restwaarde), waarom zou een aannemer daaraan kunnen verdienen en de overheid zelf niet? En er is angst dat de aannemer de materialen weer meeneemt waardoor de weg, weg is, als dit financieel aantrekkelijker is. Maar dit is juridisch gewoon vast te leggen, hier kan je afspraken voor maken. Ook financieel gezien kan je de winst bijvoorbeeld delen.

Dus de drie punten zijn: risico, juridisch en financieel.

Er is een verschil in juridisch eigendom en economisch eigendom. na(trekkingsrecht). Juridisch blijft het van de staat, maar economisch kan het wel voor de aannemer.

- **Is the shift in ownership interesting for suppliers?**

Weinig ervaring mee, de eerste stap is dit goed te laten verlopen met de klant (overheid), de vervolgstap is dit te laten werken met onderaannemers.

- **Do contractors see this shift as a threat or opportunity and why?**

Je kan als aannemer project management een project uitvoeren als dienst, want als opdrachtgever wil je geen rompslomp

Tweede verdienmodel is dat je ownership over de assets hebt. Maar dit is alleen interessant als de aannemer ook de materialen produceert, zodat die het weer kan hergebruiken. Dura is ook producent van asfalt, hier is het dus aantrekkelijk. Maar ze produceren geen beton, waardoor de prikkel hier veel kleiner is.

Het verdien model van aannemers staat überhaupt al onderdruk, wat is de rol van een aannemer.

Questions about Collaboration:

- **Do you think that fragmentation in construction holds back innovation?**

Er is heel veel wantrouwen naar andere stakeholders. Informatie wil je niet delen omdat je dan terrein verliest. Bescherming van informatie, belemmerd innovatie. Zelfs over andere sectoren.

- **Do you see different interactions between stakeholders when they use pss and how? (vertical or horizontal) are they looking for integration?**

- **Do you think that boundaries between different disciplines are clear?**

Voornamelijk de verdeling van risico is hier heel erg belangrijk, voor pss moet je die grenzen ontwikkelen. Het is een scope verhaal, wat vraagt de klant.

- **How do different parties look at a long term collaboration period and periodic payment?**

Is alleen maar interessant omdat je pieken en dalen uitgevlakt en ten tweede creëer je een ander verdien model. En ten derde, voor opdrachtgevers kunnen makkelijker blijven investeren omdat ze geen voor investering hoeven te doen.

To conclude: Getting a better understanding of the problem: Why do current construction project organisations have difficulties with the implementation of product-service systems?

- Wantrouwen tussen verschillende partijen
- Onbekendheid van de mogelijkheden om de risico's en verantwoordelijkheden te verdelen, er zijn geen standaard processen hoe leg je dit vast, we weten het gewoon nog niet
- Competenties, het vraagt om een andere manier van samenwerken en manier van denken. Hoe ga je bijvoorbeeld om met je restwaarde als er nog zoveel onbekend is.

Afstudeer interview 3 – supplier – 28/12/2020

Suppliers zouden graag willen weten wanneer ze welk component terug krijgen zodat ze hier rekening mee kunnen houden in het hergebruik.

Nu inspelen op pss zorgt voor een competitief voordeel in de toekomst.

Bedrijven verdienen prima geld zoals het nu gaat en, zullen in de toekomst businessmodellen overnemen die dan geen kinderziektes meer hebben. Het oude systeem uitmelken tot het niet meer kan, en dan overstappen.

Chainable heeft alles in house, eigen R&D, eigen design. Daardoor kan je omdenken en switchen.

Met minder materiaal, hou je geld over voor jezelf.

Er moet meer ruimte komen in de regelgeving, dat is een probleem.

Facilitaire dienst wordt getraind om hun product te onderhouden. Hierdoor verlaag je de maandlasten voor de klant en behoud je banen bij de facilitaire dienst. Dit is interessant op het gebied van coördinatie van verschillende pss systemen

General questions:

- **What do you think of the concept of pss in our industry?**

- **Does the incentive of pss go top-down or bottom-up?**

Ligt aan het marktsegment, maar over het algemeen is het top-down. Vaak wordt het duurzaamheids component opgelegd door een bestuurder en daar kan pss op in spelen. Of een ander aspect van het model dat het interessant maak, los maakbaar, tijdelijkheid of ontzorgen, denk aan onderhoud.

- **If pss is used do they take care of all phases of a life-cycle?**

Heel veel circulaire modellen opereren nog via een lineair gedachtengoed, die houden bijvoorbeeld geen rekening met het remonteren. Remonteren is demonteren en hergebruiken. Molariteit is wel key voor circulariteit. Levensduur verlenging is vaak eng omdat ze dit raakt in de portemonnee.

Questions about shift in ownership:

- **Do clients know of the possibilities of pss and the shift in ownership? (responsibilities, periodic payment, integrated product/services)**

Natrekking, als iets vast zit aan het gebouw is het eigendom van de huiseigenaar, vaak een hypotheek verstrekker. Dus een keuken is juridisch eigendom van de huiseigenaar. Maar er zijn een paar manieren om eromheen te werken.

Een goede oplossing is dat de klant juridisch eigendom heeft en de leverancier economisch eigendom

- **Is the shift in ownership interesting for suppliers?**
- **Do contractors see this shift as a threat or opportunity and why?**

Nog niet, want pss kan kosten besparen voor een aannemer. Of ze rekenen management fees, en weinig rompslomp. Facilitaire dienst wordt getraind om hun product te onderhouden.

Questions about Collaboration:

- **Do you think that fragmentation in construction holds back innovation?**

Iedereen is op zijn eigen eiland aan het werk in de toekomst zal dit misschien bij elkaar komen. Maar op dit moment is er gebrek in samenwerking. Integratie in onderhoud is er echter wel, wat de kosten aanzienlijk drukt.

- **Do you see different interactions between stakeholders when they use pss and how? (vertical or horizontal) are they looking for integration?**
- **Do you think that boundaries between different disciplines are clear?**

Hier moet je duidelijke afspraken over maken, en dingen uitbesteden die je niet in jouw pakketje hebt.

- **How do different parties look at a long term collaboration period and periodic payment?**

Ja klanten staan daarop te wachten, maar willen een financiële prikkel om het interessant te maken. Dit kan door adaptatie.

To conclude: Getting a better understanding of the problem: Why do current construction project organisations have difficulties with the implementation of product-service systems?

Product propositie, reassemblage op langere termijn. Win-win voor klant en leverancier

Total cost of ownership, er moet een verandering in de bouw komen van 1 malige transactie naar een maandelijkse betaling

Services zijn lastig om bij voorbaat in de berekening mee te nemen.

Afstudeer interview 4 – Project developer – 01/12/2021

Restwaarde is lastig om door te rekenen in je periodieke prijs

Je wilt de flexibiliteit van onder en de zekerheid van boven

Lineair is gewoon een goed verdienmodel

General questions:

- **What do you think of the concept of pss in our industry?**

Je moet onderscheid maken in gebouw onderdelen met lange levensduur en weinig onderhoud en onderdelen met korte levensduur met veel onderhoud, denk aan Stewart Brand. Voor de onderdelen met korte levensduur kan het zeker werken, die geïsoleerd zijn. Of kleine standaard projecten. Standaardisatie is nodig, in producten maar ook in afmetingen.

- **Does the incentive of pss go top-down or bottom-up?**

Het is van twee kanten een probleem, aannemers en leverancier zijn bij voorbaat conservatief en willen het liefst hun ding doen zoals ze dat altijd al hebben gedaan (makkelijk geld verdienen). Er is een volledige verandering nodig in hun businessmodel, willen zij lange termijn betrokken zijn, nu willen ze het liefst zo snel mogelijk weg zijn.

- **If pss is used do they take care of all phases of a life-cycle?**

End-of-life word amper over na gedacht maar zelfs in het ontwerp wordt er nog niet over de gebruiker nagedacht en moeten er heel veel dingen veranderd worden tijdens de bouw. Eind gebruiken komt pas in beeld tijdens de constructie.

Questions about shift in ownership:

- **Do clients know of the possibilities of pss and the shift in ownership? (responsibilities, periodic payment, integrated product/services)**

Is een psychologisch spelletje voor beleggers en dat ze lang gekoppeld zijn aan een partij vinden ze ook lastig. Het ligt heel erg aan de prestaties die je eraan hangt, klanten en beleggers moeten een financieel incentive hebben om deze keuze te maken. Denk aan subsidies van de overheid. Zodra circulariteit meetbaar wordt en gesubsidieerd wordt het interessanter en te vertalen in een financieel product.

- **Is the shift in ownership interesting for suppliers?**

- **Do contractors see this shift as a threat or opportunity and why?**

Contractor wil er gewoon zo snel mogelijk weg zijn. Dus hij wilt best het project managen maar als het opgeleverd is niet meer mee te maken hebben.

Questions about Collaboration:

- **Do you think that fragmentation in construction holds back innovation?**

Het is super gefragmenteerd die niet samen werken, en er is ook geen car trekker. Er zijn nu al wel kartrekkers op duurzaamheid, maar nog niet op circulariteit of pss. Iedereen die hiermee bezig is werkt voor zichzelf.

- **Do you see different interactions between stakeholders when they use pss and how? (vertical or horizontal) are they looking for integration?**

- **Do you think that boundaries between different disciplines are clear?**

- **How do different parties look at a long term collaboration period and periodic payment?**

Het zou werken als het performance based is, product en service werkt het goed dan betaal je je volledige bedrag werkt het niet dan betaal je minder. Minder grote investering aan het begin wat interessant is, 1 partij nodig die dat monitort en bijhoudt voor 1 vaste prijs. Op installatie en fit out niveau valt er veel te behalen, op permanenten onderdelen zoals de constructie en façade veel minder.

To conclude: Getting a better understanding of the problem: Why do current construction project organisations have difficulties with the implementation of product-service systems?

- Knowhow vanaf onderaf, de kennis zit op de verkeerde plek
- Restwaarden vast kunnen stellen, om vervolgens terug te kunnen rekenen naar npv
- Er is nog niet 1 partij aangewezen in het bouwproces die over de gehele levensduur betrokken is en dit gaat trekken (system integrator), degene die alles bij elkaar brengt.

Appendix 4: presentation solution interview

1

The transition of construction project organizations towards a Circular Economy, by implementing Product-Service Systems

Restructure the stakeholder network of a construction project organizations to increase value towards a circular economy

2

Agenda

- RECORD
- Introduction
- Interview Goal
- Definitions
- Interview

3

Interview goal

Restructure the stakeholder network of a construction project organization and form new partner networks. In such a way that product-service systems increase project value.

4

Circular Economy

"A circular economy is a systemic approach to economic development designed to benefit businesses, society, and the environment. In contrast to the 'take-make-waste' linear model, a circular economy is regenerative by design and aims to gradually decouple growth from the consumption of finite resources" (Ellen MacArthur Foundation, 2015).

5

Product-Service Systems

"Tangible products and intangible services designed and combined so that they jointly are capable of fulfilling specific customer needs" (Tukker, 2004)

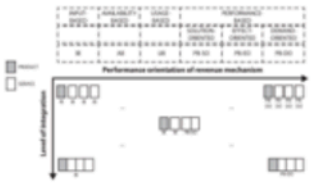
6

Product-Service Systems

- Shift in ownership and responsibilities
- Integration of products and services
- Waste reduction
- Adaptive to changing demand
- Long term contract and Periodic payment

7

Product-Service Systems



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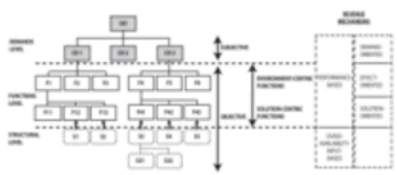
Product-Service Systems



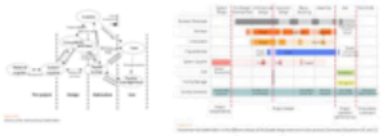
9

Construction Project Organization

"A construction project organization is a cooperative network of different stakeholders who are involved throughout the life-cycle of a project. Where a project should be seen as the collection of interrelated components, which together form a building."

10

Construction Project Organization



11

Interview goal

Restructure the stakeholder network of a construction project organization and form new partner networks. In such a way that product-service systems increase project value.

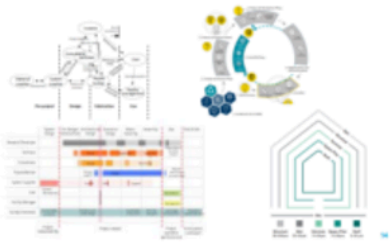
12

Difficulties with the implementation op product-service systems

- Unfamiliar with product-service systems
- Lack of collaboration and interaction
- Boundaries are unclear
- Contrast between short- and long-term goals
- Lack of phase integration

13

Possible solutions



14

Possible solutions

- Divide projects into sub-groups based on lifespan
- Per sub-group a stakeholder network
- Connecting layer with pss
- All knowledge and supply levels in-house or long-term contracts
- Driving force
- Actors focus on their core business
- Integrate all phases of the life-cycle in other phases
- Expert knowledge at start of project

15