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The Drivers and Barriers for a Circular Economy in the Built Environment of the Netherlands

An Analysis on the Drivers and Barriers of the Circular Economy

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Abstract

One of the main contributors to the Dutch GDP is the construction sector, accounting for 9% and producing 70 billion euros each year. However, the sector is also one of the largest contributors when it comes to CO_2 emissions and consumption of materials. To improve sustainability in the sector, circularity might be a useful means, however, a pathway to implement a circular economy in the sector needs to be created. Therefore, important barriers and drivers for implementing circular practices needed to be analysed. This research has thus answered the research question '*What are the barriers and drivers for implementing circular practices by Dutch SMEs in the construction sector of the Netherlands?*'. Academic theory has been tested by means of semi-structured interviews with SMEs, which have been analysed using inductive coding. This research has identified 'financial risk', 'resistance to change', 'lack of awareness', 'difficulty to measure circularity' and 'regulation hindering circular innovation' as the main barriers, whereas 'technological advancements', 'new rules and regulations', 'collaboration', 'promoting circularity', 'intrinsic motivation', 'digital innovation' and 'creating awareness' were the main drivers. Moreover, this research has shown that economic barriers are the most influential, whereas on the other hand the governmental drivers are most influential. Based on these findings useful recommendations can be provided to the Dutch government, whereas academic research can build upon these findings.

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1. Introduction

With the human population estimated to grow in the coming years coupled with changes in consumption patterns, significant challenges to well-being, health and most importantly the environment have risen. Globally, 55.7% of the people live in urban areas, with a prospected growth in the coming years (World Bank, n.d.). In the Netherlands, a similar trend can be noticed with an expected increase of inhabitants by 2035 in the four major cities Rotterdam, Amsterdam, The Hague, and Utrecht (CBS, 2019). This will result in a more densely populated built environment.

1.1 Problem Statement and Social Relevance

One of the main sectors in this built environment is the construction sector, which is also one of the main contributors to economic development (Munaro et al., 2020). The total building sector in the Netherlands accounts for 9% of the Gross Domestic Product (GDP) and produces over 70 billion euros each year (Bouwend Nederland, 2020). Thus, in addition to providing the built environment, the sector contributes to the development of the national economy as well. However, the construction sector itself is also one of the largest contributors when it comes to CO_2 emissions and consumption of natural resources (Munaro et al., 2020), representing more than 13% of the annual national emissions of the Netherlands in 2019 (CBS, 2020). Furthermore, the sector consumes 40% of the national energy and accounts for 30% of total water consumption (van Leeuwen et al., 2018). The role of the construction sector is thus crucial in economic and sustainable development.

The economic development referred to, indicated by the evolution of the global and national economy, has been dominated by “a linear model of consumption and production in which goods are manufactured from raw materials, sold, used and then discarded or incinerated as waste” (Munaro et al., 2020, p. 2). Accordingly, a new model needs to be developed that considers the impact on the environment due to emissions and resource use. One of the most discussed methods among environmental scientists, is the circular economy (CE) (Geisendorf & Pietrulla, 2018). CE has emerged as an alternative to the prevalent linear consumption model (Rios & Grau, 2019). Its core defining element is the ‘restorative use’ of resources, meaning that raw materials shall not become discarded waste and operating from a point of view that “any system based on consumption, rather than on the restorative use of resources, entails significant losses along the value chain” (EMF, 2015, p. 3). The importance of CE becomes evident as it is the key model to integrate sustainability such as the European Circular Economy Package (European Commission, 2015), the Chinese Circular Economy Promotion Law (Lieder & Rashid, 2016) and European Union Horizon 2020 strategy (Geisendorf & Pietrulla, 2018). All these strategies and laws promote the integration of CE to contribute to sustainable development.

As circularity provides methods to reduce waste and lower energy consumption, the Dutch construction sector could profit from the implementation of CE. The sector, however, is an environment in which the main constituting elements, such as buildings and infrastructure, are characterised by long lifespans, hundreds of components, and numerous stakeholders (Hart et al., 2019). Implementing CE would thus not be straight forward and a pathway towards circularity needs to be facilitated. Moreover, the spectrum of CE initiatives is broad as it relates to concepts such as cradle-to-cradle (Hart et al., 2019) and regenerative design (Geisendorf & Pietrulla, 2018). For the built environment, CE could focus on the re-use of components and products (Rios & Grau, 2019), improving resource efficiency by saving material costs (Rizos et al., 2016) and reducing energy consumption (Bilal et al., 2020).

With an increasing demand for housing in urban environments, a vast influence on the GDP of the Netherlands and a need for sustainable initiatives, research on how a sustainable transition in the construction sector of the Netherlands can be realised is necessary and of social relevance. This research will focus on the barriers and drivers that shape the pathway towards circularity in the construction sector. Effective implementation of CE will most likely foster sustainable development and would thus increase sustainability in the sector.

1.2 Objectives and Research Questions

The Dutch construction sector can be divided into the Residential and Utility Building sector (Burger & Utiliteitsbouw) and the infrastructure sector (Grond-, Weg- en Waterbouw). There are some major differences, of which the largest differences are the focus and financing of both sectors. The first sector is primarily financed by the private sector and focuses on the construction of for example real estate and rebuilding, whereas the infrastructure sector is financed mostly by the government and focuses on larger infrastructure projects (Nelissen et al., 2018). This research will focus on small and medium-sized enterprises (SMEs) that operate in the Residential and Utility Building sector. This focus is important as SMEs play a significant role in improving the national economy, by being a key player for the GDP, and are thus of great influence in a transition towards CE (van Gils, 2005).

Based on this assumption, the research question '*What are the barriers and drivers for implementing circular practices by Dutch SMEs in the construction sector of the Netherlands?*' will be answered. The barriers and drivers faced by these SMEs will be analysed according to different dimensions, that will be set out in the theory section, to guide in the categorization of the identified challenges and enablers.

This research consists of two sets of sub-questions. Through the first two sub-questions, the mismatch between the set of possible circular initiatives on the one hand, and the set of actually implemented initiatives implemented in the built environment of the Netherlands, on the other hand, will be analysed. The goal of this structure is to fill the knowledge gap of what circular initiatives can be implemented in the Netherlands and what initiatives are currently implemented. This *descriptive sub-questions* 1 and 3 are necessary to move on to the *explanatory sub-questions* 2 and 4, that seek to explain the mismatch referred to above.

1.3 Sub-questions regarding circular initiatives

The first two sub-questions related to circular initiatives are:

1. *Which circular initiatives, according to academic literature, are implemented by SMEs in the construction sector of the built environment to transition to a circular economy?*
2. *Which R-strategies are implemented most frequently by SMEs in the construction sector of the built environment of the Netherlands?*

For the first question the initiatives will be derived from academic literature according to the 9R Framework developed by Potting et al. (2017). The framework consists of ten 'R-strategies' with the goal of transitioning towards CE through less resource and material consumption in product chains. The answers to the first question will show what SMEs can do in connection with circularity, whereas the answers to question two will show what the actual initiatives are in practice. Also, the answer to question two will be linked to the 9R Framework.

1.4 Sub-questions regarding barriers and drivers

The second set of sub-questions related to barriers and drivers is:

> 3. *What are the barriers and drivers that have hindered or helped the implementation of circular initiatives, found in academic literature?*
>
> 4. *What barriers and drivers apply to the construction sector of the built environment of the Netherlands and have hindered or helped the implementation of circular initiatives?*

First, the barriers and drivers will be identified by reviewing existing academic literature, after which they will be researched in the built environment of the Netherlands. Both will either be confirmed or rejected, and result in the identification of new barriers and drivers. Moreover, the barriers and drivers will be categorized under six dimensions set out by Pomponi and Moncaster (2017).

1.5 Scientific Relevance

Lastly, the scientific relevance of this research is required to be discussed. Hart et al. (2019) suggest that future research should test their analysis on barriers and drivers in CE of the built environment by defining 'what is required to put the enablers into practice and accelerate the uptake of CE in the built environment' (Hart et al., 2019, p. 624). As this research analyses drivers and barriers in the construction sector of the built environment of the Netherlands, the results of Hart et al. (2019) can be tested. This research will contribute to their line of reasoning by filling a knowledge gap using both sets of sub-questions to identify the key barriers and drivers for the implementation of circular initiatives in the Dutch construction sector. Moreover, only one paper was found specifically focussing on barriers and drivers of CE for SMEs in the construction sector of the Netherlands (van der Sande, 2019). However, that research focused on the before mentioned Infrastructure sector, whereas this report will focus on the Residential and Utility Building sector. Moreover, other research such as Kirchherr et al. (2017 & 2018), have looked at barriers to CE in the European Union. Thus, as multiple authors emphasise that their findings on drivers and barriers for CE are most likely sector- or region-specific (Ghisselini et al., 2018; Kirchherr et al., 2018), research on barriers and drivers in the Dutch construction sector could provide useful contributions. The knowledge gap will be filled by discovering the differences and similarities in barriers and drivers presented in academic literature and those perceived by SMEs in the Dutch construction sector.

1.6 Build-up of Research

The first section of this research presents the theoretical frameworks, identified initiatives, barriers and drivers derived from academic literature, and the summary of the theory. After the theory, the methodology is discussed focussing on how data is acquired and analysed. In the results section, initiatives, barriers, and drivers will be derived from interviews with employees and owners of SMEs in the Dutch construction sector. These results will be compared to the theory in the discussion whereby a more elaborate interpretation of the results is provided as well. In the conclusion the research question will be answered, and a recommendation and take-home message are presented.

2. Theory

To answer the research questions a selection of concepts need to be defined. This section will focus on defining 'the circular economy', 'barriers and drivers' and 'the dimensions of applicability'. After explaining the concepts, existing literature on the barriers, drivers, and circular initiatives for a circular economy in the built environment will be analysed to answer sub-questions 1 and 3.

2.1 The Circular Economy

Interest in CE has increased in recent years, with a rapid growth of peer-reviewed articles on the topic (Kirchherr et al., 2017) and gaining importance on the agendas of policy makers (Geissdoerfer et al., 2017). Kirchherr et al. (2017) were the first to investigate CE definitions comprehensively and systematically, as, until that research, no commonly accepted definition of CE was present. CE was, however, seen as the natural point of departure in other research streams such as industrial eco-systems (Jelinkski et al., 1992), cleaner production (Ghisellini et al., 2016; Lieder and Rashid, 2016), eco-efficiency (Haas et al., 2015), product-service systems (tucker, 2015) and cradle-to-cradle design (Braungart et al., 2007; McDonough & Braungart, 2002). Apart from differences in defining the concept itself, differences in which concepts relate to CE also occurred. Therefore, both will be analysed and set out.

2.1.1 CE and Sustainable Development

According to the WCED-report, sustainable development "is development that meets the needs of the present without compromising the ability of future generation to meet their own needs" (WCED, 1987, p. 8). A concept portrayed as an overarching idea for many different concepts that relate to sustainability. Sustainable development is thus often described as a diversely structured area of discourse (Brand & Jochum, 2000; Dryzek, 1997; Springett, 2003). What most research agrees on, is the link between the Triple Bottom Line model and sustainable development. The Triple Bottom Line, also referred to as the triple P model and the three-pillar model, highlights three dimensions for sustainable development (Gimenez et al., 2012; Hacking & Guthrie, 2008). These dimensions are the ecological, social, and economic dimension (Boersema & Bertels, 2000; Gerlach, 2002).

When the link between CE and sustainable development is discussed, research on CE often focuses on only one concept, namely the ecological dimension, while taking a holistic view on all three dimensions (Geissdoerfer et al., 2017; Korhonen et al., 2018). This is also confirmed by Kirchherr et al. (2017), who state that that the link between CE and sustainable development is weak. However, whereas Geissdoerfer et al. (2017) and Korhonen et al. (2018) stated that CE mainly related to the ecological dimension, Kirchherr et al. (2017) revealed that most authors see CE as an avenue for economic prosperity, thus relating mainly to the economic dimension. What the articles agree on is that CE relates mostly to the economic and environmental dimensions and less to the social (Homrich et al., 2018; Murray et al., 2017).

Nevertheless, CE is still seen as a vital strategy for achieving sustainable development (George et al., 2015). As sustainable development relates to meeting the needs of the present and allowing future generations to meet their own needs, CE can help to accomplish just that. Kirchherr et al. (2017) define CE as "an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling, and recovering materials in production/distribution and consumption processes" (Kirchherr et al., 2017, p. 229). Similarly, other definitions are "a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, re-use, remanufacturing, refurbishing, and recycling" (Geissdoerfer et al., 2017) and "an economic model wherein planning, resourcing, procurement, production and reprocessing are designed and managed, as both process and output, to maximize ecosystem functioning and human well-being" (Murray et al., 2017).

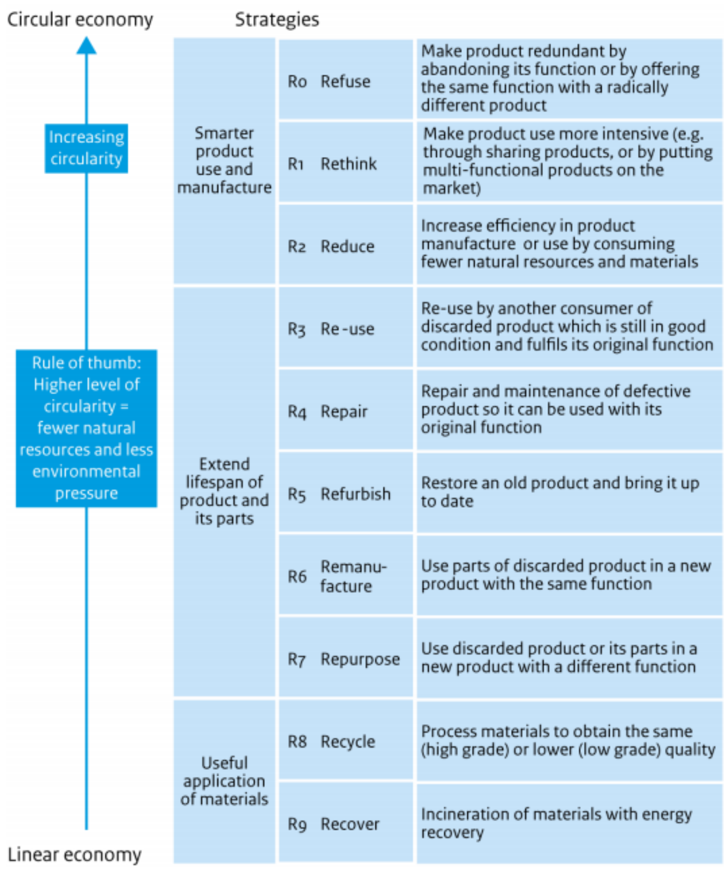
Based on the existing literature, this research will define a circular economy as *an economic model of closed loops that replaces the 'end-of-life' concept by creating a circular life cycle of products to minimize waste creation, emissions, and energy leakage.* Minimizing the creation of waste, emissions and energy leakage can be achieved by different methods, but this research will focus on circular strategies visible in 'R Frameworks'.

2.1.2 CE and the 'R Frameworks'

From the three definitions a few concepts can be derived such as 'recycling', 'remanufacturing' and 'refurbishing'. These concepts relate to the so-called 'R frameworks', which are strongly connected to CE (Kirchherr et al., 2017). Authors such as Zhu et al. (2010a, 2010b) and Reh (2013), see the R frameworks as the 'how-to' of CE and thus a core principle of it. Various R frameworks have been used in academic literature, varying from 3R frameworks to 9R frameworks. The concepts of these frameworks and their relationship with CE requires a more thorough explanation. Figure 1 summarises the 9R framework used in this research which is also the most elaborate form of an R framework. Categorizing the R strategies is possible in various ways such as life cycle stages (Potting et al., 2017) or the length of material loops (Reike et al., 2018). This research will focus on the life cycle stages categorization utilized by Potting et al. (2017), as this enables the implementation of drivers to overcome barriers and connects to sub-question 1 of this paper.

Figure 1

Circular Strategies Within the Production Chain (Potting et al., 2017, p. 15)



2.1.2.1 The 9R Framework

Refuse (R0) can be analysed from a consumer and producer point of view. As this research focuses on SMEs, the producer perspective is most important. From this perspective, refuse applies to the concept and design cycle, in which SMEs refuse to use specific hazardous materials for example (Reike et al., 2018).

Rethink (R1) is defined by Kazancoglu et al. (2020) as using products more intensively. However, rethink might also relate to rethinking an entire supply chain (van Buren et al., 2016). Meaning that producers fundamentally rethink their production and distribution processes prior to the latter R strategies (Ghisellini et al., 2016; Kirchherr et al., 2017).

Reduce (R2), relates to reducing the consumption of resources and the generation of waste in the process of production, circulation, and consumption (Yang et al., 2014). Reduce is explained by Potting et al. (2017) as increasing efficiency in product manufacturing or usage, mainly by consuming fewer natural resources and materials. According to Goyal et al. (2018), reduction of resources involves innovative ways to change the usage of non-renewable raw materials, while at the same time replacing scarce resources with renewable, recyclable, and biodegradable resources.

Re-use (R3) on the other hand, involved extending the functional life of the product as long as possible, thus relating to the use phase of the product (Goyal et al., 2018). According to Ghisellini et al. (2016), the re-use principle refers to “any operation by which products or components that are not waste are used again for the same purpose for which they were conceived” (Ghisellini et al., 2016, p. 15).

Repair (R4) is defined in various ways, with the meaning of repair seeming to defy misinterpretation (Reike et al., 2018). Reike et al. (2018) cite different sources describing repair in a different manner such as ‘bringing back to working order’ (Fernández & Kekäle, 2005; Fleischmann et al., 1997) and ‘making it as good as new’ (Srivastava, 2008). Potting et al. (2017) describe repair as maintenance of a defective product so it can fulfil its original function.

Refurbish (R5) is defined by Kazancoglu et al. (2020) as reviving old products to give them new life by transforming them into updated products. Blomsma et al. (2019) describe this process as extending new use cycles by returning a product to a satisfactory condition, superior to the original specification. The main difference between repair and refurbish is thus the new state of the product, whereas with repairing the original product is still intact. The product is thus given an ‘upgrade’ as many components are replaced or repaired (Fernández & Kekäle, 2005).

Remanufacture (R6) is described by Blomsma et al. (2019) as rebuild, overhaul, or remake. With remanufacturing, parts of a discarded product are used in a new product with a similar function (Potting et al., 2017). Stahel (2016) described remanufacturing as a solution after a product cannot be re-used, recycled, or repaired. In connection,

Repurpose (R7) is giving alternate use to a product (Blomsma et al., 2019). By reusing the discarded goods or only components of these goods, the material gets an entirely new life cycle. Repurpose does thus refer to the entire product or only the materials used in a product. However, the product or material must be used in a distinctly different manner than before. To be more precise, the product or material is extended to new use cycles for different functions (Blomsma et al., 2019).

Recycling (R8) is the “recovery operation by which End-of-Life waste is reprocessed into products, materials, or substances that can serve the original or comparable purposes” (Haas et al., 2015). A simpler definition is given by Goyan et al. (2018) who see recycling as translating waste into new resources.

Recover (R9) is seen by most authors as the last step in the circular economy, when the product or its components are of little use (Blomsma et al., 2019; Potting et al., 2017; Reike et al., 2018). There are authors like Goyal et al. (2016) and Haas et al. (2015) who attribute a different meaning to the concept, by referring to recovering materials and reusing these materials in new products.

2.2 Identified Circular Initiatives in Academic Literature

As shown in Figure 1, the R-strategies mentioned moving from the bottom to the top transitioning from a linear economy to CE. Therefore, in terms of circularity, the R0 strategy 'refuse' is the most circular strategy, whereas the R9 strategy 'recover' is the least circular strategy. This section will follow the same order as section 2.1.2, meaning that the first strategy discussed is the most circular strategy and should thus be considered first while moving towards the least circular strategy. Moreover, to adhere to the description of strategies presented in section 2.1.2, this research will categorize described processes under the right strategy. This means that if for instance an article discusses different initiatives referred to as recycling methods, these can be attributed to other strategies than recycling if the description matches a different strategy than recycling.

2.2.1 R0 – Refuse

The description of the first R strategy in section 2.1.2 already indicated that refuse can be interpreted in various ways. In academic literature, refuse is seen as the starting point of CE as it makes it possible for businesses to apply new materials, products or services and thus making others redundant.

For CE, the main reason for refusing certain materials is not necessarily the hazardous aspects of the material, but to what extent the material can be used in CE. A prime example is described by Pawlyn (2019), who refers to the low-emissivity coating currently applied to glass. This coating makes other R strategies impossible and thus companies should refuse to apply this coating in the future. This also applies to other materials as Pawlyn (2019) also states that many standard materials in the construction sector are finished with paints, seals and other coatings that reduce the reusability and recyclability. Instead, the author describes new techniques involving biomimicry. For glass for example, 'structural colour' can be achieved by a microstructure that refracts and scatters light. It might therefore be possible to create a nanostructure from the glass itself that could perform in a similar way to the low-emissivity coatings currently applied as a separate material.

Another initiative to increasing circularity by refusing to use a certain material is discussed by Guy et al. (2006). They argue that buildings designed for deconstruction should include the dis-entanglement of systems, hereby refusing to use disparate binders that keep the structural components together.

2.2.2 R1 – Rethink

According to Pawlyn (2019), rethinking is fundamental in transforming to CE and creating comprehensive, zero-waste systems for cities. Not only should companies focus on rethinking their own processes (Gravagnuolo et al., 2019; Raitu et al., 2015), but rethinking should also focus on the entire industry (Mangialardo & Micelli, 2017). This new form of production should incorporate the R strategies I will discuss in the following sections. Rethinking is thus, after refusing to use certain materials, the second step in transitioning towards CE in the construction sector.

A new model frequently discussed in academic articles, is a rigorous switch from regular product to product-service-systems (PSS). According to Stephan and Athanassiadis (2018), PSS could potentially enhance efficient re-use and secondary resource utilisation. Thus, rethinking the system enhances the other strategies. Instead of selling a product, maintenance becomes more important to lengthen the lifespan of construction elements whereby the manufacturers provide a service (Hillebrandt, 2000). According to Tazi et al. (2021), integrating PSS in the construction sector can be an opportunity to consider re-using and leasing high-performance concrete-based products. Also, products will be valued more by the producer as well as the consumer.

2.2.3 R2 – Reduce

As stated in section 2.1.2, reduction in this research relates to reducing consumption of materials and waste. As reduction of waste can be seen of the generic purpose of CE, this section will focus solely on the decrease of consumption of materials and reduction in the production process of the construction sector.

Reduction of materials is seen as critical by Gravagnuolo et al. (2019) who state reduction in the construction sector can be achieved by SMEs by applying innovative and advanced technologies. This is agreed upon by Hillebrandt (2000) who states that reducing in itself is a major benefit of CE. Reducing the quantity of materials used is discussed by the author as designing buildings with fewer materials, while also using bio-based construction materials. This trend is seen as either relative or absolute decoupling (relative meaning to use fewer resources per unit of economic growth while absolute decoupling refers to a total reduction in the use of resources). Achieving decoupling can be influenced by efficient structures based on biomimicry which is described by Pawlyn (2019), who introduces the concept by stating that 'in nature, materials are expensive, and shape is cheap' (Pawlyn, 2019, p. 9). According to the author, reduction of materials can be achieved by focusing on structures rather than materials, adapting shapes from nature to enhance strength with fewer materials. The construction elements vary from the smallest beams to larger foundations, but what is concluded by the author is that biomimicry would contribute to using resources much more efficiently. As stated in Brütting et al. (2019), reducing the weight of structural design can also be a practical example of reducing material consumption without losing strength in the construction.

Crawford (2011) on the other hand, mainly focuses on reducing impact by reducing material usage and using new materials instead. Moreover, preservation of non-renewable resources and sustainable consumption of renewable resources, or more efficient resources, should be a priority in construction (Munaro et al., 2020). According to Crawford this can be achieved by design for adaptive re-use (DfAR). DfAR can reduce demand for raw materials as it implies that materials, components, and other resources will be re-used instead of new materials entering the supply chain. Moreover, reductions in non-renewable resource use can be gained by rationalizing the design of buildings. Another example is the earlier mentioned Design for Deconstruction (DfD), which not only allows for deconstruction but also greatly reduces materials used (Guy et al., 2006; Nußholz et al., 2019). The last example is reducing the size of the building itself. Reducing the size can most obviously result in resource savings, which in itself will reduce resource extraction in mostly depleted areas (Tazi et al., 2021).

According to Allacker et al. (2014), reduction of resources can be achieved by the other R-strategies, as recycling of materials and the use of recycled material both have the potential to reduce the number of virgin materials that needs to be produced. This is also confirmed by Zanni et al. (2018) who state that repurposing reusable materials will help to reduce consumption of renewable resources and by (Núñez-Cacho et al., 2018) who state that reducing, reusing, and recycling are the basis of the 'new productive systems'.

To conclude, practical steps for material reduction are using substitutes by reducing the use of hazardous resources, efficient design which can be achieved by for example biomimicry, DfAR and DfD, and improving other R-strategies to enhance material reduction.

2.2.4 R3 – Re-use

Re-use in the construction sector can be interpreted in various ways and has been attributed in academic literature to re-use of components (Arora et al., 2019; Pawlyn. 2019). How SMEs can utilize this strategy will be discussed in this section. As stated in section 2.1.2, when an article refers to this R-strategy in any other form than when the product or component is used again for the same purpose, it will not be included under this section.

As re-use implies that the component will not be touched and transferred directly to fulfil the same purpose, it is of high importance that the components used in construction are of high-quality (Geldermans, 2016). When this is achieved, the components can be recovered before demolition and re-used in multiple buildings without adjustments. Some design concepts that can be used in this manner are the transfer of structural insulated panels, which are light weight panels consisting of durable materials, two factors that are important for the applicability of re-use (Araújo et al., 2019; Guy et al., 2006). The direct re-use of whole components obtained during the demolition of structures, can be facilitated when buildings are viewed as material banks, rather than solid structures (Munaro et al., 2020). In this way, it is known what components are included in the building and are appropriate for re-use. Currently, especially load-bearing components are currently poorly valued but re-use of these components offers great potential to save materials, energy, and resources (Brütting et al., 2019). However, also other components such as bricks can be recovered from demolition sites and only need to be cleaned for re-use (Nußholz et al., 2019). The reclamation of these bricks is feasible using two methods, either saw-cutting or punching (Ajayabi et al., 2019).

Re-use in academic literature also refers to the re-use of old buildings (e.g. Gravagnuolo et al., 2019). However, this assumption is false as all articles refer to re-use when changes to the function of design of the building are made. Therefore, these will be discussed under the other R-strategies.

2.2.5 R4 – Repair

Repair is probably the most well known and most used circular strategy, not so much by SMEs but especially by customers themselves (Guy et al., 2006). During the lifetime of a building, maintenance in the form of reparation is a reoccurring activity in the form of repairing what is broken (Crawford, 2011; Ghaffar et al., 2020; Hillebrandt, 2000). The role of SMEs is to perform regular inspection of buildings and systems to ensure that the components do not become beyond repair (Crawford, 2011). These repairs will be carried out throughout the lifetime of the construction as the necessity arises due to damage or deterioration. Repairing is considered preferable to interventions such as demolition or reconstruction (Mangialardo & Micelli, 2017). However, new demolition techniques have emerged as well that allow for separation and repair of structural components (Ajayabi et al., 2019).

After repair, the components can be used longer in the same building or re-used at a different location. SMEs should facilitate reparation of components to outwear other materials and hereby fostering CE (Pawlyn, 2019). On a small scale, reparation would entail the little adjustments in a building. Especially focusing on smaller construction components and sub-components (Guy et al., 2006).

On a larger scale, repair could focus on repairing the construction of a house, making it useable again and safe to live in. DfD can facilitate in reparation of constructions by using screws and bolts for instance, which allows to take out parts of the construction that need to be repaired (Guy et al., 2006). They also state that caulking and sealants need to be eliminated to improve the ease of removing components for repair.

Components can also be made suitable for re-use by reparation, moving components in end-of-service-life (EoSL) buildings to fulfil a similar function (Hopkinson et al., 2018). This similar function would most ideally be fulfilled in new local builds to minimise costs. An example of reparation given by Hopkinson et al. is three-dimensional printing to repair concrete elements. The printing is in this case able to fill holes that have appeared in the concrete and strengthen the material again. This is a form of retrofit techniques, that help to strengthen existing structures. Severely damaged structures are often repaired through this technique to become useful again (Napolano et al., 2015). Other than three-dimensional printing, cracks can be injected with fine grout, which has a similar functioning.

A more advanced form of reparation is discussed by Pawlyn in the form of self-repair achieved through biomimicry. Using biomimicry, materials are able to repair themselves, of which a prime example is self-repairing durable concrete. Not only does it no longer require maintenance, but the material is also more suitable for re-use in other buildings. Lastly, in PSS, reparation can help in keeping up with client demand. When the materials provided through a service do not cover the demand of the client anymore, they can be taken back, repaired, and replaced (Stephan & Athanassiadis, 2018).

2.2.6 R5 – Refurbish

Refurbishment has been referred to in academic literature in the form of refurbishing old buildings (Gravagnuolo et al., 2019) and refurbishment of structural elements (Mangialardo & Micelli, 2017). A frequently used synonym for refurbishment in the construction sector is renovation, restoring older buildings etc. to create an up-to-date product (Hopkinson et al., 2018). Refurbishing is thus especially important to maintain building value over time (Gravagnuolo et al., 2019).

According to Roberti et al. (2017), refurbishment of buildings has two main benefits. Not only does it extend the lifecycle of buildings, reducing the use of new materials, but it also helps to improve comfort and increase energy savings by up to 50%. Refurbishment according to the authors should therefore focus on both extending the life cycle and improving technical conditions such as isolation. Gravagnuolo et al. (2019) argue that during refurbishment of old buildings, circular design and dismantling should be considered when bringing the buildings up to date. Mangialardo and Micelli (2017) refer to this as Design for Adaptability (DfA), making refurbishment straightforward in the future.

In most cases, renovation of a building is seen as necessary and inevitable (Pili, 2017). Especially refurbishing the roof and interior of the building is deemed necessary by customers. Currently, mainly in the construction aspect of buildings, refurbishment is hard due to failure to remove and upgrade building systems and components (Munaro et al., 2020).

In terms of structural elements, refurbishment is mainly related to for example improving structural beams (Gravagnuolo et al., 2019). It is also important again in a PSS, where instead of maintaining building value, the value of materials and elements is maintained overtime whereby the building again is seen as a material bank. Moreover, this shift in ownership initiated by PSS, should encourage SMEs to develop recovery schemes and material to refurbish as effortlessly as possible (Stephan & Athanassiadis, 2018).

2.2.7 R6 – Remanufacture

Remanufacture, other than re-use, repair and refurbish, deals particularly with resources in construction elements that can be used in other elements once the older element is discarded (Carus

& Dammer, 2018; Hillebrandt, 2000). According to Hopkinson et al. (2018), this form of material circulation will also enhance the value of components as parts of the component are valued more. However, as using the whole component is seen as a superior strategy, remanufacturing deals with those elements that cannot be repaired (Ghaffar et al., 2020). Nevertheless, remanufacturing is still valued more than recycling as it conserves more value (Ness & Xing, 2017).

Again, remanufacturing requires new building techniques, technical innovation and design frameworks that allow for materials to be transported and used in other elements in new builds. We have encountered different design-for-x methodologies to which a new 'design-for-remanufacture' (DFRem) framework is added (Shu & Flowers, 1999). DFRem should priorities minimizing damage to parts, to allow re-use of these parts. It overlaps with DfD as ease of disassembly is important, with no damage to the product affecting functional performance or aesthetic appearance (Ijomah et al., 2007). Both authors do however stress that it is important that frameworks should be adopted simultaneously to consider the full life-cycle perspective.

Remanufacturing also provides a useful solution in PSS. When the service is over, the SME takes back the elements it does not lease it out to another customer but uses its components to remanufacture the product for a different service (Cruz-Rios & Grau, 2020). Hereby, the life and longevity of goods will be extended and will further enhance stewardship of goods (Ness & Xing, 2017).

2.2.8 R7 – Repurpose

Repurposing in the construction sector is a difficult undertaking, as each structural element has a specific function in the construction and can be considered a rare activity (Debacker et al., 2017; Sieffert et al., 2014). Beams, for example, have been calculated to be the precisely desired width and height to withstand forces on the structure. Due to the specific functions, providing a new function for elements and materials is near to impossible (Lee et al., 2011).

It is therefore, that materials from outside the Residential and Utility building sector are used in new ways in constructions. According to Sieffert et al. (2014), repurposing of materials should bridge the gap between other sectors and architecture through hands-on projects. Prime examples are constructions with used tires, plastic bags, and low weight foundations for soft soils (Sieffert et al., 2014). This use of discarded products is also referred to as upcycling, giving better life to discarded products (Pawlyn, 2019).

A more elaborately discussed type of repurposing in the construction sector, is the repurposing of buildings for residential housing (Gravagnuolo et al., 2019). This form of repurposing is particularly relevant in historic cities, where the strategy of dismantling and circular design of new buildings can be rarely applied. According to Hillebrandt (2000), repurposing should be considered first at the very start of the construction process. Especially buildings from outside the Residential and Utility building sector are seen as potential buildings for repurposing such as office spaces that can be transformed into housing (Mangialardo & Micelli, 2017). This is considered important by Lee et al. (2011) as well, as the original purposes of buildings shift, and existing buildings no longer support their new roles and functions. It is thus not materials and components that enter a new life cycle, but the building itself. You could however argue, that for repurposing of buildings, other strategies such as remanufacturing, refurbishing and repairing are needed as well to minimize material consumption. In this manner, the existing buildings can be readapted for other purposes (Lee et al., 2011).

What can be concluded is that SMEs that focus on repurposing materials, components, or entire buildings, can substantially reduce demolition waste (Munaro et al., 2020).

2.2.9 R8 – Recycle

Nearly all analysed academic articles related to circular strategies in the construction sector, referred to recycling. Nevertheless, despite the frequent mentioning of the strategy, recycling has been referred to in other ways than intended in this research. Arora et al. (2019) for example discuss recycling of whole components but describing it as re-use. Other than such examples, recycling is regarded as the starting point of CE and should lie at the basis of transforming the construction sector (e.g. Górecki et al., 2019; Luciano et al., 2020; Nunez-Cacho et al., 2018). It therefore important to define the forms discussed in academic literature in which recycling can be applied by SMEs.

The main form of recycling in construction is dedicated to using recycled materials from larger structural elements. Bricks and tiles, for example, can be made from recycled concrete (Gravagnuolo et al., 2019), whereas reinforcing steel can be used for support beams (Guy et al., 2006; Lee et al., 2011). Other than recycling concrete itself, recycled aggregates have proven to be effective in concrete manufacturing (Tazi et al., 2021). In case of the recycled steel, the material can also be used to reinforce existing buildings and extend their lifetime (Napolano et al., 2015).

What becomes apparent is that the construction sector could be an excellent consumer of several secondary raw materials derived from recycled waste (Zanni et al., 2018). Examples of such secondary raw materials are fly ashes from waste incineration, which can be used in concrete manufacturing, and several end-of-life polymers.

Materials can also be transported from life cycles in other sectors into the material life cycles of the construction sector. Examples of full components have been seen under the repurposing strategy but recycling specifically deals with recycling materials. For example, plastic from recycled plastic bottles has been used to manufacture thermal insulation for buildings in Italy (Pomponi & Moncaster, 2016). Moreover, the same logic can be reversed, by stating that recycled aggregates from the Residential and Utility building sector, could be used as backfill or foundation layer for roadworks (Tazi et al., 2021).

A new design-for-X framework has also emerged in the form of Design for Recycling (DfR) (Geldermans, 2016). The framework aims to anticipate high-quality re-use of recovered materials in ‘end-of-pipe’ solutions. A form of DfR can be found in structural insulated panels, which have been referred to under the re-use strategy, that allow for easy recycling of the materials used in the panels (Guy et al., 2006). However, the other design-for-X strategy DfD is also useful in terms of recycling, as steel structures can be deconstructed more easily, which will enhance the recyclability of the material (Lee et al., 2011).

According to Bao and Lu (2020), appropriate waste recycling technologies must be developed by SMEs to fulfil the full potential of recycling. One of these methods could be on-site waste recycling, which has the advantages of lower investment, lower transportation costs and easier management (Bao & Lu, 2020; Ghaffar et al., 2020).

2.2.10 R9 – Recover

Recovery is a strategy mentioned in numerous articles (Arora et al., 2019; Geldermans, 2016; Ghaffar et al., 2020; Tazi et al., 2021), however, the strategy mentioned in these articles does not comply with the meaning of recovery in the 9R-Framework. Recovery referred to in these articles mainly relates to either recovery of materials (e.g. Tazi et al., 2021) or recovery of structural components (e.g. Stephan & Athanassidis, 2018). However, these aspects of CE have been discussed in the previous strategies. Recovery in this research, means recovery energy by incineration of materials.

Incineration of waste is only referred to as the last step of the construction process when other strategies are not applicable anymore. Evidently, it is always seen as an option with little circular aspects despite providing a function in CE. As only little initiatives can be attributed to this strategy, the articles discussing incineration refer to waste incineration (e.g. Crawford, 2011; Huang et al., 2018).

However, the most interesting perception on waste incineration provided a solution for the waste of incineration. Both Gragnuolo et al. (2019) and Zanni et al. (2018) argued that waste for incineration such as fly ashes, can still be used as secondary raw material in construction. These fly ashes can then be used in cement production as a recycling alternative to landfill, however, more research on this topic is needed as the fly ashes result in concrete with high total heavy metal contents (Lederer et al., 2017).

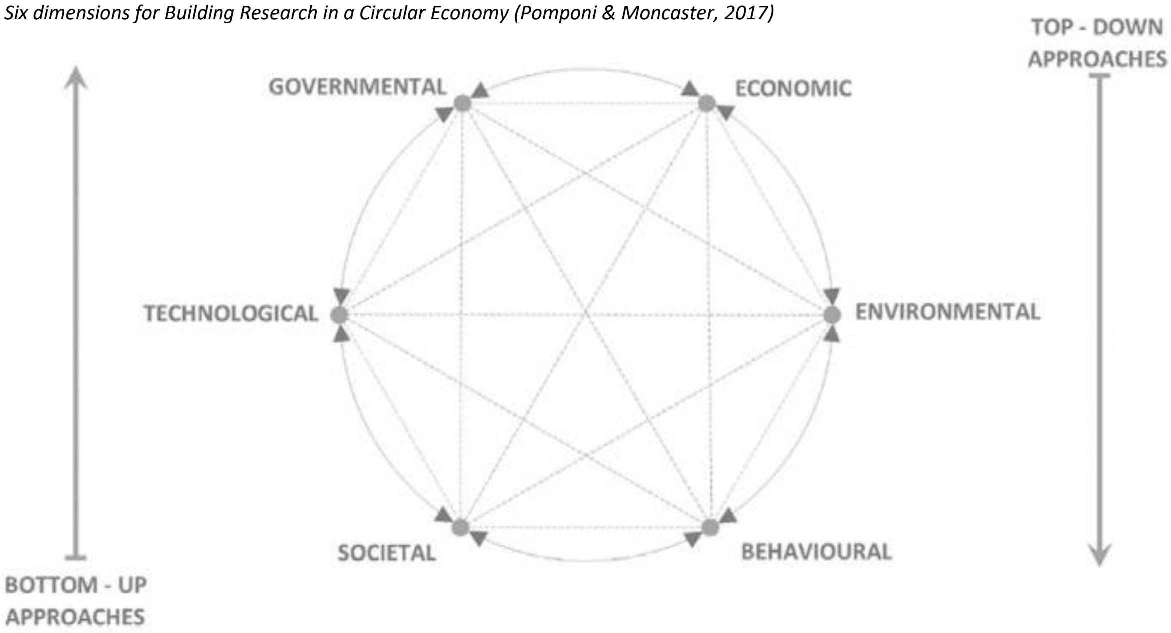
2.3 The Six Dimensions of Barriers and Drivers in the Circular Economy

This research has identified barriers and drivers for the mentioned R-strategies based on academic literature and data gathering in the built environment of the Netherlands. These influencers, however, need to be categorized to facilitate implementation in the field. Therefore, a frame of reference is set up regarding six dimensions of sustainability and the circular economy. This section will describe the model presented in Figure 2 thoroughly and most importantly, set out the meaning of each dimension for this research and describe the influence of the dimensions on circular economies.

2.3.1 A Research Framework for the Six Dimensions

As set out earlier, the construction sector is a sector in which the main constituting elements, such as buildings, are characterised by long lifespans, hundreds of components, and numerous stakeholders (Hart et al., 2019). Especially the diversity in stakeholders poses challenges for SMEs, as businesses already focus on more than for example customer relationships and stakeholder interaction in their supply chain. Due to this complexity, barriers and drivers that hinder or stimulate development cannot be limited to solely one dimension. Pomponi and Moncaster (2017) therefore introduced a model that focused on six influential dimensions by which barriers and drivers in CE can be categorized. These six fundamental dimensions, also referred to as pillars, were identified, integrating both bottom-up and top-down initiatives in facilitating the transition to ‘circular buildings’ and thus a ‘circular construction sector’ (Pomponi & Moncaster, 2017, p. 715). The framework can be applied to capture current barriers, and in this research also drivers, in embedding CE principles in the construction sector.

Figure 2
Six dimensions for Building Research in a Circular Economy (Pomponi & Moncaster, 2017)



2.3.2 The Six Dimensions Set Out

Research on sustainable development has always focussed on the three pillars mentioned previously in this theory section. The People, Planet, Profit – Triple P Model – or the Triple Bottom Line model focused only on the environmental, social, and economic dimensions of sustainability (Geissdoerfer et al., 2017). However, CE relates to more than environmental, social, or economic factors, hence why the model by Pomponi & Moncaster (2017) adds and specifies the Triple P Model into six dimensions. The meaning of these dimensions is free to the interpretation of each researcher and thus the meaning for this research and the connection with CE for each dimension is required to be explained. The dimension and its related definition for this research can be found in Table 1 below.

Table 1.
The Definitions of the Six Dimensions

Dimension	Explanation
Governmental	The *governmental* dimension, often referred to as the institutional dimension (Morea et al., 2017), will focus on governmental policies and initiatives hampering or stimulating the implementation of circular initiatives by businesses. The dimension has been used in academic research in the form of a sustainability assessment (Espinoza et al., 2017) and its influence on other dimensions such as the economic dimension (Ruiz-Lozano et al., 2019). Barriers and drivers related to the governmental dimension will thus relate to governments influencing SMEs through for example rules, regulation, financial aid and guidance.
Economic	The *economic* dimension will focus on models of profitability, relating to the ability for SMEs to be profitable from a circular business model. The dimension is present in earlier models and one of the pillars in the Triple Bottom Line model (Gerlach, 2003). As the economic dimension has been a prior dimension in earlier research, different interpretations on the dimension have been given (Kajikawa et al., 2014; Geissdoerfer et al., 2017; Reike et al., 2018). In this research, any profit-related barrier or driver will be categorized under the economic dimension. Moreover, the dimension relates to financial opportunities or risk,

	economic models, the financial market, and profitability or the lack of profitability.
Technological	The *technological* dimension in this research mainly focuses on schemes for technological innovation in the form of innovations in manufacturing or operations. Based on previous research, barriers and drivers in this research that relate to the technological dimension will focus on technological advancement the business is aiming for. Moreover, it may apply to tools of measurement and technical difficulties or opportunities in production processes.
Environmental	The *environmental* dimension is, similar to the economic dimension, one of the three dimensions in the Triple Bottom Line model (Geissdoerfer et al., 2017). Hence, the dimension is one of the most discussed dimensions in academic literature (Walker et al., 2018). In this research, all barriers and drivers of which environmental factors were the main reason for implementing circular initiatives or the hindering of this implementation. Example of such environmental factors are resource scarcity, environmental impact and damage done to the environment are included.
Societal	The *societal* dimension is the third and last dimension related to the Triple Bottom Line model, where the societal dimension is referred to as 'people' (Geissdoerfer et al., 2017). The societal dimension relates very much to the societal structures such as educations systems that are in place, rather than the behaviour of people. In this research, all barriers and drivers that are a result of societal structures fall under this dimension.
Behavioural	The *behavioural* dimension is seldom discussed in CE literature (Pomponi & Moncaster, 2017); however, it can be viewed as part of the Triple Bottom Line model as well. Where the societal dimension refers to societal structures, the behavioural dimension focuses on the behaviour of individuals instead of entire SMEs and its influence on how SMEs behave. These individuals are either employees or owners of SMEs.

2.4 Identified Barriers and Drivers in Academic Literature

This section includes the barriers and drivers identified in academic literature related to the R-strategies set out in section 2.2. The barriers will focus on what hinders SMEs from implementing circular initiatives whereas the drivers will focus on what stimulates them to implement the strategies.

2.4.1 Identified Barriers

The first identified barrier is **obstructing law and regulation** which has been acknowledged in different forms in academic research (Hart et al., 2019). According to Hart et al. (2019), these obstructing laws are usually in relation to the handling and categorisation of waste. However, other research attributes the barrier because energy efficiency and high energy performance are prioritised (Henrotay et al., 2017). They state that this "may unintentionally result in building design and materials that do not lend themselves to dismantling, refurbishments, re-use and high-quality upcycling" (Henrotay et al., 2017, p. 229). The design-for-x frameworks in section 2.2 have shown that dismantling is important to facilitate different R-strategies (e.g. Geldermans, 2016; Lee et al., 2011). Therefore, the obstructing laws and regulation can be seen as a highly influential barrier. Moreover, obstructing laws and regulation may result from conflicting energy and environment policy measures and a fragmented policy framework (Debacker et al., 2017).

Apart from obstructing laws, some articles also see the **lack of regulations and laws** as a barrier to the implementation of CE in the built environment (Bilal et al., 2020). In that particular research, the lack of environmental laws and regulations is even seen as one of the two major barriers that are driving other barriers. Gallego-Schmid et al. (2020) see the lack of regulations as limited political support preventing businesses to innovate, whereas Ollár et al. (2020) describe it as the lack of legislative guidance for sustainability and circularity. The lack of regulations also includes an absence of global consensus around policy support for CE and a lack of targets such as energy efficiency (Hart et al., 2019). This is also acknowledged by Karhu and Linkola (2019) who identified a fragmented policy framework from the European Union to municipalities. In some way, this barrier is related to drivers, as the regulations and laws that are not implemented can be drivers for circularity (Debacker et al., 2017).

The third barrier is a **lack of interest, knowledge and engagement throughout the value chain,** a barrier that can be found in all aspects of the value chain. Hart et al. (2019) see a lack of interest in the case of suppliers, customers and even internally in businesses. According to them, it can be viewed as an overarching barrier as, especially due to lack of interest in circularity, progress will be slow. Adams et al. (2017) and Gallego-Schmid et al. (2020) also identify limited awareness, interest, and knowledge as a significant barrier. The main problems, according to Debacker et al. (2017), is that the concept of reversible buildings is largely unknown to the general public and thus initiatives remain undiscovered. Moreover, other than only focussing on customer and public awareness, Bilal et al. (2020) also attribute a large part of the lack of awareness to a lack of support from public institutions.

A fourth identified barrier is the **lack of collaboration between businesses and business functions**. Hart et al. (2019) attribute this barrier to competitive instincts of companies and when businesses collaborate, horizontal collaboration in the supply chain is often neglected. Moreover, when businesses are willing to exchange information and collaborate, information exchange systems between different stakeholders are missing (Bilal et al., 2020). Lack of collaboration can result from a lack of bandwidth compounded by an absence of a coherent vision for the industry (Hart et al., 2019). This was also discovered in a case study in Finland, where they found a lack of common understanding and a joint vision of how the construction sector should develop (Karhu & Linkola, 2019). Collaboration of business functions is mainly identified as the inability of function within a business to work together and transparently around a common goal (Hart et al., 2019). What can thus be said, is that the construction sector is a conservative, uncollaborative and adversarial sector (Rizos et al., 2016).

The fifth barrier, a **lack of regulatory mechanisms**, is an overarching concept based on different articles that identified several mechanisms and links to the previous barrier named a lack of regulations. Adams et al. (2017) identified a lack of market mechanisms to aid greater recovery, which was also ranked as one of the top challenges. Thus, new market mechanisms that facilitate a CE-related infrastructure need to be introduced (Gallego-Schmid et al., 2020). Moreover, a lack of regulatory mechanisms resulted in insurance and warranty issues of using re-used materials (Adams et al., 2017). Again, this links to the lack of policies as Gallego-Schmid et al. (2020) state that currently risk, quality and assurance need to be balanced better. However, the main mechanism that is lacking is a certification mechanism for quality assurance regarding, for example, recycled materials (Debacker et al., 2017). Also, mechanisms to reduce environmental are lacking which we will follow up on in a later section (Rios & Grau, 2019). Lastly, a lack of regulatory mechanisms for material recovery has been identified (Gallego-Schmid et al., 2020).

The sixth barrier is the **high upfront cost** of implementing CE (Gallego-Schmid et al., 2020; Hart et al., 2019; Kirchherr et al., 2018). This is mainly due to the fact that the majority of existing buildings were not designed for adaptation, disassembly, or high-value re-use (Hopkinson et al., 2018). Moreover, costs are higher for management and planning as well (Bilal et al., 2020). A concrete example is that steps such as material screening and reprocessing are very cost-intensive (Ghaffar et al., 2020). Even though the benefits in the long-term for companies are present, the main barrier in this case is the profit-oriented short-term goal-setting employed by a vast number of businesses (Ollár et al., 2020), also referred to as being accused of operating with short-term blinkers (Hart et al., 2019).

The seventh barrier following up on the high upfront cost is the **low virgin material prices** and even lower end of life values (Kirchherr et al., 2018). These low values of products and materials at the end of life are mainly present due to quality degradation (Gallego-Schmid et al., 2020). As we have identified that there is also a lack of certification and quality assurance, the lower end of life values will most likely cause expenses to increase further. Added to this, the high costs related to recycled materials in the supply chain often cause the recycled materials to e more expensive than the virgin materials (Adams et al., 2017). An example of this are the very low prices of steel, which make re-use hardly economically viable (Pomponi & Moncaster, 2017).

The eighth barrier is the **technical challenge related to material recovery** (Hopkinson et al., 2018; Ollár et al., 2020). Technical challenges mainly arise in the complexity of buildings and especially the technical components of that building. Examples are separating bricks or the re-use of concrete elements (Hart et al., 2019). Another technical challenge is how components that are designed 150 years ago can be envisaged to be re-used today (Adams et al., 2017). As these components were not designed to be re-used, new techniques need to be developed to overcome this barrier. Furthermore, components are often subject to damage during deconstruction which will likely prevent re-use (Rios & Grau, 2019). Also, built environment assets tend to have long lifecycles in which multiple actors and their incentives interact which further complicates CE (Arup, 2016). Currently, the **lack of adequate technology** is thus a barrier related to the technical challenges. Moreover, financial barriers arise as there is most evidently a higher complexity to deconstruction compared to demolition (Debacker et al., 2017).

Connected to the lack of collaboration and information sharing between businesses, the ninth barrier is **lacking standardisation** (Hart et al., 2019). The lack of standardization mainly refers to the context of specifications for recycled materials, related to the earlier mentioned quality assurance. Debacker et al. (2017) attribute the lack of standardisation to qualitative data and information over the entire value chain of the building and its materials. Moreover, a few articles referred to insufficient use and development of CE-focused design and collaboration tools, information, and metrics (Henrotay et al., 2017; Ollár et al., 2020). This includes mainly design tools and guides covering design for CE and standards for Design for Disassembly (DfD) tools (Hart et al., 2019; Adams et al., 2017). Moreover, the lack of information and metrics were viewed as important and connect to the lack of standardisation (Bilal et al., 2020).

The tenth barrier is related to **inadequate financial resources** mainly due to limited funding (Bilal et al., 2020; Hart et al., 2019). Funding is important as it is one of the major barriers influencing other barriers and holding businesses back from overcoming these barriers (Bilal et al., 2020). For example, the earlier mentioned barriers of high upfront costs can be overcome if access to funding is made simpler. Kirchherr et al. (2017) add to this by stating that often longer-term finance is needed for leasing models etc. related to CE. The unclear financial case of reusing materials and deconstruction of buildings makes acquiring funding even more challenging (Adams et al., 2017).

The eleventh and last barrier is the **fragmented and linear supply chain** of the current built environment (Debacker et al., 2017). As stated before, construction elements have long lifecycles (Hart et al., 2019), connected with complex and long supply chains (Ollár et al., 2020). The main challenge is to preserve value throughout these long lifecycles, making the materials available for re-use (Henrotay et al., 2017). Moreover, the linear supply chain itself needs to be changed towards a circular supply chain, reducing for example the lifecycle carbon footprint of buildings (Gallego-Schmid et al., 2020). To conclude, the main barrier in this aspect is the fragmented linear supply chain which needs to be changed to a lifecycle approach that optimizes the buildings (Leising et al., 2018).

2.4.2 Identified Drivers

The first identified driver is only mentioned by Hart et al. (2019) in their literature review and is called **leadership**. Especially in instances where there is confusion about who should lead (e.g. contractors, investors, construction clients), Hart et al. (2019) see leadership as an important enabler. Rizos et al. (2016) build upon the driver leadership by referring to a company environmental culture.

The second driver, **company environmental culture**, refers to “the philosophy, habits, and attitude of the company, thus including leadership. However, due to the other aspects of a company’s culture, we account company environmental culture as a separate driver. Connecting to this enabler, Rizos et al. (2016) mention **personal knowledge** as a driver as well. This driver is supported by other researchers such as Karhu and Linkola (2019) who link the need for sufficient knowledge to all aspects of CE but especially the need for knowledge on circular material choices. Also, Huovila et al. (2019) argue that CE can only thrive in the construction sector when sufficient knowledge is acquired about circular construction by businesses in the industry.

Two drivers related to governance and policies are **policy support** and **regulatory reform**, both initiated by Hart et al. (2019) and supported by, for example, Karhu and Linkola (2019). Nevertheless, these drivers are still rather broad. Joensuu et al. (2020) specify this driver in their research by stating that local municipalities should consider circular construction in their urban planning. Also, they state that governments should facilitate market initiatives. Adams et al. (2017) specify policy support in the form of green public procurement, but also economy specific legislations. These legislations are closely connected to financial support, initiated by Joensuu et al. (2020).

Financial support can be linked to a driver mentioned by Rios and Grau (2019) who state that CE in the construction sector should have a **financial incentive.** This incentive for CE (Hart et al., 2019) is mentioned by many researchers including Rizos et al. (2016) and Adams et al. (2017). The last research specifically considers a financial incentive to use secondary materials as important. In terms of incentives, Rizos et al. (2016) mention that **recognition** is also an important driver. This can either be external recognition of a green business model, such as an award or prize by an external organization, or internal recognition within the organization.

These green business models are in the case of a circular construction sector **Circular Business Models (CBMSs)**, referred to by Rizos et al. (2016) and Hart et al. (2019). Huovila et al. (2019) mainly state that the business models should be effective in implementing CE, whereas Adams et al. (2017) state that businesses should have a clear and effective business case. Especially articulating the value aspects of the circular economy was viewed as paramount during their research.

Within the organisation, different authors argue that technological solutions are necessary (Hart et al., 2019; Joensuu et al., 2020; Pomponi & Moncaster, 2017). The forms of solutions, however, differ between each research and vary from **web-based innovation** for information sharing (Pomponi & Moncaster, 2017), to **efficient designs** incorporating fewer materials (Huovila et al., 2019). Web-based innovation will lead to connecting demand and supply by handling, storing, and managing the huge amount of data that a CE requires. Efficient designs on the other hand, will lead to reduced waste in construction and an increase in re-use and recycling. Moreover, Adams et al. (2017) argue that mainly **development of enabling technologies to recover materials** is a highly significant driver whereby the SME should prioritize innovation. On the other hand, Joensuu et al. (2020) focus on developing **technologies to enable close loop material cycles**, that are important in the construction sector to reduce its environmental impact, promote a higher utilization rate and a longer service life. What is needed for these forms of innovation, however, are design tools and strategies (Hart et al., 2019).

The tools and strategies are mentioned by various other authors as well (Adams et al., 2017; Huovila et al., 2019). According to Adams et al. (2017), the tools must **measure the value of materials and products** whereas also **standards and guidance for DfD design tools** are required. Especially measuring the value of materials and products will help companies to better communicate and document which materials are viable for re-use or recycling (Heisel & Rau-Oberhuber, 2020). A different form of tools and strategies are the **information metrics** that are required by businesses (Hart et al., 2019; Ollár et al., 2020). Information and metrics are specified by referring to tools for creating and implementing new business models in organisations. The information required mainly relates to the three major constituting elements of the business model: the value proposition, value creation and delivery system (Ollár et al., 2020). According to Adams et al. (2017), the metrics should be set up in the form of assurance schemes for re-used/secondary materials. Another metric that is mentioned is an **environmental assessment metric** that can be used to either assess the impact of the entire supply chain or the impact of materials/products (Forsberg & von Malmborg, 2004).

From a 'businesses in a larger system' perspective, the main drivers relate to collaboration between different actors in the construction sector, support from stakeholders and a change within the system itself. Firstly, **collaboration** is an important driver, however, the way authors describe collaboration varies. Hart et al. (2019) describe collaboration as setting up databases, building passports and knowledge gateways, thus collaboration in the form of knowledge sharing. Rizos et al. (2016) especially deem **networking** important. They describe networking as joining groups of like-minded SMEs that strive for sustainability and as a member of a supply chain partnership. Karhu and Linkola (2019) argue that effective collaboration can take place with stakeholders and unconventional partners to widen the knowledge acquired by the SMEs. Ollár et al. (2020) describe this as setting up **multi-stakeholder connections** that helps SMEs to evaluate their value proposition and create an action plan for transitioning towards a circular business model.

An important driver related to support from stakeholders, is **support from the demand network**. Rizos et al. (2016) state that it is important that customers need or prefer 'green' products or services, as this motivates the adoption of a circular business model by SMEs. In order for this to happen however, **intrinsic motivation** is required which means the client believes that choosing the circular option is the right thing to do (Rios & Grau, 2019). Moreover, **successful engagement with clients** in the form of community engagement (Joensuu et al., 2020), or awareness-raising campaigns (Adams et al., 2017) is also an important driver. Especially since the designer of circular buildings will need to engage with the client during the design process (Rios & Grau, 2019).

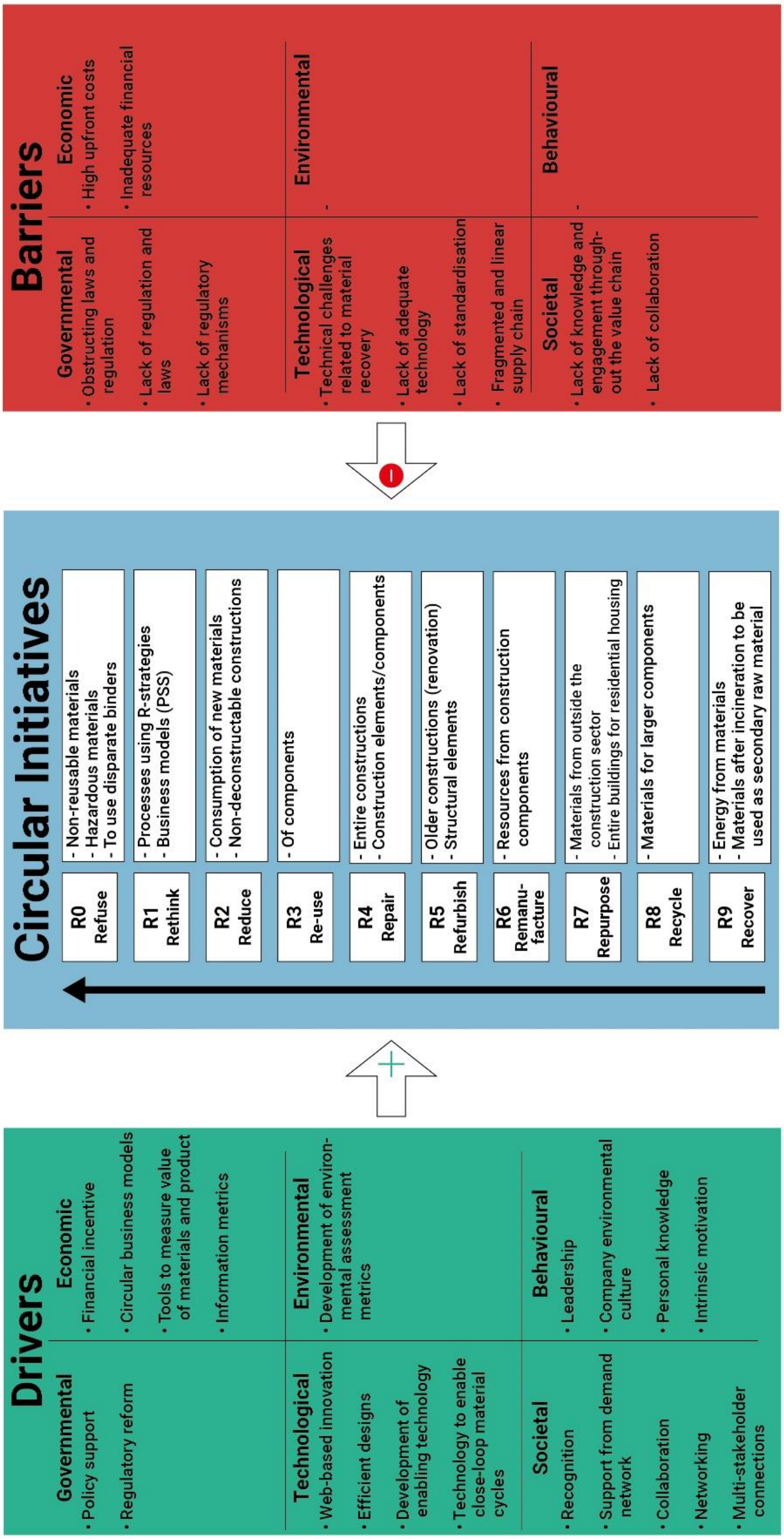
The driver which relates the most to the entire system in which the SMEs operate, is switching to a **product-service system** (PSS) (Hart et al., 2019; Rios & Grau, 2019). This system will enable the collaborative consumption of products and service and therefore represents an innovative relationship between supplier and user by selling function instead of value. PSS will focus on extending services associated with products and materials and will complement the CE model with services such as leasing, whereby **establishing leasing models** is seen as an important driver by Adams et al. (2017).

Lastly, there are some drivers mentioned by individual papers that did not correspond with any of the other papers. Nevertheless, these drivers are considered. These drivers are listed below with the corresponding author above the list.

2.5 Summary of Theory

Presented in Figure 3 (next page) is the summary of the theory for this report and answers sub-questions 1 and 3 of this research. The two identified frameworks are incorporated in one model to present the identified barriers and drivers from section 2.4 and the initiatives identified in section 2.2. This figure will be used to compare the findings of this report in the discussion.

Figure 3
Conceptual Framework Barriers and Drivers



3. Methodology

The following section seeks to throw light on how empirical data was obtained through researching into circular businesses. The sample selection, operationalisation, data collection, analysis, reliability and validity, and ethical issues are discussed.

3.1 Sample Selection

This research has identified circular initiatives and the barriers and driver for circularity of the construction sector in the built environment with a focus on SMEs. Within twenty SMEs the implemented initiatives, and the barriers and drivers faced by the SMEs were studied. A company was considered an SME when the number of employees is fewer than 250, based on a definition provided by the *Kamer van Koophandel* (KVK) (KVK, n.d.). The sample group consisted of actors working in SMEs operating in the construction sector of the Netherlands. These actors were selected via LinkedIn, filtering based on their affection with circularity. Actors that were actively involved in circular initiatives were then taken from this group and approached for an interview. Most importantly, the businesses were required to be registered businesses, which in the Netherlands corresponds to possessing a KVK-number (KVK, n.d.b). To avoid survival bias, snowball sampling was used, in the form of asking interviewees for names of SMEs that have failed to implement circular initiatives. This has aided in identifying two SMEs that had not yet implemented circular initiatives or failed in doing so.

3.2 Operationalisation

In terms of operationalisation, this research has used two sets of indicators to analyse the circular initiatives as well as the barriers and drivers. For the initiatives, the 9R Framework by Potting et al. (2017), set out in the theory section of this report (2.1.2), was the basis of the operationalisation of the identified circular initiatives. The barriers and drivers were operationalised based on the six dimensions discussed by Pomponi and Moncaster (2017), which are also set out in the theory section (2.3). The interviews were transcribed and coded using NVivo, based on these six dimensions. A more elaborate formulation of the coding process is presented in the data analysis (3.3). Moreover, the interview questions aided in operationalisation, meaning to answer the research question appropriately.

3.3 Data Collection

Data was collected by means of semi-structured interviews and was analysed qualitatively. These assisted in identifying barriers, drivers and circular initiatives in the sector and discussed the companies related to these initiatives. "A semi-structured interview is a verbal interchange where one person, the interviewer, attempts to elicit information from another person by asking questions" (Longhurst, 2003, p. 143). Compared to structured and unstructured interviews, semi-structured interviews are guided by a predetermined set of questions while still being flexible in how the interviewee addresses certain questions (Longhurst, 2016). Thus, a set of questions was prepared beforehand, which is translated and presented in Appendix I of this research. Moreover, additional questions were asked during the interviews to clarify and/or further expand certain issues. This was vital for this research, as the interviews were analysed descriptively, meaning that barriers and drivers were derived from the experiences of the interviewee. According to Barriball and While (1994), an advantage of semi-structured interviews is that standardized questions make the qualitative data comparable. This allowed comparing the data to the initiatives, barriers and drivers derived from academic literature.

As this research took place during a global pandemic, national guidelines permitted to execute the semi-structured interviews online using Microsoft Teams. The interviews lasted between 45 minutes and one hour. The first part of the interviews focused on the most important circular initiatives implemented by the companies. Whereas the second part focused on what factors, barriers, and drivers, influenced the implementation of these initiatives. The barriers and drivers were compared to the list of factors that was set up beforehand (2.4) after the interview took place.

3.4 Data Analysis

The first step in analysing the interviews was to link the circular initiatives to the 9R framework and determine how frequently each 'R' is mentioned. Secondly, a list of barriers and drivers was identified by means of inductive coding and immediately grouped under the six dimensions. Inductive coding, or open coding, allows to code a textual unit (sentences or words) that is close to the data without being predicated on any theory, construct or concept (Chandra & Shang, 2019).

Hereafter, the grouped individual barriers and drivers were ordered under 1st and 2nd order concepts and 3rd order themes. Therefore, all three categories include barrier and drivers that were mentioned by interviewees, however, the order was arranged in a later stage of the research based on relationships between them. The 3rd order themes were indicated as the main barriers and drivers and would thus be discussed in the discussion. As an example, under the behavioural barriers (4.3.6) the 1st order concept 'stuck in old habits' is a form of the 2nd order concept 'stuck in routines' which then again is a reasoning for the 3rd order theme 'resistance to change'. In the results section, the frequency of the main barriers and drivers was highlighted at the end of each paragraph. Lastly, the list of initiatives, barriers and drivers was compared to the list derived from the theory.

3.5 Reliability and Validity

To ensure the reliability of the questionnaire, two pilot tests were carried out using two subjects that were not included in the sample. The interview results were compared and checked using previous literature to see if the results compare to these findings. Furthermore, peer- and supervisor-checking was used to review the established coding scheme. This helped to verify if they agreed with the code and the interpretation of this research.

Moreover, demonstrating the accuracy of findings was necessary regarding the validity of this research. This was done in terms of credibility, transferability, and confirmability. First of all, credibility was achieved by triangulation of sources and analyst triangulation, as different data sources were used in the form of circular SMEs and non-circular SMEs and review of the coding scheme by multiple observers. Transferability was achieved as the sample group was specifically described, SMEs in the Residential and Utility Building sector of the Dutch construction sector, therefore the context of the data was discussed. Lastly, to achieve confirmability the researcher's lens was explicitly described. This assisted in understanding the perspective by which the data was interpreted.

3.6 Ethical Issues

To cover ethical issues faced in this research the following measures were taken. First of all, interviewees were provided more than sufficient information beforehand to make an informed decision about whether or not to participate in this research. This included the signing of a consent form, provided in Appendix II, based on the General Data Protection Regulation (GDPR) principles or confirmation in a recorded video. Moreover, personal data obtained during the interviews, including recordings for transcription purposes, was safely documented and stored on a password-protected laptop. To ensure anonymity, the businesses interviewed were not named and were referred to as 'interviewee *X*'.

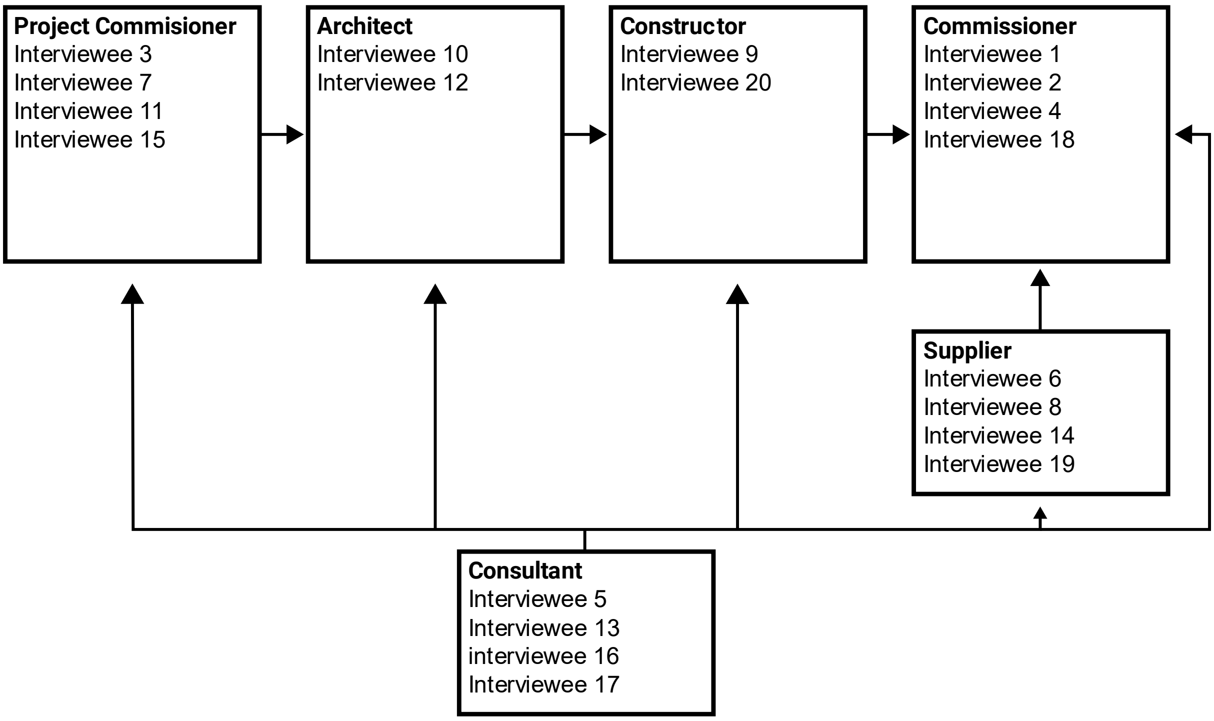
4. Results

4.1 Research setting

This section will aid in answering sub-questions two and four of this research, identifying the main barriers and drivers mentioned during the interviews. The findings presented in the following sections are based on twenty interviews, conducted with practitioners in the Dutch Residential and Utility Building sector. Figure 4 presents an overview of where actors are placed in the sector. Project commissioners initiate projects, after which architects provide the design. A constructor calculates the construction based on building regulations and commissioners execute the project. Lastly, suppliers supply the commissioners with resources, whereas consultants have an influence on all actors in the sector, advising them on opportunities for CE.

Figure 4

Division of Interviewee through the Dutch Construction Sector



4.2 Identified Circular Initiatives

The circular initiatives mentioned in the interviews were analysed based on the ten R-strategies presented in Figure 1. A similar approach will be taken as in section 2.2 of this research, referring to circular initiatives categorized under each strategy. The following sections will discuss the initiatives for each strategy mentioned by the interviewees. It will thus seek to answer sub-question two, supported by quotes from the interviews.

4.2.1 R0 – Refuse

Refuse is mentioned by nine interviewees of which most references referred to refusing to use toxic substances in materials and to assemble different construction elements. For example, interviewees argued that refusing to use adhesive bonds would benefit CE. Especially as this enhances deconstructivity and will eliminate toxic gases (interviewee 9, constructor). Interviewees also referred to refusing hazardous materials. Two materials mentioned by the interviewees were glass wool and concrete. Especially since these materials, due to the hazardous substances, cannot be applied in CE. Nevertheless, it is a struggle to eliminate the materials from construction as they are used extensively.

Interviewee 5 (consultant) has advised companies to refuse glass wool, especially to reduce harmfulness when the building is deconstructed. Concrete on the other hand is one of the most used materials in construction, although the impact on the environment is high. Other alternatives such as wood construction would be a better alternative according to interviewee 18:

"For several years I have sold concrete constructions to other companies, but it is a finite product. Also, the CO_2 footprint is so high, and the amount of water spilt during production is just ridiculous. I don't really see a reason to not refuse to use concrete in constructions." (Interviewee 18, Commissioner)

4.2.2 R1 – Rethink

Rethinking models to intensify product use is a reoccurring theme in nine interviews. Interviewees implemented rethink approaches in their SME to transform their business, or help transform other businesses, by implementing a product-service system (PSS). This 'as a service' model is seen as an important step towards CE as materials and construction elements are used more intensively. According to interviewee 11 (project commissioner), leasing out products such as a façade will help as these elements are often of good quality when a building is deconstructed. Some interviewees implemented PSS in their business to lease out entire houses (Interviewee 1). This was also done by interviewee 12:

"We established lease constructions for our wooden modular buildings. We lease the houses to people and buy them back if needed." (Interviewee 12, Architect)

Lastly, more intensive material use can be created by rethinking joints between construction elements. This is essential as elements that are glued together cannot be re-used. Interviewee 18 discussed such a new joint:

"In Japan and China new methods of woodworking led to connections stronger than glue or screws, but which were easier to take apart. This has led to more intensive use of the construction elements." (Interviewee 18, Commissioner)

4.2.3 R2 – Reduce

Reduce was mentioned by three interviewees who focused on reducing chemical materials and minimizing the use of natural resources. Moreover, all three interviewees agreed that constructions should be designed for deconstruction and the number of non-deconstructable constructions should thus be reduced.

"It is essential that a minimum of chemical material is used." (Interviewee 19, Supplier)

4.2.4 R3 – Re-use

Re-use was referred to by seven interviewees in different forms ranging from whole buildings to components. It is important that these constructions are built from lighter materials such as wood, in which case the whole structure can be transported and installed on a different location (interviewee 1, commissioner). Moreover, components such as support beams could fulfil similar functions in other constructions. Again, when the building is demolished, the elements are of excellent quality, meaning that they can perform the same function in a different construction. Interviewee 20 (constructor) very specifically stated that the re-use strategy was the main advantage of the screw foundation they used. It could be taken out of the ground using the same machines that were used to bring the screw piles into the ground. During these stages, the piles do not require any adjustments.

4.2.5 R4 – Repair

Repair was mentioned as a strategy by five interviewees and was seen as 'the new standard' and not hard to do. The construction company interviewee 9 (constructor) works at are already quite far in incorporating repaired elements in their calculations. Repairing construction elements would eliminate the need for buying new materials. An example was provided by interviewee 4:

"With sand-lime brick for example. You can use it again after 30 years with only adding about 15 percent new material. Your product is as new." (Interviewee 4, Commissioner)

Moreover, repair was referred to as making re-use possible in a different way. Interviewee 16 (consultant) argues that repairing elements is not hard to do, but necessary.

4.2.6 R5 – Refurbish

Refurbish was mentioned by six interviewees whereby the main difference between refurbish and repair was indicated by interviewee 4.

"We can take the elements in and use them for a different purpose. All we have to do is apply a new coating for example." (Interviewee 4, Commissioner)

Moreover, according to the theory (2.2), renovation was analysed as a synonym for refurbishing. Therefore, renovated buildings have been incorporated into projects of some SMEs. Especially in renovation, one of the project commissioners (interviewee 7) saw business opportunities in the long term. According to interviewee 16 (consultant), this is the case because buildings from the '70s might be technically degraded, but the construction itself or the building ground still provide significant value. Therefore:

"Restoring the true value of the buildings and bringing them up-to-date will help a lot in the shortage of houses and will be profitable in the long term." (Interviewee 16, Consultant)

Moreover, interviewee 18 indicated that the buildings could have different functions before renovation. He argues that all buildings have the potential to be transformed into houses.

4.2.7 R6 – Remanufacture

Remanufacture was mentioned by four interviewees, mainly arguing that parts of a discarded product could be used in new material. An example was given by interviewee 8 (supplier), who works with a producer of paint that makes their paint from 38% used paint. Another example was described by interviewee 19 (supplier) who has already seen reclaimed wood applied in construction elements. Interviewee 16 indicated that remanufacturing is an important part of CE:

"Remanufacturing products is possible. You can use construction elements and resources without very large adjustment. It is something I always advise companies to do, and some have actually followed up on the advice." (Interviewee 16, Consultant)

4.2.8 R7 – Repurpose

Repurpose was mentioned by seven interviewees. Like re-use, repurpose strategies ranged from using housing units to construction elements or materials. The earlier mentioned wooden constructions introduced by interviewee 1 (commissioner), could also be given a different function. Former living rooms could for example function as a bedroom or the other way around. Moreover, materials can be repurposed in new construction elements according to interviewee 19 (supplier). Four interviewees referred to repurpose by working together with different sectors and repurposing materials coming from these sectors. Metals from the automotive industry could be used in construction elements (interviewee 4, commissioner) and jeans are currently used to create insulation panels (interviewee 17, consultant). Moreover, interviewee 14 (supplier) supplies projects with insulation material made from old newspapers and cardboard boxes. He argued that this market is growing, especially with the rise of e-commerce and the cardboard waste coming from this sector. According to interviewee 10 (architect), the possibilities for repurposing materials in the construction sector are endless as most of the materials are manoeuvred away inside the construction.

4.2.9 R8 – Recycle

Recycling was mentioned by nine interviewees whereby respondents made a difference between recycled materials used and materials that could be recycled. The latter was indicated by four interviewees. Interviewee 1 (commissioner) stated the wood his SME uses is 100% recyclable. Interviewee 4 (commissioner) made a similar statement, saying that the steel they use is easily recyclable. However, steel recycling has already received critique throughout the interviews due to the emissions during this process.

As stated, there were also SMEs that used recycled materials in their process. Interviewee 6 (supplier) made climate regulation devices using recycled plastic, whereas interviewee 20 (constructor) prescribed screw piles from recycled steel. Nevertheless, two consultants, interviewees 3 and 17, criticised recycling as a circular method. According to them, most recycled materials are downcycled and end up as asphalt for example.

4.2.10 R9 – Recover

The last strategy, recover, was mentioned by three interviewees. Both interviewee 1 (commissioner) and 19 (supplier) identified recovering energy from waste as the last strategy, as their company focused on wooden constructions. For interviewee 4 (commissioner), recovering energy was mentioned as a possible strategy for other companies, but was not possible for this company. Nevertheless, the interviewees acknowledged that recovering energy is not fitting for CE and should thus be avoided. Only one solution was proposed by interviewee 19:

"The last possible solution is using the material as biofuel in presumed sustainable power stations." (Interviewee 19, Supplier)

4.3 Identified Barriers in the Dutch Construction Sector

The following section will highlight the identified barriers for each dimension in sections 4.3.1-4.3.6. As discussed in the methodology, inductive coding was used to derive 1st order concepts from the interviews. These 1st and 2nd order concepts were then grouped under 3rd order themes. The 3rd order themes are then identified as the main barriers for each dimension.

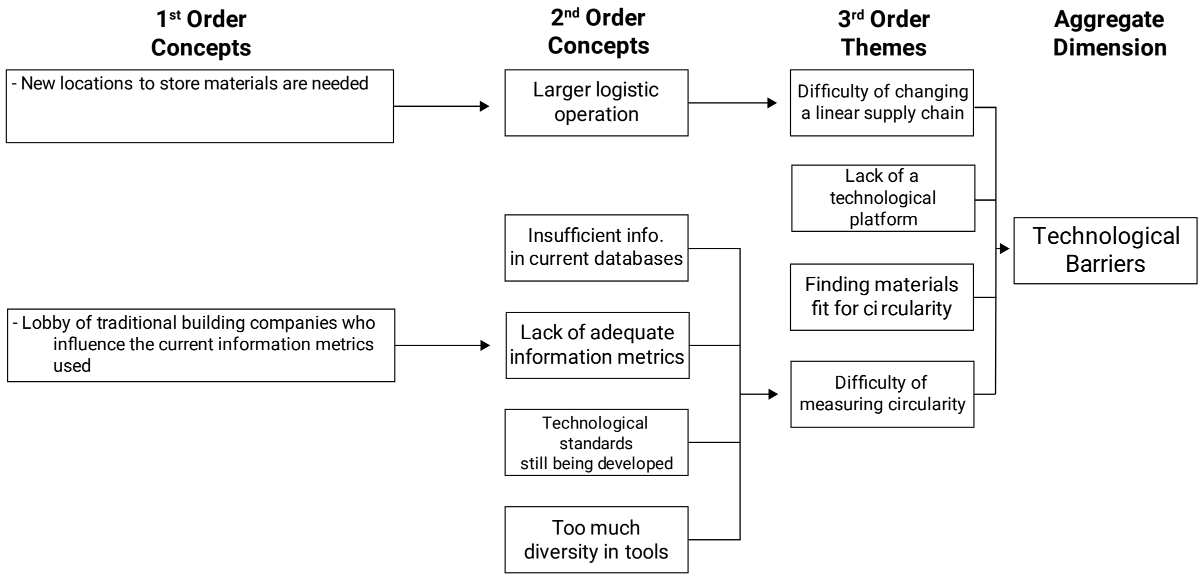
Firstly, a Figure will be presented to visualize the concepts and themes and how they relate to each other. The order of concepts and themes does not indicate the importance of each barrier. This will be highlighted at the end of each chapter as a bar chart will be shown to demonstrate the total number of interviewees referring to a barrier and how these interviewees are divided between the different groups identified in Figure 4.

To provide context, a brief description will be provided again at the beginning of each dimension. This description applies to both the barriers, as well as the drivers.

4.3.1 Technological Barriers

During the interviews, 16 interviewees mentioned at least one technological barrier. In total, four 3rd order themes were mentioned under the technological dimension. How the concepts and themes relate to each other is visualised in Figure 5. All barriers and drivers (4.4.1) related to this dimension apply to a technical aspect such as schemes for innovation, tools of measurement and technical difficulties or opportunities in production processes.

Figure 5
Technological Barriers



Difficulty of changing a linear supply chain

This barrier was mentioned by six interviewees of which two suppliers have had technical trouble in changing their supply chain. According to six interviewees, SMEs experience difficulty in changing a linear supply chain because of the larger technical logistic operation. The interviewees referring to this barrier were thus in different groups of the sector. The main concerns regarding a larger logistic operation focussed on time, pressure, and insecurity of material storage, concluding that changing the logistic operation is not technologically feasible. Both consultants referring to the barrier provided an outside view, and both referred to the difficulty of storing materials, which can be identified as a 1st order barrier. Interviewee 13 said:

"It will cost a lot of effort and manpower to set up a large hall in which materials can be stored. However, they cannot be directly used in new buildings, so it is necessary to do." (Interviewee 13, Consultant)

Lack of a technological platform

Secondly, according to five interviewees, a technological barrier is making sure that all materials available in the circular economy, are matched with demanding parties, experiencing a lack of a technological platform. Two project commissioners and supplier had experienced the problem themselves, while the consultant and constructor were aware of the problem in other companies. Especially timing the technical alignment of the two companies was experienced and seen as difficult, thus missing a platform where one party can indicate what materials come from a construction at what moment so other parties can use these materials. This was addressed by interviewee 7 as:

"When I am planning to build a construction, the materials might still need to be harvested from existing buildings. I need to calculate what foundation we need etcetera. So, I need to calculate the cost of materials now, but can only acquire the materials in two years." (Interviewee 7, Project commissioner)

Finding materials fit for circularity

Five interviewees mentioned that a main barrier for SMEs is finding materials that are technologically fit for a circular economy. One consultant provided a global view and stated that even though some commissioners ask for circular materials, suppliers cannot provide them. Also, according to interviewee 7, it is difficult to find these materials in the first place. He states:

"You cannot just go to a marketplace and look for whatever material you want." (Interviewee 7, Project commissioner)

Difficulty of measuring circularity

The fourth technological barrier is the difficulty of measuring circularity. According to ten interviewees, SMEs are hindered in transitioning towards a circular economy in the construction sector because they are unsure of how circularity can be measured. The interviewees stated that the main difficulties arise from how to use the right tool, that the current tools are not fit for circularity and that there is too much diversity in tools. This causes SMEs to be unsure of which tools to use and feel that they need to comply with all tools.

Difficulty in measuring circularity is also caused by the lack of adequate information metrics. This means that SMEs focussing on circularity will not have the benefit of more individuals buying their product or choosing them as commissioners. Interviewee 20 stated:

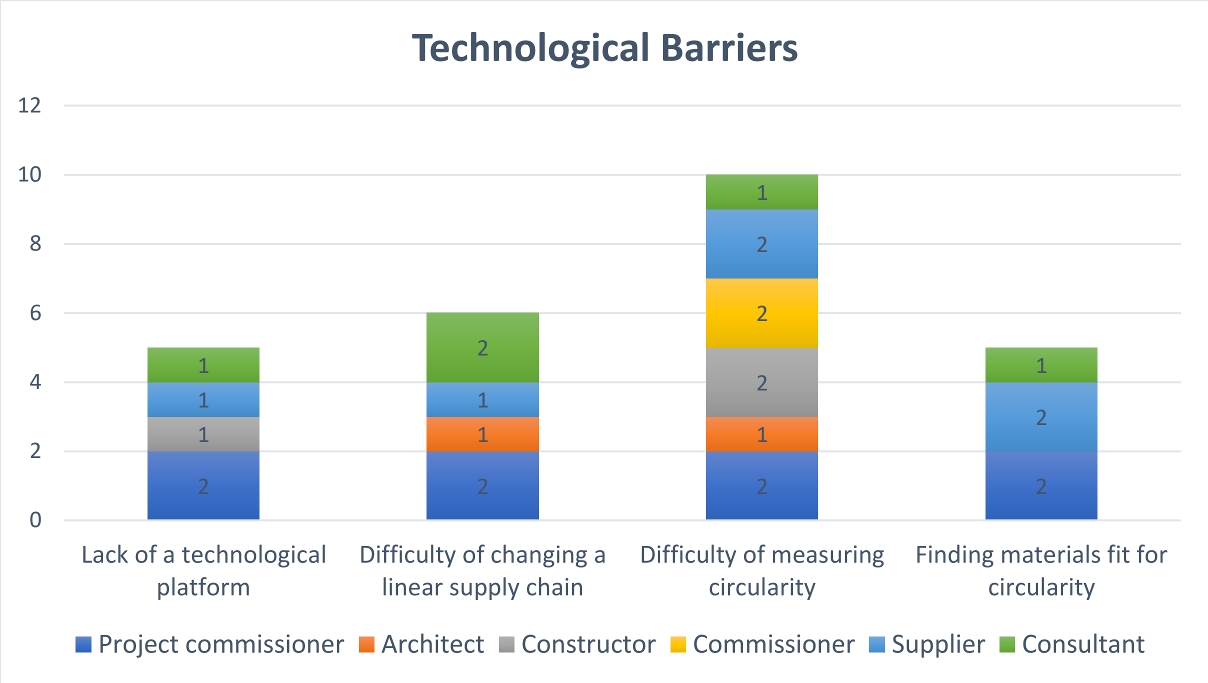
"We have already stepped forward to municipalities, stating that there is no circularity label A, B or C for foundations for example. This means that private individuals cannot make a decision based on any criteria related to circularity." (Interviewee 20, Constructor)

Apart from the information metrics, one interviewee argued that there is insufficient information in current databases. The current tool in place to measure sustainability and circularity is the MPG, which is based on a climate database and existing construction elements but does not consider innovation. Therefore, according to interviewee 9 (constructor), these elements cannot be measured on circularity.

Lastly, technological standards are still being developed, meaning that standardisation and automation in measurement is not possible. Currently, traditional SMEs base their innovations on existing standards that for example show the constructive and insulation values for materials. In case of the insulation values, when these cannot be determined for circular insulation, the materials cannot be applied in houses. Therefore, SMEs do not want to transition into CE.

Figure 6

Number of Interviewees mentioning a Technological Barrier

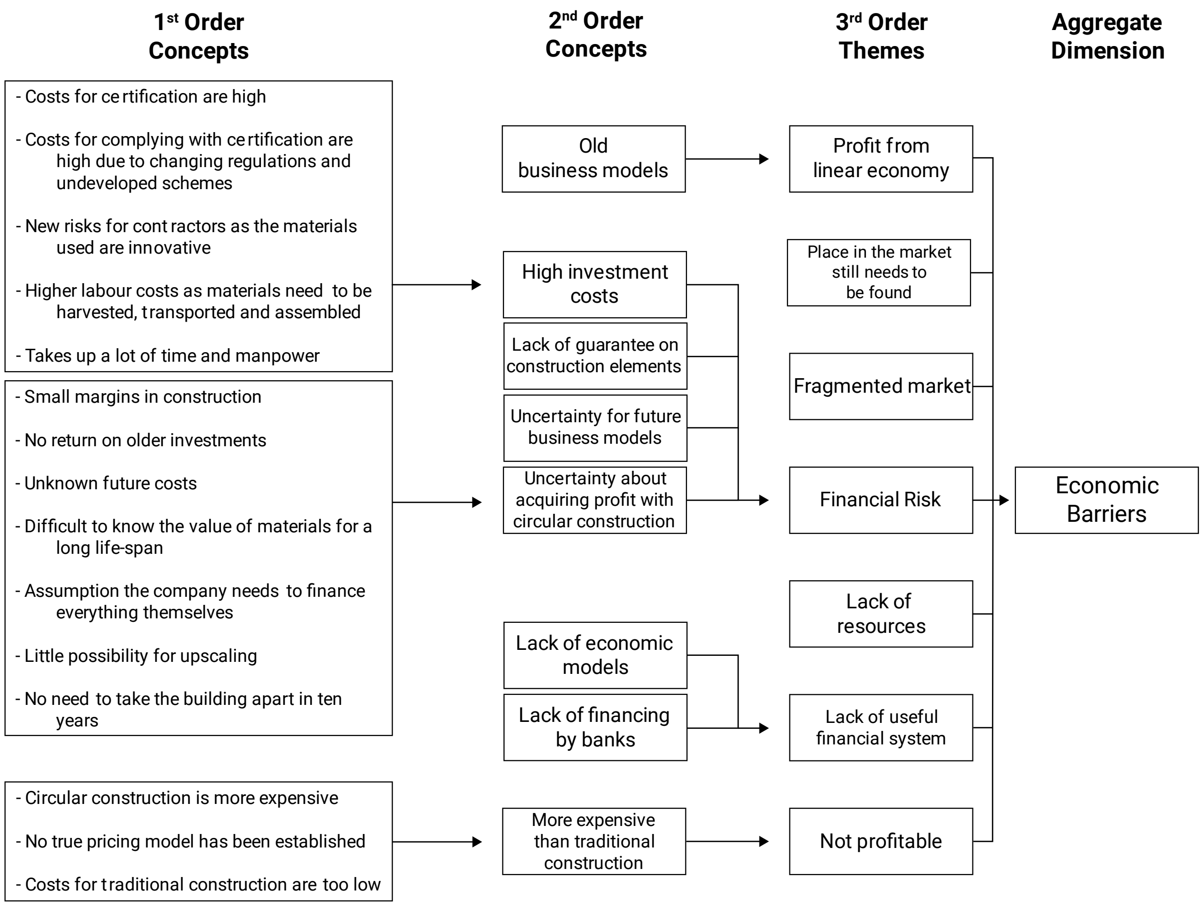


4.3.2 Economic Barriers

Under the economic dimension seven 3rd order themes could be analysed. All twenty interviewees mentioned at least one economic barrier, either 1st or 2nd order concepts or 3rd order themes. The economic barriers and how they relate to each other are visualised in Figure 7. Barriers and drivers (4.4.2) related to this dimension deal with financial opportunities or risk, economic models, the financial market, and profitability or the lack of profitability.

Figure 7

Economic Barriers



Profit from linear economy

The first economic barrier is proposed by six interviewees, who stated that some SMEs currently profit too much from a linear economy and thus do not want to focus on any other opportunities. Interviewee 18 (commissioner) made a connection with Kodak, a company formally focused on cameras. He said that they were the inventor of the digital camera but did nothing with the invention because they made too much money with their 'older' product. According to the interviewee, a similar pattern can be noticed in SMEs in the construction sector. The position of SMEs in the current economy is in their perception good enough to not make the transition.

Four interviewees specifically mentioned the old business models of SMEs as a barrier. Especially since the business models are linear with little flexibility. According to interviewee 3 (project commissioner), SMEs want to stick with the business model they are used to. An older business model thus hinders SMEs in the transition, also when they are willing to transition:

"Our business model was very much focussed on the linear economy. This made switching to a circular economy very difficult and caused the transition to happen less quick than we wanted to." (Interviewee 8, Supplier)

Place in the market still needs to be found

This barrier was mentioned by two interviewees who focussed on the lack of belief amongst parties in the ability to seize a place in the market. Although interviewee 2 states that a place in the market is crucial for upscaling, SMEs often do not understand how and where their place in the market currently is. According to interviewee 4, commissioners do not have the confidence to make bold statements because of this barrier. He states:

“Commissioners could do a lot more with the power they could have. However, they are afraid of all the other parties in the market, whereas the commissioners could have a more powerful position.” (Interviewee 4, Commissioner)

Fragmented market

A second economic barrier, according to three interviewees, is the fragmented market that shapes the construction sector. This means that there are a lot of parties on the market, which, according to interviewee 10 (architect), is why a lot of SMEs do not want to make in-depth investments. Interviewee 10 also stated that the construction sector does not have a few major players such as the smartphone or car industry, but instead, there are around 12,000 architects in the Netherlands. This hinders the transition as a lot more businesses need to make the transition to circularity for the sector to become truly circular. Moreover, the SMEs that are willing to transition, need to cooperate with a lot of different parties that are active in the market. As interviewee 7 described it:

“When you as an SME want to take the initiative, you need to find investors, an architect, a commissioner with a decent price, suppliers and sometimes even sub-commissioners. In every section of the market there are just too many parties.” (Interviewee 7, Project commissioner)

Financial risk

This barrier was mentioned most frequently out of all barriers with 18 interviewees referring to it at least once. Interviewees argued that the financial risk of a circular transition hindered SMEs from this transition. Four important 2nd order concepts were considered the main rationales for the financial risk. The first concept ‘high investment costs’ was mentioned by 13 interviewees. Especially the costs for certification, the time and manpower that needs to be invested and the costs for complying with certification were considered important.

The second concept is a ‘lack of guarantee on circular construction elements’. This barrier, mentioned by six interviewees, related to the difference between a provided guarantee on traditional materials and circular materials. For example, interviewee 4 (commissioner) stated that their buildings could have a guarantee for fifty years but was nonetheless assured of ten years.

Thirdly, the barrier ‘uncertainty for future business models’ mentioned by two interviewees, focuses on the uncertainty of which business model will be leading in the future. According to interviewee 3 (project commissioner), this makes SMEs scared to make the transition as they are likely to choose the wrong model.

Lastly, there is a major ‘uncertainty about acquiring profit with circular construction’. This second largest 2nd order concept mentioned by 12 interviewees is mainly caused by small margins on projects that currently apply to the sector and no return on older investments that needs to be compensated. The uncertainty about profit mainly causes SMEs to not transition to CE, especially as they are risk-averse and do therefore not want to innovate.

Lack of resources

According to five interviewees, most SMEs simply lack the resources to make the transition. As just discussed, a transition towards circular construction goes hand in hand with high investment costs. The interviewees thus meant that it was partly the high cost, but mainly the inability to pay for the transition even though SMEs wanted to. An example was cited by interviewee 17 (consultant), who referred to the ‘Circl’ building, a circular building initiated by ‘ABN Amro Bank’, and its elevator. He insisted that the construction as it stands now, could not have been present if Mitsubishi had not had the resources to follow all procedures to set in place the current structure. On the other hand, according to interviewee 5 (consultant), project commissioners often work with budgets that are often not sufficient for circular construction. They thus lack the resources for circular projects. Lastly, interviewee 7 stated:

"When you look at social housing for example. The owners want to reduce costs and earn as much as they can, while the people living in those houses do not have a budget for higher prices. SMEs building the construction therefore need to reduce costs and cannot switch to circular construction." (Interviewee 7, Project commissioner)

Lack of useful financial system

Six interviewees argued that the current sector lacks a useful financial system. As project commissioners do not have the resources themselves to fully fund projects, investments from banks are always needed. However, according to interviewee 12, the current rules on financing need to change as banks often choose not to finance projects that focus on circularity. According to interviewee 17 (consultant), we are trying to make a technical process more circular, while on the other hand the financial system is capitalistic. The interviewee, therefore, argues that the technical process is not the problem, but the economic model. The barrier is summarized by interviewee 7 who stated:

"The long-term focus is a major problem in the construction sector. We currently have a financial system that is not right for a circular sector as the focus is short term. We really need to make changes to that system for the transition to be successful." (Interviewee 7, Project commissioner)

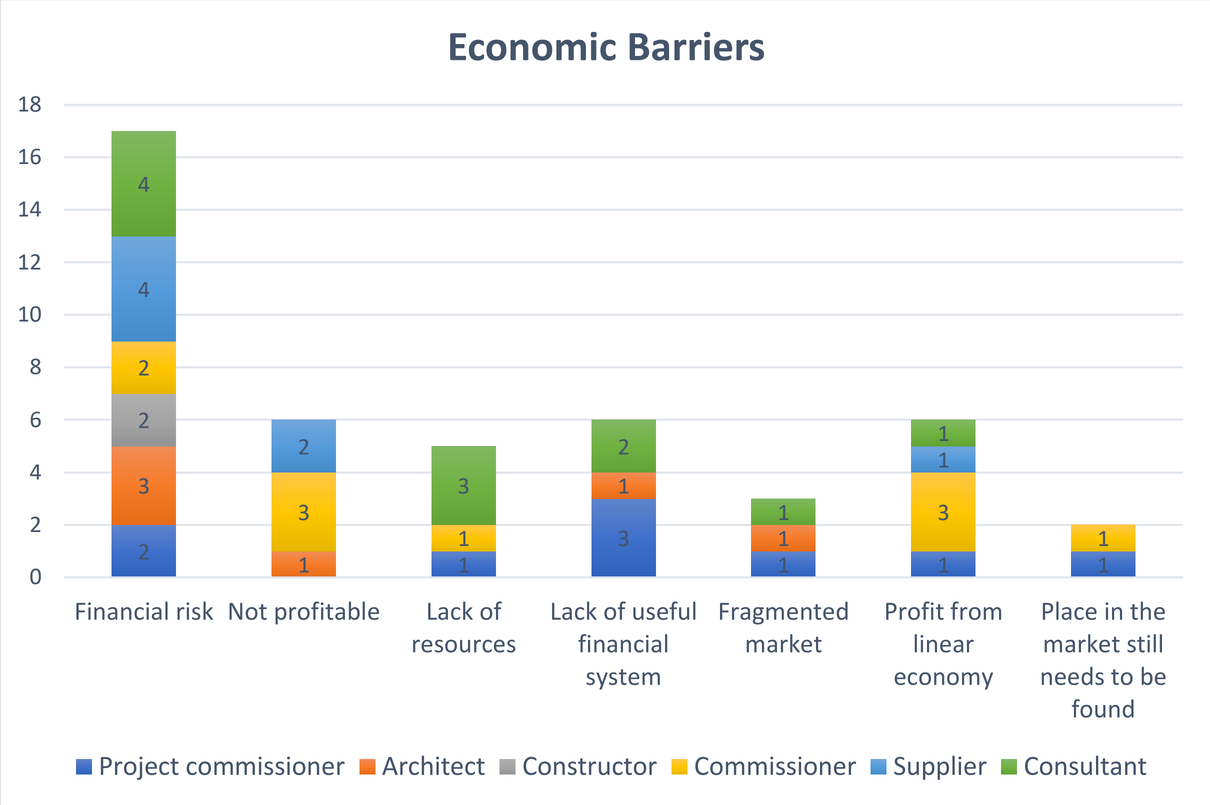
Not profitable

Six interviewees stated that some SMEs do not want to transition to a circular sector as this is not profitable for them. This barrier focuses solely on the profitability of circular construction, therefore not considering the current business model of companies which was done for the 'profit from linear economy' barrier. Moreover, the main difference with the 2nd order concept 'uncertainty about acquiring profit with circular construction' is that this concept is focused on assumptions rather than presumed facts. These facts are presented as 1st order concepts as six out of six interviewees state that circular construction is more expensive than traditional construction. Two other 1st order concepts that arose are 'circular materials are more expensive' and 'no true pricing model'. In terms of materials, the two interviewees mentioning this barrier both stated that concrete is more affordable than wood for example, which makes it hard for SMEs to switch in material choice. The true pricing model was mentioned by interviewee 10 (architect), who stated that the current model does not stimulate circular construction as only the short-term costs are considered. An interesting perspective came from the same interviewee, as he reversed this barrier into a separate barrier by stating:

"I don't think circular construction is too expensive. Currently it is more expensive than traditional construction, but I think that is because currently traditional building is too cheap. Not the other way around." (Interviewee 10, Architect)

Figure 8

Number of Interviewees mentioning an Economic Barrier

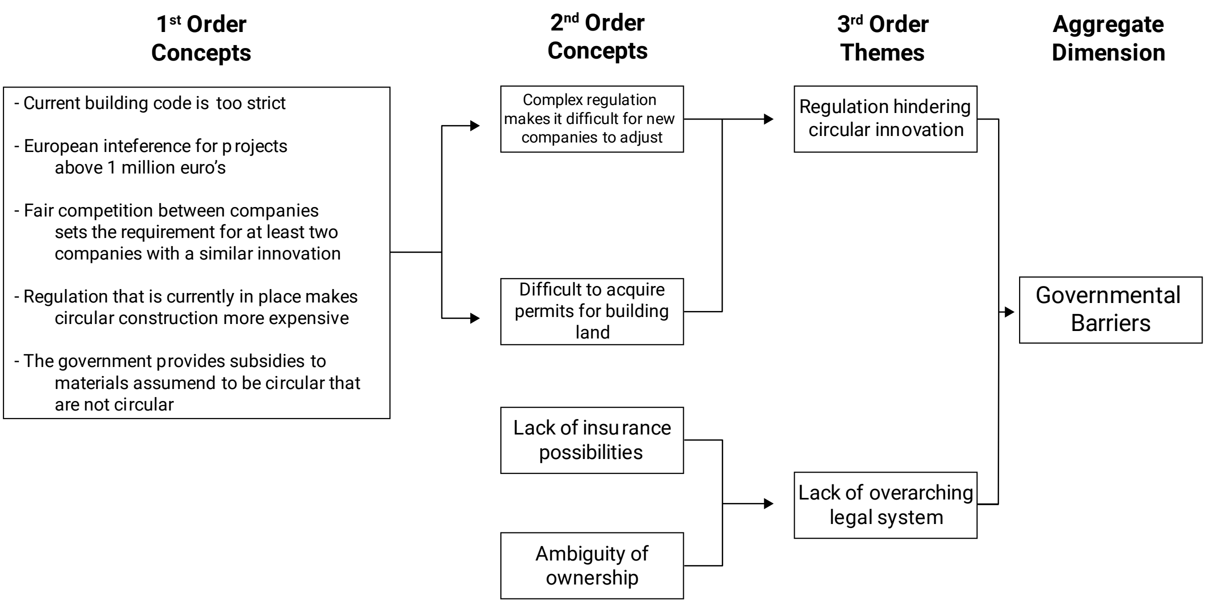


4.3.3 Governmental Barriers

Under the governmental dimension, two 3rd order themes could be analysed and are presented in Figure 9. Under the governmental dimension, we account for all barriers and drivers (4.4.3) that are related to governments influencing SMEs through either rules, regulation, financial support and guidance.

Figure 9

Governmental Barriers



Regulation hindering circular innovation

This barrier was mentioned by ten interviewees who referred to concrete rules that hindered circular innovation. As can be noticed in Figure 9, two 2nd order concepts and five 1st order concepts could be derived from the interviews. These can be interpreted as examples of hindering regulation. The first 1st order concept mentioned by 5 interviewees was the current building code, known as 'het Bouwbesluit', in the Netherlands. According to interviewee 13 (consultant), this code was set up to ensure safe and sustainable construction. However, the requirements, norms and guidelines summarized in the building code are hindering innovation in CE. This was the case, according to interviewee 20 (constructor), because the requirements are built upon traditional construction. The two other important 1st order concepts were European interference and fair competition. The first concept was seen as a barrier because other European countries need to get a chance to take on large projects. Only reaching full circularity in the Netherlands alone would thus not be preferable. Innovation was also hindered by the barrier 'fair competition', which was mentioned by three interviewees. Interviewee 15 stated:

"Uniform tendering means that whenever I have a very innovative idea, the government will say they will only buy the product from me when two other parties can offer a similar product. When they cannot, the government is simply not allowed to buy my product." (Interviewee 15, Project commissioner)

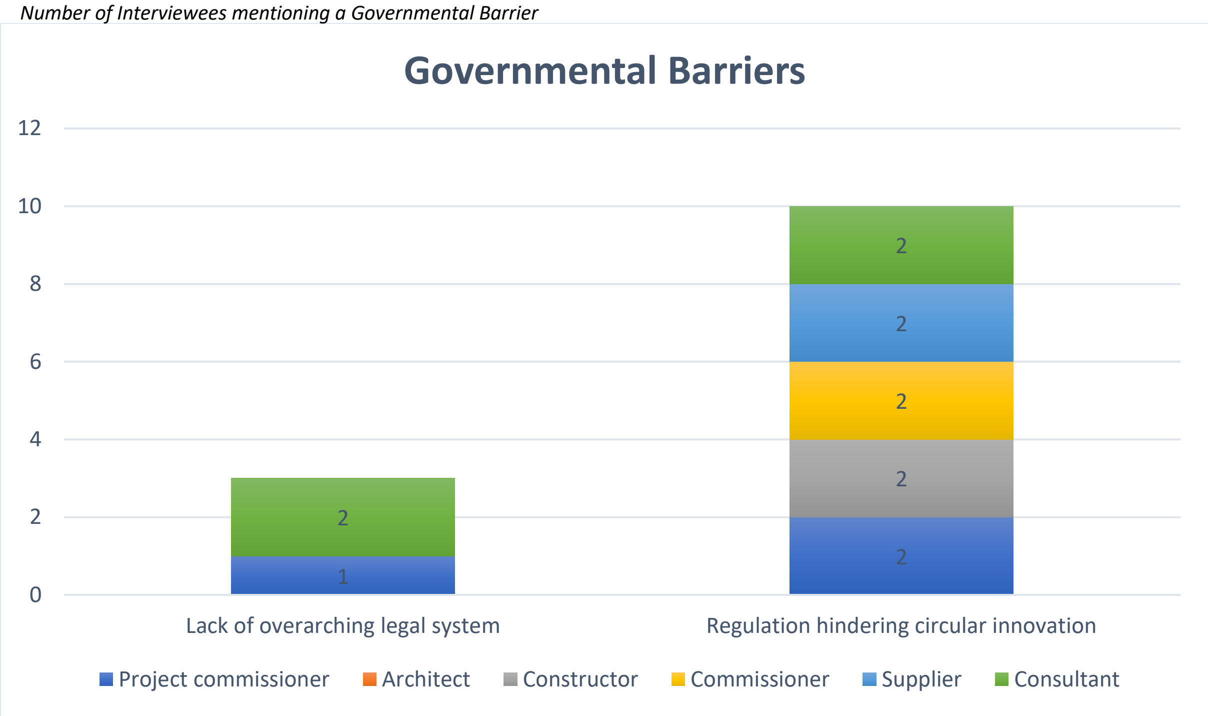
Lack of overarching legal system

This barrier was mentioned by three interviewees, focussing mainly on how the current juridical and insurance systems hinder contracting in CE. The main difference with the first barrier is that the former discusses concrete rules, whereas interviewees also indicated that the legal system overarching the rules and regulation was lacking. Two 2nd order concepts were mentioned in the form of ambiguity of ownership and lack of insurance possibilities. The lack of insurance possibilities mainly related to re-used materials, with interviewee 17 (consultant) stating that for example, isolation material that is re-used cannot get the appropriate insurance. In terms of ambiguity of ownership, two interviewees used the Circl Building in Amsterdam and their collaboration with Mitsubishi as an example. Interviewee 7 (project commissioner) worked on the project himself and stated:

"When I worked at the project we said, what if the owner of the building goes bankrupt. The curator will look at everything that is stuck to the building, including the elevator. So, we had to take legal actions to make Mitsubishi the owner of the exact surface the elevator was placed on." (Interviewee 7)

Figure 10

Number of Interviewees mentioning a Governmental Barrier



4.3.4 Environmental Barriers

As an environmental barrier, only one barrier was mentioned. Under the environmental dimension, we account for all barriers and drivers (4.4.4) that are related to environmental factors such as resource scarcity, environmental impact and damage done to the environment. Circular resource scarcity was referred to by two interviewees. Resource scarcity was seen as a barrier for circular construction in particular, as wood, a material that is frequently used for circular construction, is running short faster than concrete for example. Interviewee 19 stated:

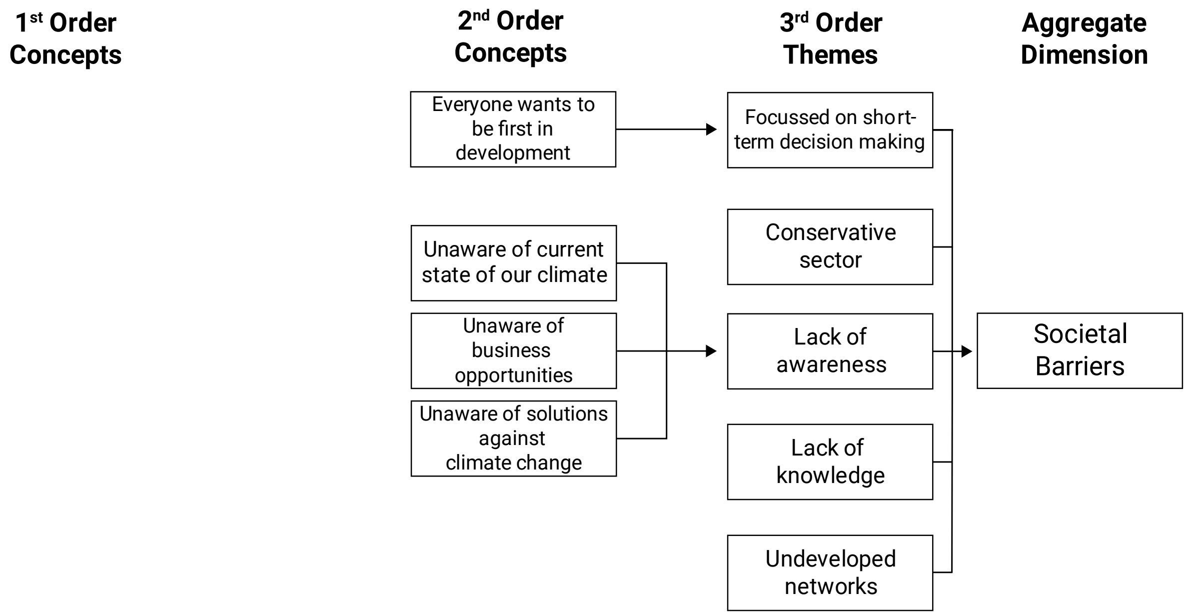
"Demand has grown substantially in the last period, so we currently have a lack of wood to build with." (Interviewee 19, Supplier)

This was acknowledged by interviewee 4, who also said that we quickly need to replant trees to keep up with demand. Not only for building houses, but also to reduce CO_2 in the atmosphere. The barrier was thus highlighted by a supplier as well as a commissioner. Both parties had more experience in wood construction than other interviewees.

4.3.5 Societal Barriers

In this research five societal barriers were identified as 3rd order themes. Moreover, four 2nd order concepts could be derived, whereas it was not necessary to arrange barriers as 1st order concepts. In total, 16 interviewees mentioned at least one societal barrier. The barriers and how they relate to each other are presented in Figure 11. Under this dimension, this research accounts for all barriers and drivers (4.4.5) that relate to the entire sector and the interaction between different SMEs operating in the sector.

Figure 11
Societal Barriers



Focused on short-term decisions

As economic barriers are already discussed, these short-term decisions in collaboration between SMEs. The barrier was mentioned by five interviewees. Interviewee 10 (architect) stated that we, as a society, are biologically programmed to make short-term decisions. As a result, problems such as the housing shortage in the Netherlands are dealt with on the short-term as well. Interviewee 15 stated:

"You notice that everyone wants SMEs to build more houses now, well okay then we will start to build houses. But strategic planning in the long run is not possible, everything is focussed on short-term decision making by both SMEs and the government." (Interviewee 15, Project commissioner)

Moreover, according to interviewee 13 (consultant), this short-term vision is mainly caused by most SMEs wanting to be first in development. Although most interviewees stated that collaboration is important, SMEs compete and lose sight of the long-term perspective, hindering the transition towards circularity.

Conservative sector

Seven interviewees mentioned that a main societal barrier is the sector itself, being a conservative or traditional sector. Especially the culture within the sector is extremely conservative according to these interviewees. This conservative culture makes it difficult for SMEs to make a transition (interviewee 12, architect) and hinders innovation (interviewee 8, supplier). According to the interviewees, conservativeness is mainly present in the hierarchical structure of the sector, referring to how different SMEs work with each other.

Lack of awareness

This barrier was referred to by nine interviewees, whereby three 2nd order concepts could be analysed. These were unaware of the current state of the climate, unaware of opportunities and unaware of solutions. Four interviewees mentioned that SMEs are unaware of the current state of our climate and thus do not act and are not willing to shift to a circular sector. Two other interviewees mentioned unawareness of business opportunities as a barrier, stating that if SMEs saw the opportunities that circularity brings instead of the risks, transitioning would be much easier. Lastly, lack of awareness of solutions against climate change was mentioned by two interviewees. Hereby mainly focussing on SMEs not being able to look in the right place for solutions.

Lack of knowledge

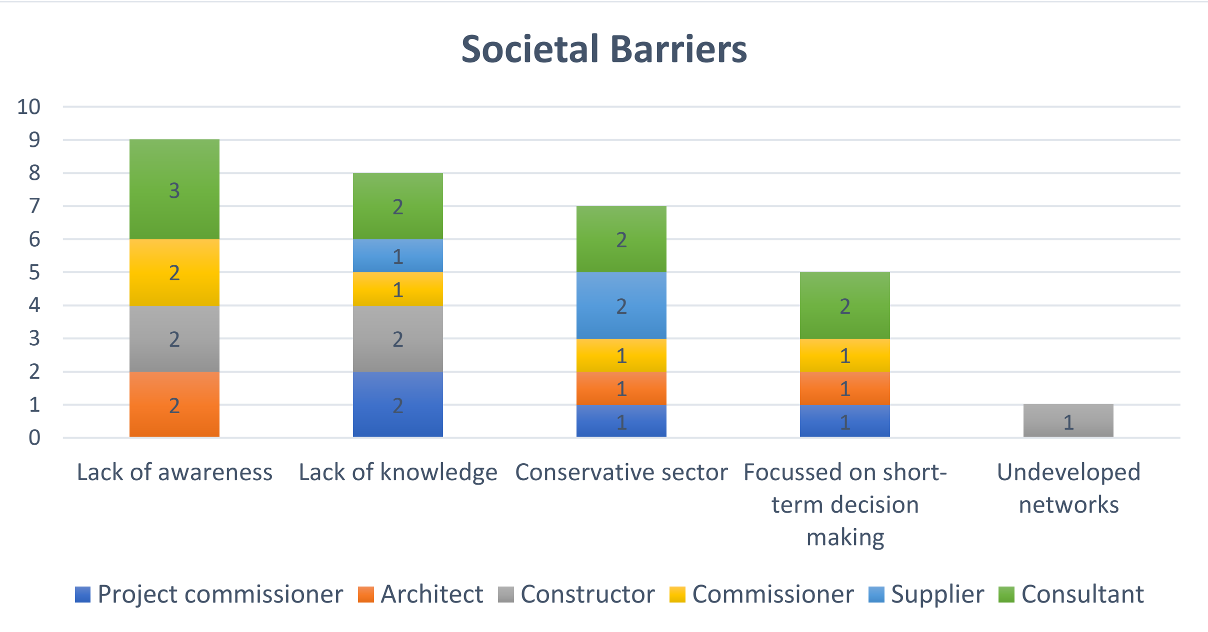
Another main barrier mentioned by eight interviewees is the lack of knowledge to transition to a circular sector. Again, quotes on this barrier showed similarities between interviewees agreeing that there is a lack of knowledge on circularity within the sector. The main problem was summarized by interviewee 1 who stated:

"When you lack the knowledge to do something about it, you cannot do something about it can you?" (Interviewee 1, Commissioner)

Undeveloped networks

The last barrier was mentioned by one interviewee. These undeveloped networks hinder in fully transitioning towards CE. Interviewee 9 (constructor) argued that when SMEs are finally able to find a demolisher that wants to deconstruct rather than demolish the building, this demolisher is stuck with materials as he cannot currently sell the harvested product. Moreover, the interviewee argues it is difficult for SMEs to find the right partners in the first place.

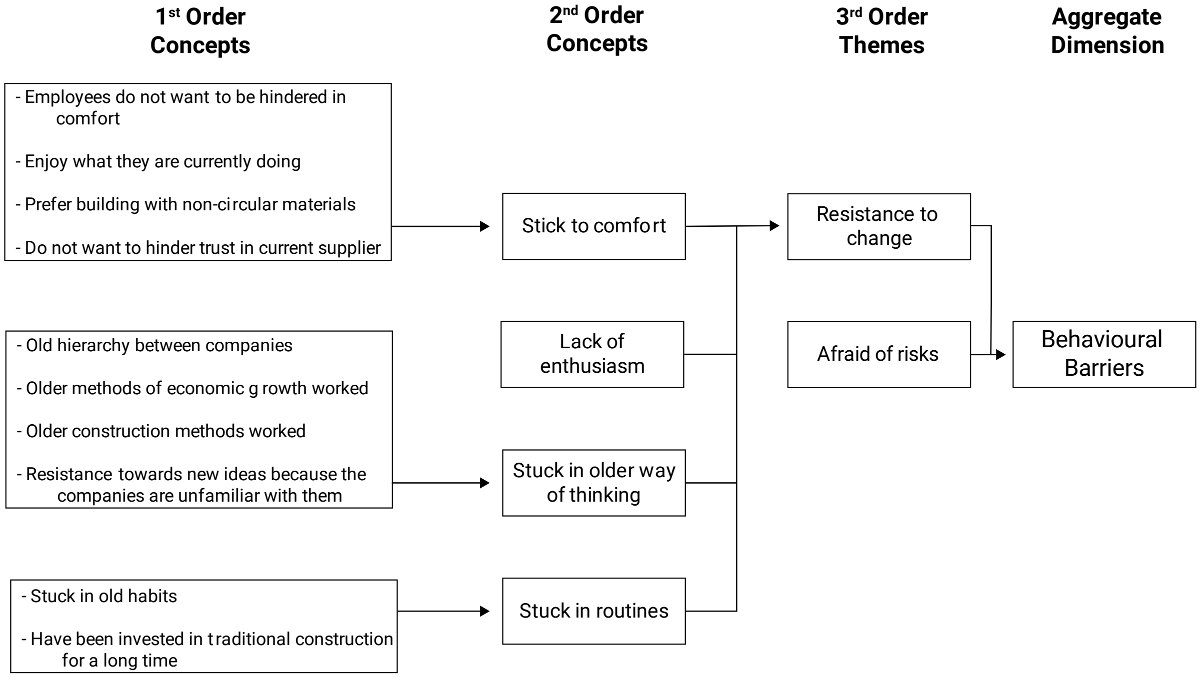
Figure 12
Number of Interviewees mentioning a Societal Barrier



4.3.6 Behavioural Barriers

Within this dimension, barriers were analysed that come from the personal perception of SME owners or employees. In total, 15 interviewees referred to at least one barrier within this dimension that had hindered their business or hinders other businesses. The overall assessment of interviewees was that behavioural barriers from a select group of employees could hinder the transition of an entire business. However, the main behavioural barriers related to the owners of SMEs. In total, five 2nd order and ten 1st order barriers were identified. These can be found in Figure 13 of this paper. Different to the societal dimension, barriers and drivers (4.4.6) under the behavioural dimension relate to the behaviour of individuals instead of entire SMEs and the influence on how SMEs behave. These individuals are either employees or owners of SMEs.

Figure 13
Behavioural Barriers



Resistance to change

The main barrier for SMEs is the resistance to change, either because employees want to stick to comfort, lack enthusiasm, are stuck in an older way of thinking or are stuck in routines. Resistance in this case comes from the behaviour of either employees or owners of SMEs. The barrier was mentioned by 14 interviewees, whereby the overall perception during the interviews was that the building sector of the Netherlands is a traditional sector due to the behaviour of actors.

According to six interviewees, leaders, and employees in SMEs of the construction sector stick to comfort and thus not make the transition towards circularity. They want to continue what they are used to doing and feel good about doing so. Under this barrier, four 1st order concepts could be identified.

Another concept is a lack of enthusiasm for transitioning towards circularity. According to five interviewees, SME leaders often are not willing to transition because they cannot find the enthusiasm to set it in motion. It is often that the initial response, according to the interviewees, is resistance towards new ideas because of the extra effort that is required.

Thirdly, seven interviewees stated that most SMEs are stuck in an older way of thinking. From the interview with interviewee 18 (a commissioner), a 1st order barrier could be identified in the form of an old hierarchy. He stated that transitioning to a circular economy required collaboration between parties, however, most of the SMEs are stuck in the old hierarchical structure of the sector. They want to remain the party that orders you to do something, instead of the other way around and do not see how this hierarchy needs to change. Interview 19 explained this concept as:

"When we introduce a new concept to project commissioners, the base reflex in 80% of the cases is, what I do not know, I will reject." (Interviewee 19, Supplier)

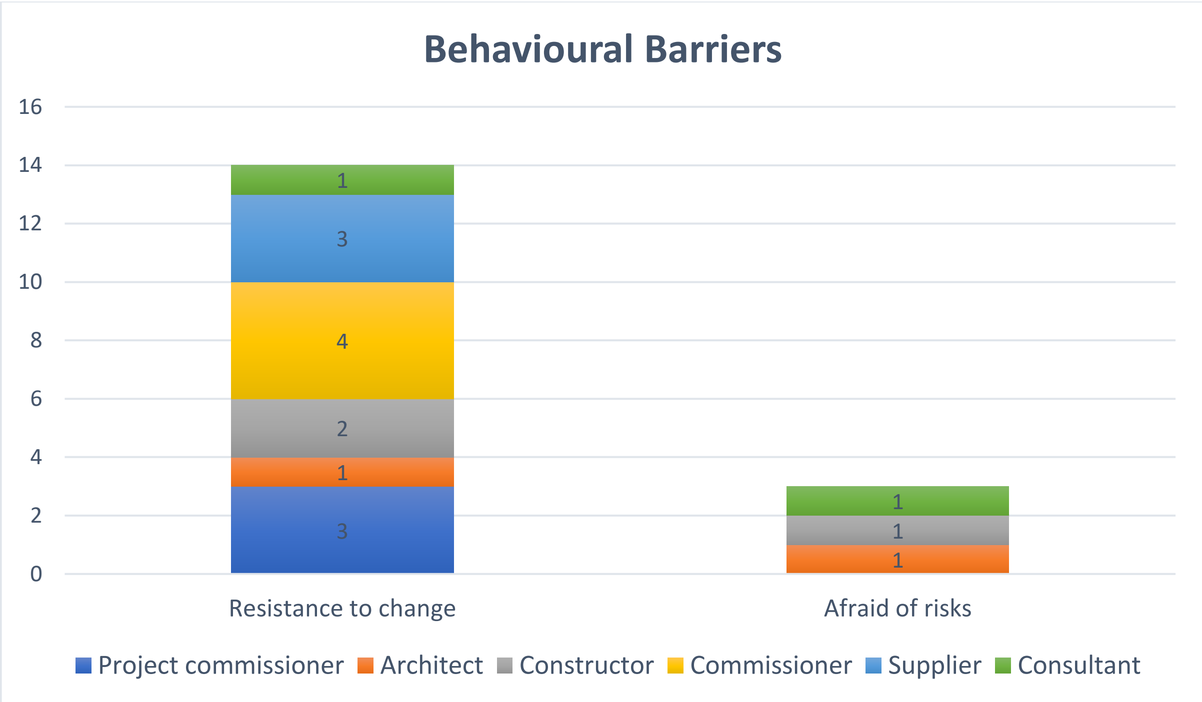
Lastly, seven interviewees argued that leaders and employees of SMEs are stuck in routines. Interviewee 18 (commissioner) stated that the average commissioner is 'good at laying bricks' and have become fast in doing so. They know all details for constructions and could give you a price based on measurements. The interviewees, therefore, argued that they are not wanting to make a change in such successful tasks.

Afraid of risks

According to three interviewees, SMEs are unwilling to change due to owners that are afraid of taking risks. These risks, according to the interviewees, go together with transitioning to a circular sector. What became apparent is that the interviewees that did not have to take risks, were those referring to this barrier. The three interviewees namely included an architect, constructor, and consultant, three groups that work on behalf of commissioners or advice companies. A clear distinction needs to be made between this barrier and the financial risk barrier mentioned under the economic dimension, as interviewees clearly stated that owners are afraid, instead of not willing to take a financial risk. This was for example stated by interviewee 9:

"It is very much in the behaviour of the owner, but also a change in that behaviour. Something new and risky that might be scary to them." (Interviewee 9, Constructor)

Figure 14
Number of Interviewees mentioning a Behavioural Barrier



4.4 Identified Drivers in the Dutch Construction Sector

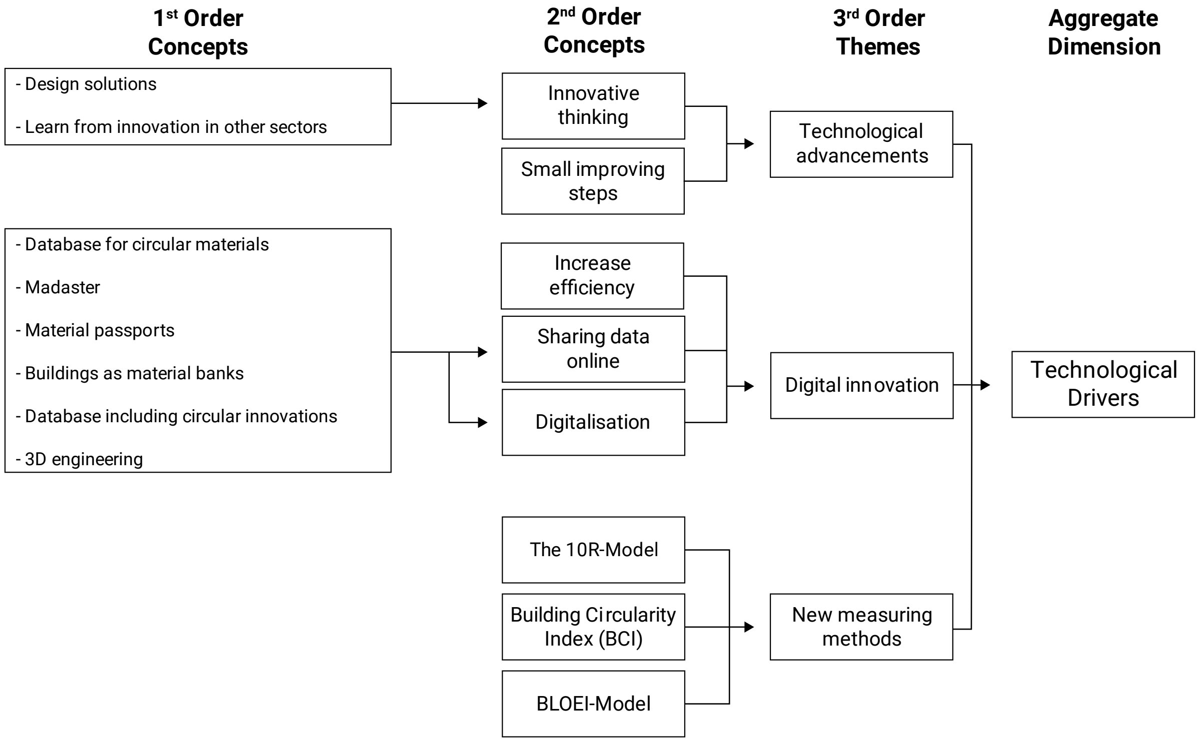
The following section will highlight the identified drivers for each dimension in sections 4.4.1-4.4.6. Like section 4.3, inductive coding was used to derive 1st order concepts from the interviews. These 1st and 2nd order concepts were then grouped under 3rd order themes. The 3rd order themes are then identified as the main drivers for each dimension.

Firstly, a Figure will be presented to visualize the concepts and themes and how they relate to each other. The order of concepts and themes does not indicate the importance of each driver. This will be highlighted at the end of each chapter as a bar chart will be shown to demonstrate the total number of interviewees referring to a driver and how these interviewees are divided between the different groups identified in Figure 4.

4.4.1 Technological Drivers

During the interviews, 19 interviewees mentioned at least one technological driver. The drivers mentioned under the technological dimension mainly referred to technological developments that could foster change in the construction sector. In total, three 3rd order themes drivers were mentioned. The visualisation of the technological drivers and how they relate to each other can be seen in Figure 15.

Figure 15
Technological Drivers



Technological advancements

Nineteen interviewees mentioned that technological advancement has helped their SME to transition a lot, however, more technological advancements are still needed. Fifteen out of the 19 interviewees saw innovative thinking in SMEs as necessary to facilitate technological advancements. Innovative thinking, in terms of design solutions and learning from innovation in other sectors, could be an important driver for technological advancements. The SMEs need to think out-of-the-box (Interviewee 11, project commissioner) and need to change continuously (Interviewee 18, commissioner).

Eight interviewees argued that small improvement steps will eventually lead to technological advancement. According to these interviewees, the steps are important to not lose sight of the bigger picture. According to interviewee 4 (commissioner), these steps need to be appreciated as bigger steps are currently not possible, or as interviewee 7 put it:

"We need to be happy with constructing two houses, because next time we might construct five or ten. This will also help technology to evolve step by step." (Interviewee 7, Project commissioner)

Digital innovation

This driver was mentioned by 13 interviewees, in the form of sharing data online, increasing efficiency and digitalisation. Ten interviewees stated that digitalisation in construction has already been an important driver for change towards circularity. Additionally, all 13 interviewees stated that sharing data online is an important driver. Both concepts were therefore ranked as 2nd order concepts. According to the interviewees, data can be shared in six distinct ways, of which material passports, a database for materials and ‘madaster’ were mentioned most frequently. Interviewee 14 (supplier) stated that sharing data allows other SMEs to see which materials can be re-used or taken into their supply chain. All parties have access to information on which materials are available.

Through ‘madaster’, data can be shared through the categorization of data for one building in the Netherlands. This has already helped to drive circularity in the sector but needs to be developed more according to three interviewees to become useful. Lastly, sharing data through material passports can be useful to track the full life cycle of materials. Some progress in material passports has been made, however, more advancements are still needed. According to two interviewees, this would help in the categorization of materials.

Lastly, increasing efficiency through digital innovation has proven to benefit circularity as construction will be faster and therefore more time and cost-effective. Interviewee 8 stated:

“I think there are some SMEs that are focussed intensively on technology. When they could analyse processes in construction and implement improvements, I think they can achieve great things.” (Interviewee 8, supplier)

New measuring methods for circularity

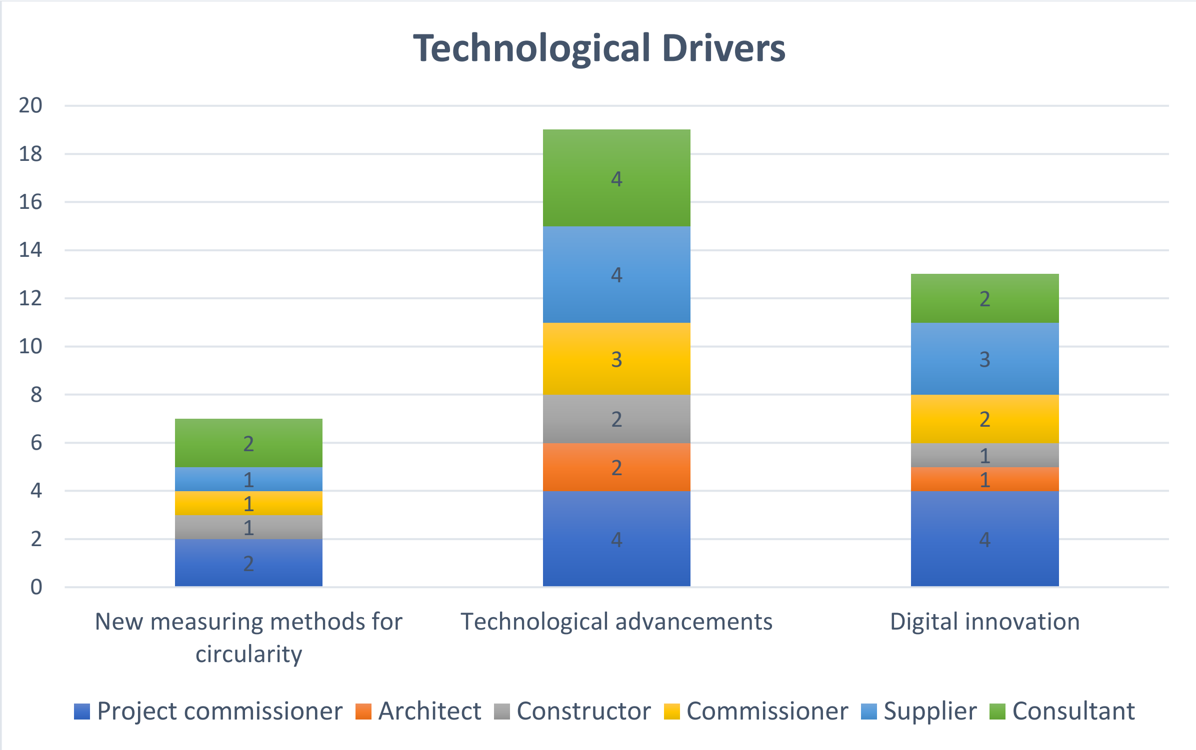
Seven interviewees argued that new models to measure circularity could come from SMEs with some already promising cases. According to them, it is important that the data is reliable and that all companies need to know what to implement to be circular. Interviewee 3 stated:

“When all the standards are in place then we can really kick off. We just want a checklist to cross off and when we match all criteria, we are circular.” (Interviewee 3, Project commissioner)

The three methods that were mentioned by the interviewees are indicated as 2nd order concepts, these are the ‘10R-model’, also used in this research, the ‘Building Circularity Index’ and the ‘BLOEI’ model.

Figure 16

Number of Interviewees mentioning a Technological Driver

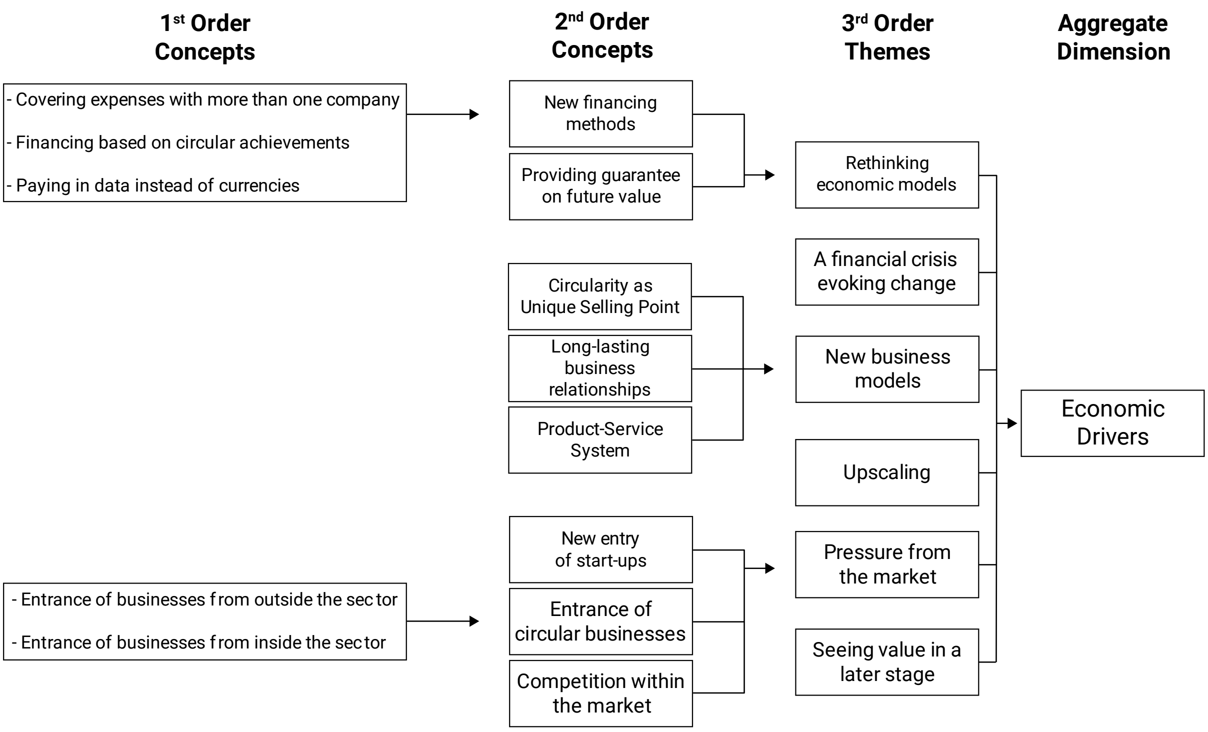


4.4.2 Economic Drivers

Under the economic dimension, six 3rd order themes and nine 2nd order concepts were analysed. In total, 17 interviews mentioned at least one economic driver. However, the frequency of references was diversified as only one driver was mentioned in more than ten interviews. The economic drivers are visualised in Figure 17.

Figure 17

Economic Drivers



Rethinking economic models

According to nine interviewees, changes in economic models have shown to facilitate SMEs to transition to circularity. Economic models can be seen as models overarching SMEs, bonding them together. The changes in economic models mentioned are twofold, either by new financing methods or by providing a guarantee on future value. Interviewees identified both concepts as drivers for a transition towards circularity.

Three interviewees argued that new financing methods come from banks that base their financing on circular achievements. Interviewee 16 (consultant) stated that as a bank you could increase interest rates for non-circular projects, whereas circular projects would benefit from lower rates. Moreover, financing could be taken on by more SMEs to cover expenses together to change the market (interviewee 5, consultant). This would overcome the barrier of SMEs that are hindered in transitioning as they assume that they need to cover all investment costs.

Secondly, according to interviewees 7 (project commissioner) and 14 (supplier), commissioners should be given a guarantee on future value. This will assure them of a return on investment and would stimulate more commissioners to transition towards circularity.

A financial crisis evoking change

This driver was mentioned by two interviewees and mainly based on past financial crises. It was mentioned by interviewee 1 (commissioner) and 19 (supplier) as, according to them, history has shown that after a major crisis the strongest parties survive. This would shift out the non-circular businesses and help circular SMEs strive. This driver will however not be considered in the discussion, as SMEs or governments have no influence, or do not want to have influence, on this driver.

New business models

A third driver that could be identified in the interviews was 'new business models'. This driver was mentioned by nine interviewees. According to the interviewees, transitioned SMEs have shown that businesses need to change their business model to have a chance in a circular economy. They could either use circularity as their unique selling point, establish long-lasting business relationships or switch to a product-service system (PSS), earlier discussed in the theory. According to six interviewees, leasing out construction elements should be a main part of the business model to transition to circularity. Lastly, according to interviewee 7 (project commissioner), long-lasting business relationships are needed in the sector. Currently, when buildings are constructed, 'commissioners run away as fast as they can and hope they will not get called again'. According to the interviewee, this needs to change in a circular economy as:

"When you establish long-lasting business relationships, you know you will be friends with the other SMEs for a long time. You can therefore be sure that materials that you harvest are bought by another company or that they can help you establish a circular supply chain in general." (Interviewee 7, project commissioner)

Upscaling

According to two interviewees, upscaling has helped SMEs to achieve a profitable market position. In many instances, SMEs are not able to compete on price as their offset is not large enough, however, they will be able to when their volume is large enough.

Pressure from the market

This driver can be considered the main economic driver as it is mentioned by ten interviewees. These argued that other industries, such as the car industry, how shown that more companies want to transition when other businesses have started to transition or have entered the market. The main 2nd

order concepts for this driver are the entrance of circular businesses, new entry of start-ups and competition within the market. According to the interviewees, both the entrance of circular businesses and start-ups gives SMEs the feeling of missing out. They are afraid to miss out on new developments and thus lose their competitive position. Moreover, according to interviewee 17:

"The entrance of new circular construction companies will bring new ideas to the market, providing an untampered view on circularity. This will most likely not come from the larger construction companies." (Interviewee 17, consultant)

The businesses, coming from either outside or inside the sector, thus not only pressure existing SMEs to make the transition, but also stimulate innovation in the sector by bringing new ideas to the table. Also, interviewee 18 (consultant) states that start-ups are the main driver for a change in the construction sector, especially when the big companies are not wanting to shift. He states:

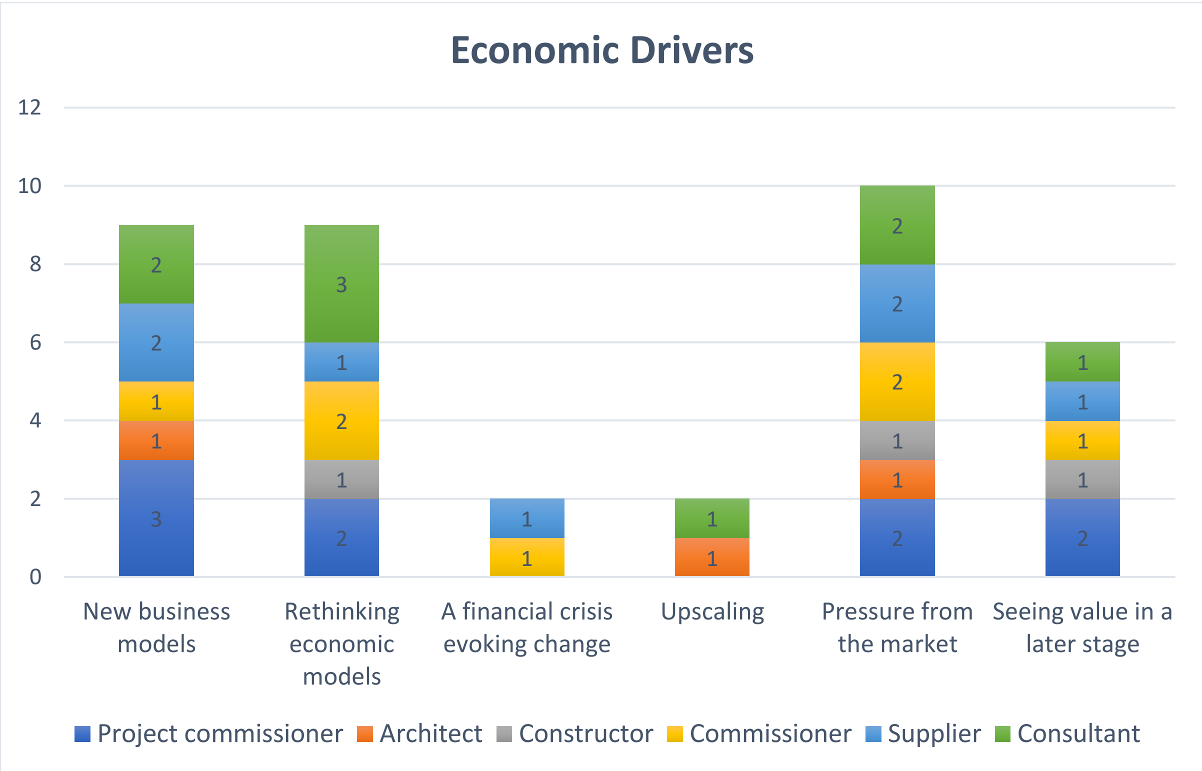
"The start-ups can be the reason for a shift in the market because other organisations realise something needs to change drastically." (Interviewee 18, Commissioner)

Seeing value in a later stage

Lastly, interviewees argued that it helped their SME to see value in a later stage as this is important for SMEs to see the true economic value of a project. This will stimulate repurchasing materials and elements, as the value is already predetermined. According to the interviewees, this driver will show SMEs that circular construction is not more expensive when the true value is considered. To provide context, interviewee 13 stated:

"I consulted a company that built two circular buildings that were 25% cheaper than traditional construction. Why? Because I could calculate all residual value in my resources and pass it on in my calculation." (Interviewee 13, consultant)

Figure 18
Number of Interviewees mentioning an Economic Driver

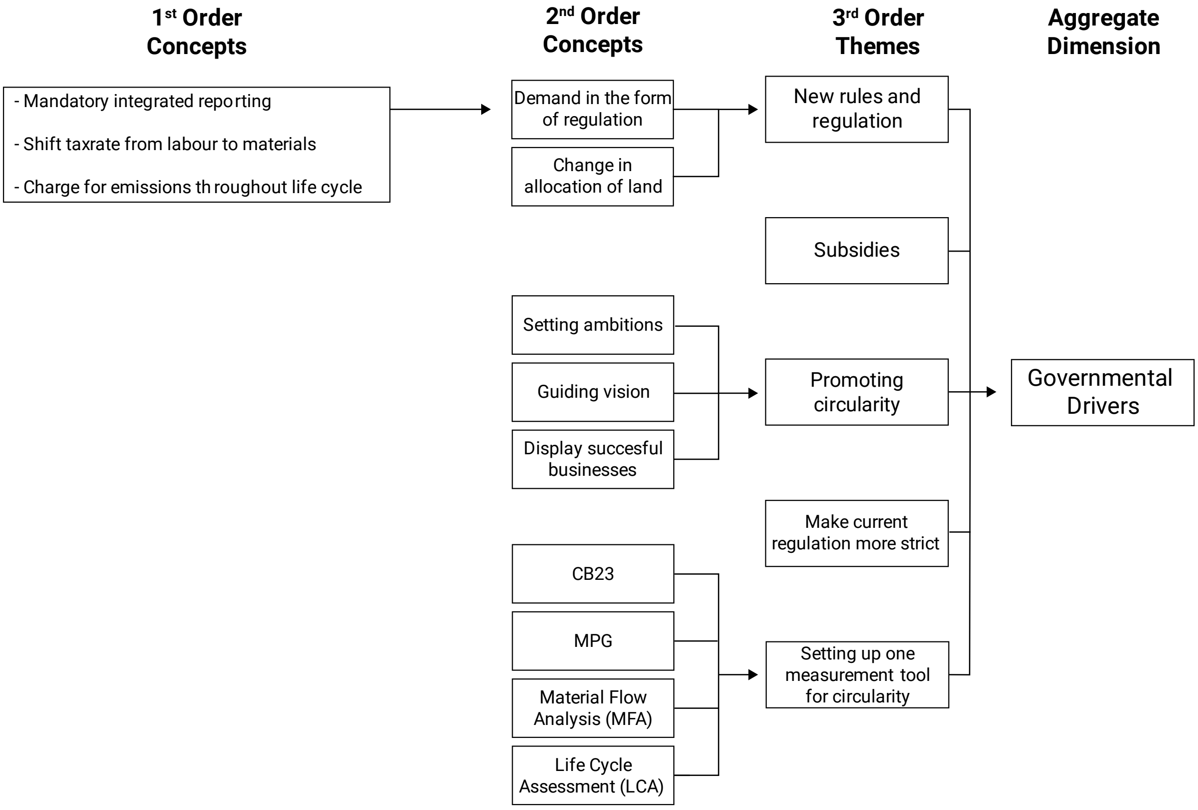


4.4.3 Governmental Drivers

For the governmental dimension, five 3rd order themes could be identified. Four of these themes were mentioned in at least ten interviews. All interviewees mentioned at least one governmental driver in the interview. Figure 19 shows the themes, concepts, and structure of the governmental drivers.

Figure 19

Governmental Drivers



New rules and regulation

According to all interviewees, apart from interviewee 1 (commissioner) and 20 (constructor), the government needs to implement new rules and regulation to stimulate the transition to a circular construction sector. These regulations take the form of a change in the allocation of land or demand in the form of regulation. The last 2nd order concept was mentioned most frequently by 15 interviewees. Demand could be created by shifting the tax rate from labour to materials or by charging for emissions throughout the life cycle of materials. The overall perception of the interviewees referring to these drivers was that the true costs of materials are shown. Interviewee 10 provided context to charging for emissions:

"When the total damage for the future is not charged correctly, commercial organisations will always find a method to go for the cheapest option. So, the government needs to charge for emissions throughout the whole life cycle." (Interviewee 10, Architect)

Mandatory reporting on the other hand would force SMEs to consciously implement circular initiatives and would also provide transparency in the process. Reporting, according to interviewee 16 (consultant), should be forced upon by European law and should also be enforced. Lastly, a main problem in circular construction is the allocation of land. Three interviewees, therefore, argue that a change in allocation of land is needed. Especially, while taking the future into account, meaning that with a declining population the land can be used for a different purpose again.

Subsidies

A second governmental driver that was mentioned by 12 interviewees is subsidies which have been proven to be successful, according to the interviewees, in other sectors. They state that subsidising circular construction in some form is always beneficial, mainly because it eliminates certain economic barriers. Interviewee 19 (supplier) stated that you saw a similar movement with electric cars which would indicate the driver could have an impact on circularity in the construction sector. Subsidies are analysed as a governmental driver because the interviewees argued that subsidisation should come from the government and municipalities.

Promoting circularity

According to 13 interviewees, it is the task of the government to promote circularity. This is possible through three 2nd order concepts which the government has already taken the first steps in. The first concept ‘setting ambitions’ was mentioned by 12 interviewees. The Dutch government has already stated that by 2023 tendering by the government will be fully circular, whereas in 2050 the whole economy should be 100% circular. These ambitions, according to the interviewees, will stimulate SMEs to make the transition. Secondly, a guiding vision by the government will aid in paving a path for SMEs to follow. This driver was mentioned by three interviewees. According to interviewee 19 (supplier), the government needs to show leadership in creating this path. Lastly, one interviewee stated that circularity can be promoted by displaying successful business cases. According to interviewee 15 (project commissioner), it is the task of the government to make sure circularity gets attention.

Make current regulation more strict

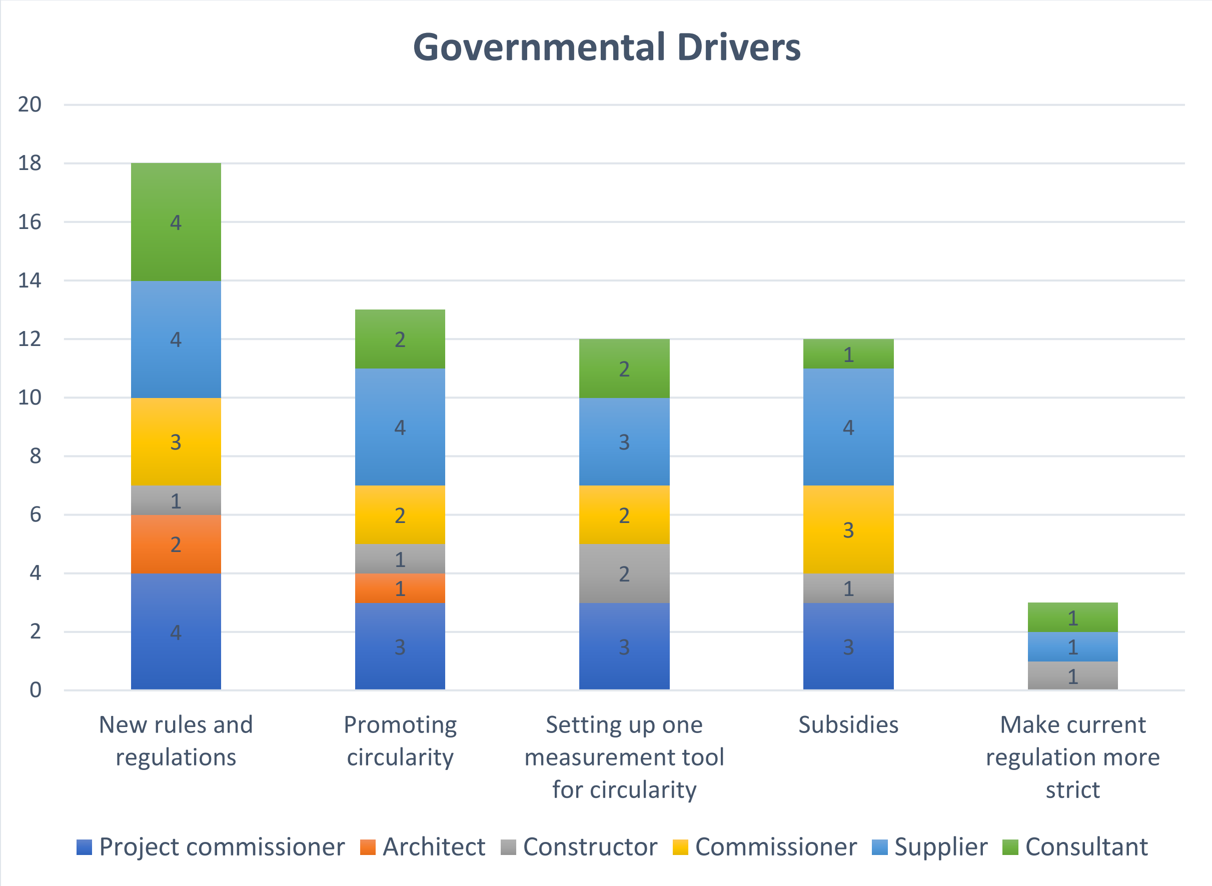
Three interviewees stated that current regulation needs to be stricter. All three interviewees stated that the current MPG score that is in place for sustainable construction needs to be tighter as currently, it is not as effective as it should be. According to interviewee 8 (supplier), making regulation stricter will cause commissioners and project commissioners to use other materials and methods of construction.

Setting up one measurement tool for circularity

Lastly, following up on the barrier that there are too many tools that are currently in use, 12 interviewees argued that the government should take the lead in setting up one measurement tool for circularity. Opinions differed however on which tool should be used. As each tool was seen as a driver for circularity, these are considered separate 2nd order concepts. The tools that are mentioned most frequently are CB23, MPG, Material Flow Analysis (MFA) and a Life Cycle Analysis (LCA). A driver that will be implemented by the government is CB23. Although the tool is still in development, it will be the intended objective norm for measuring circularity in 2023.

Figure 20

Number of Interviewees mentioning a Governmental Driver



4.4.4 Environmental Drivers

Under the environmental dimension, three drivers could be analysed. In total, six interviewees referred to one or more drivers. As no 2nd order concepts could be identified, a visualisation of the drivers was not deemed necessary.

Resource scarcity

The environmental driver that was mentioned most often in different interviews was resource scarcity. The driver was mentioned by five interviewees amongst which were three commissioners and two consultants. Resource scarcity mainly focused on the awareness of SMEs that resources are running out and thus new ways of building are necessary. This driver is thus the exact opposite of the barrier resource scarcity. Therefore, according to interviewee 13 (consultant), resource scarcity creates the need for SMEs to find regenerative material or use materials for a longer period, thus transitioning to circularity. According to interviewee 17 (consultant), SMEs are beginning to realise that the ones that use resources as effectively as possible are the ones that will manifest themselves in the long run. Interviewee 1 (commissioner) even sees an opportunity for businesses because of resource scarcity. He states:

"A building you build now, might be worth more in 15 years due to resource scarcity." (Interviewee 1, Commissioner)

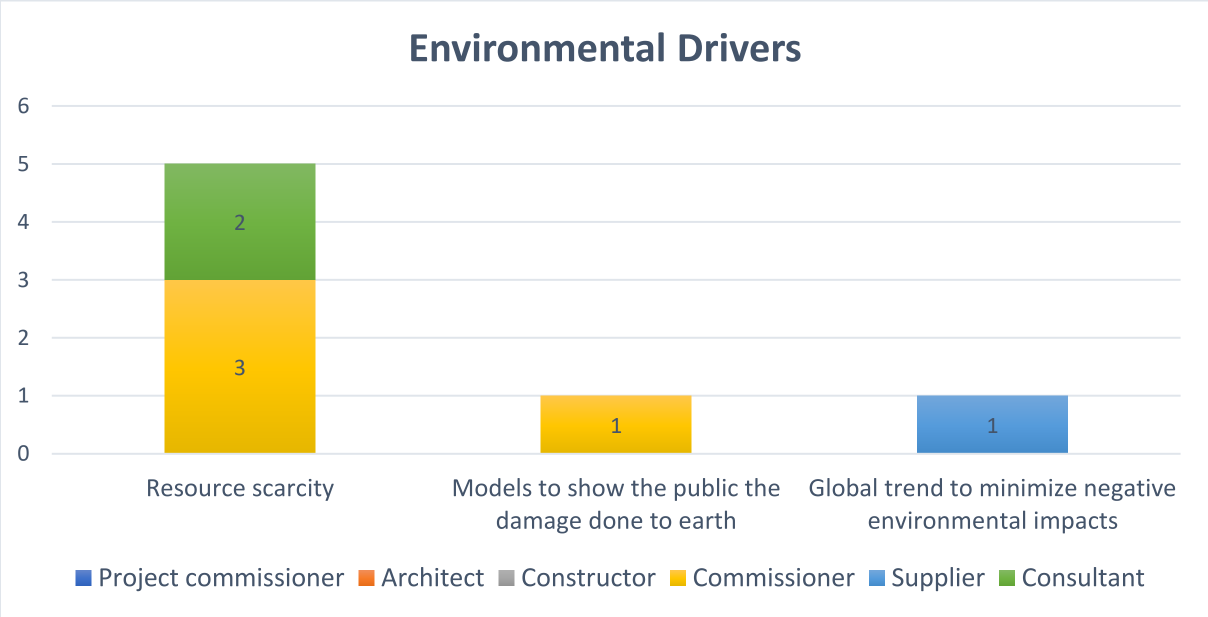
Models to show the public the damage done to the earth

One commissioner stated that models are necessary to show the public what damage we are doing to the earth. He hopes that eventually, this will create intrinsic motivation amongst SME leaders and that it will also enhance the need to transition to circularity.

Global trend to minimize negative environmental impacts

One supplier stated that the global trend to minimize negative environmental impacts also stimulates the transition. According to the interviewee, as sustainability, circularity and a clean environment are becoming more popular, or the global trend, SMEs will need to switch to circularity to satisfy the public opinion.

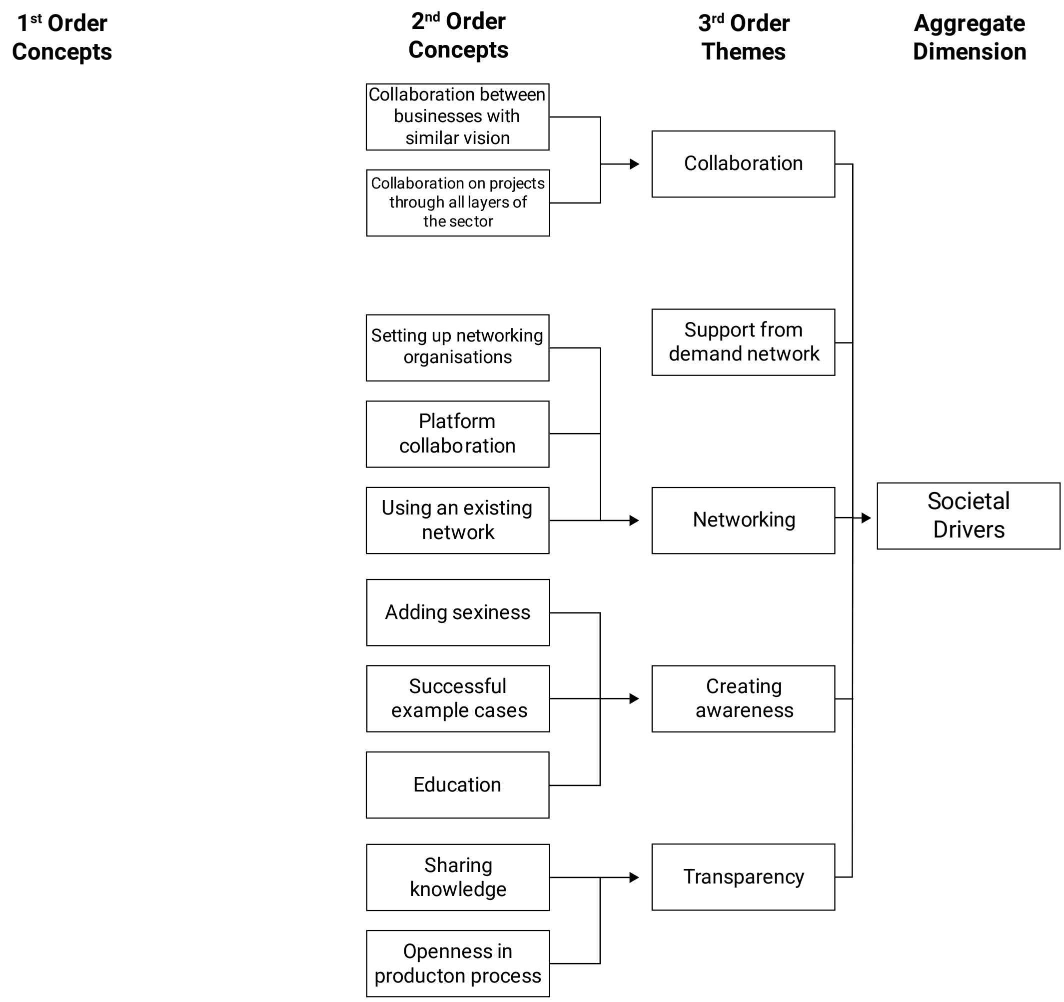
Figure 21
Number of Interviewees mentioning an Environmental Driver



4.4.5 Societal Drivers

Under the societal dimension, five 3rd order themes and ten 2nd order concepts were analysed. In total, 19 interviewees mentioned at least one societal driver, which makes it the second most referred to dimension in conjunction with the technological dimension. The order of societal drivers is visualised in Figure 22.

Figure 22
Societal Drivers



Collaboration

According to 15 interviewees, collaboration between SMEs was essential for them to transition to a circular economy and is needed more in the sector. Collaboration could focus on working with businesses with a similar vision, but also on projects that overarch all layers of the sector. In the first case, for commissioners, this would mean that they work together with suppliers that produce circular materials (interviewee 10, architect), whereas architects could collaborate with constructors and commissioners that want to execute their circular designs (interviewee 11, project commissioner). On the other hand, nine interviewees argued that collaboration should not solely focus on circular SMEs, but SMEs in general. An example of such a supply chain collaboration was mentioned by interviewee 13 who stated:

"What we need to do is work together. For example, when I have some residues, I want to work together with a company that can ship it in a container and bring it to other businesses. We thus need to take on projects together." (Interviewee 13, Consultant)

Support from demand network

According to five interviewees, other industries such as the car industry, have shown that customers need to be willing to buy sustainable (or circular) products to drive SMEs in transitioning. Such switches in demand could for example be preferring wood construction over concrete construction (interviewee 2, commissioner). According to interviewee 3 (project commissioner), it is a similar case as with the previous drivers related to collaboration. The whole market needs to work together, including the customers.

Networking

According to eight interviewees, networking and thus sharing knowledge, has helped their SMEs in transitioning and will help many other SMEs if work is put into it. Three 2nd order concepts could be grouped under this driver. Firstly, setting up (more) networking organisations is an important step according to five interviewees. These organisations would aid in sharing knowledge between SMEs (interviewee 12, architect). Moreover, platform collaboration is also seen as a driver by three interviewees, meaning that SMEs can show circular innovations on the platform and receive feedback (interviewee 16, consultant). Lastly, self-evidently existing networks can be used to aid in networking between businesses.

Creating awareness

According to 12 interviewees, it is the task of society to create awareness amongst SMEs. This could either be done by successful example cases, education or 'adding sexiness'. Nine interviewees stated that successful example cases in society would show SMEs the possibilities within CE. These possibilities range from financial possibilities (interviewee 14, supplier) to the realisation of projects (interviewee 1, commissioner). According to the interviewees, showing the right example could stimulate in two directions, either the bigger organisation shows smaller organisations how projects can be realised successfully or conversely. A significant point was made by interviewee 7 who stated:

"When you look at the financial crisis between 2009 and 2014, some architects remained pretty successful. I am convinced this was due to their effort in circularity. So, this also showed other SMEs that even in a financial crisis, it offers opportunities." (Interviewee 7, Project commissioner)

Four interviewees argued that education is important as currently there is insufficient knowledge amongst SMEs in the construction sector. Employees need to be schooled in new techniques and machinery. Interviewee 9 (constructor) for example argued that in civil engineering classes, the focus is mainly on steel- and concrete constructions. However, the transition towards circularity would be stimulated when wood constructions were emphasized more as well.

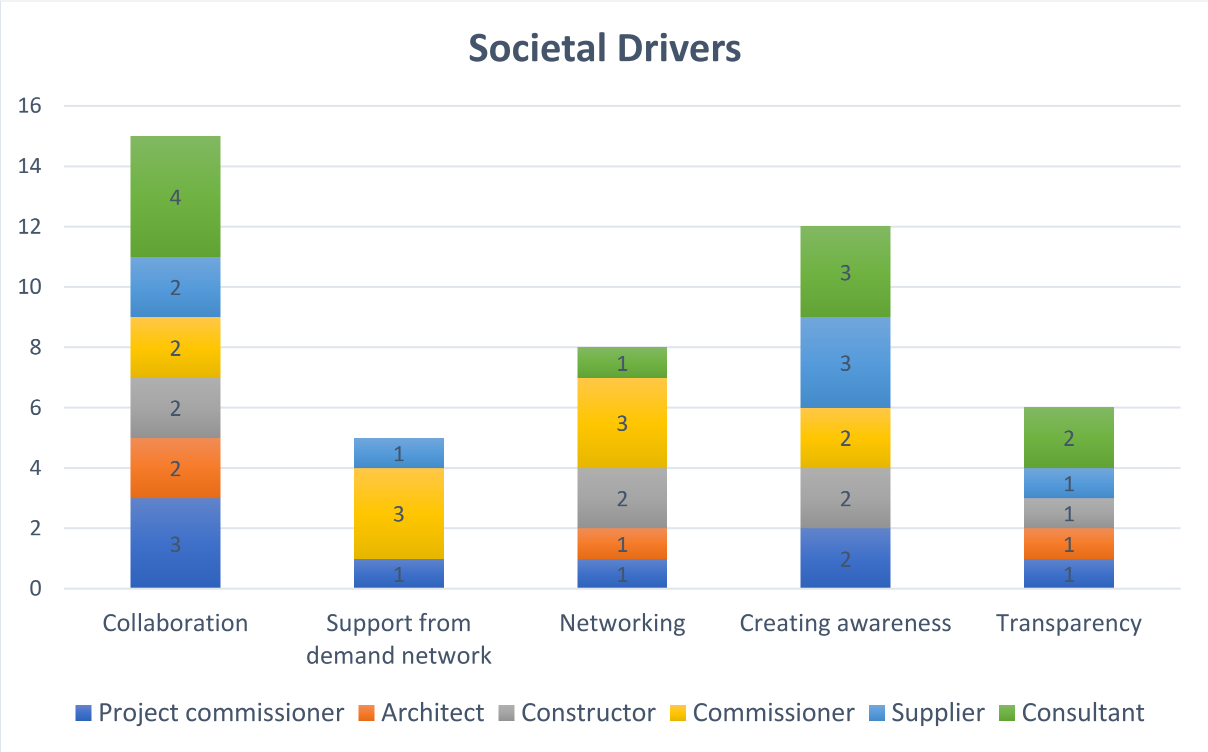
Lastly, the term 'adding sexiness' was introduced by interviewee 15 (project commissioner) who stated we should take circularity 'out of the dust'. This was acknowledged by interviewee 16 (consultant) who said we need to add the 'wow factor' to circularity.

Transparency

Lastly, six interviewees argued that transparency is important both in sharing knowledge and in openness in production processes. Both factors were also arranged as 1st order drivers. According to interviewee 12 (architect), when SMEs are more transparent, they can discuss the problems they face in their transition and help other SMEs to overcome these problems. Whereas sharing knowledge is mainly focussed on transparency between businesses, openness in the production process also related to transparency to customers. Interviewee 20 stated:

"All the products we use are marked with a registration number. Therefore, we can achieve full traceability for our customers and protect ourselves against copy-cats. We and our customers think this is really important." (Interviewee 20, Constructor)

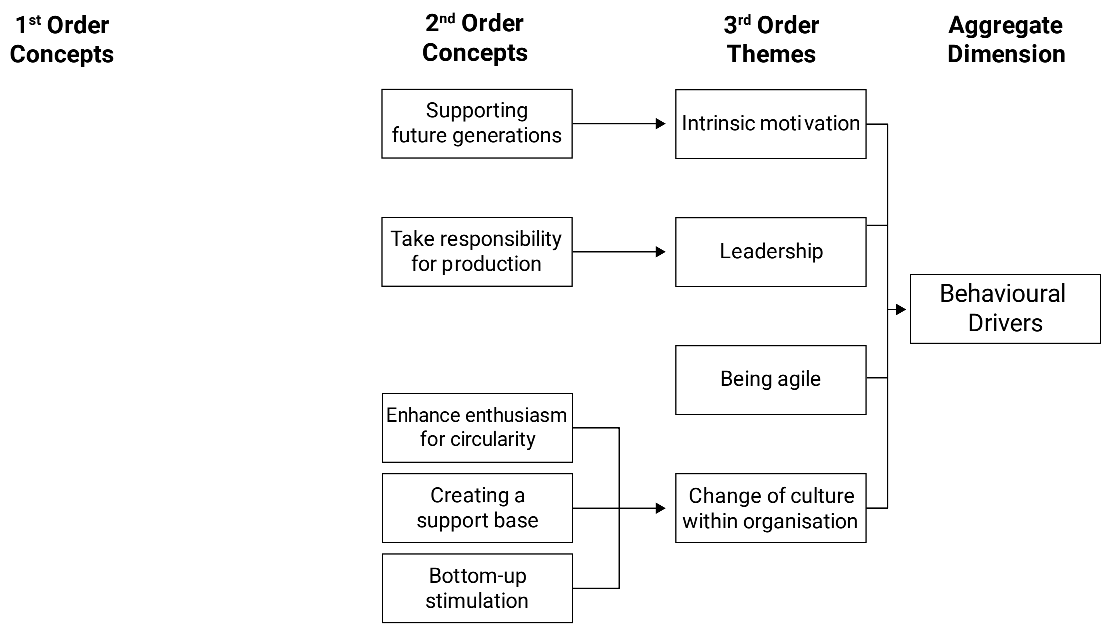
Figure 23
Number of Interviewees mentioning a Societal Driver



4.4.6 Behavioural Drivers

Under the behavioural dimension, five 2nd order concepts and four 3rd order themes could be analysed. In total, 17 interviewees mentioned at least one behavioural driver. Like the behavioural barriers, these drivers focus on the behaviour of SME leaders or employees, thus focusing on drivers within the organization. Also, behaviour in this analysis not only focuses on individual behaviour, but also on the behaviour of groups within the SME. The structure of the behavioural drivers can be found in Figure 24**.**

Figure 24
Behavioural Drivers



Intrinsic motivation

With 14 interviewees mentioning this driver, it was the largest amongst the behavioural drivers. Intrinsic motivation was seen as essential for both employees and SME leaders, with some interviewees arguing it is the intrinsic motivation of the whole company that needs to be present. Interviewee 5 (consultant) stated that the leader of an SME needs to be intrinsically motivated to say 'we are going to make a change in our business'. This driver was also indicated as an important factor in the transition of SMEs the interviewees worked at. Interviewee 6 (supplier) stated that it was the main reason they felt circularity was very important and should be incorporated in their business. Three interviewees stated that one of the main drivers for their SME was 'supporting future generations' and that they felt intrinsically motivated to do so. All three stated that their SME wanted to leave the world behind in a better state than it currently is. This was their main motivation in transitioning to circularity.

Leadership

This behavioural driver was mentioned by four interviewees, seeing true leadership as an important driver for change within an SME. The interviewees also identified that leadership was present in their SME. Leadership was associated with the courage to realise a dream and to stick with the plans you make. Interviewee 1 made a clear distinction between managers and leaders:

"Managers always need certain models within which they can function. Leaders per definition step out of that model and show leadership." (Interviewee 1, Commissioner)

One way to show leadership was taking responsibility for production, indicated as a 2nd order driver in Figure 24. According to interviewee 7 (project commissioner), when leaders take full accountability for the product they produce, they will also care more about this product.

Being agile

Four interviewees saw being agile as an important driver as the pathway for their SME was not paved and needed to be discovered by themselves. According to these interviewees, being agile is essential to succeed in a rapidly changing market. SMEs thus need to be able to form a path in the transition and should not be dependent on just one specific material. Being agile was also linked to the perseverance of an SME by interviewee 15 who stated:

"There are maybe one hundred reasons to not do it, put please look at the five reasons to do it. SMEs need to be agile in finding ways to succeed." (Interviewee 15, Project commissioner)

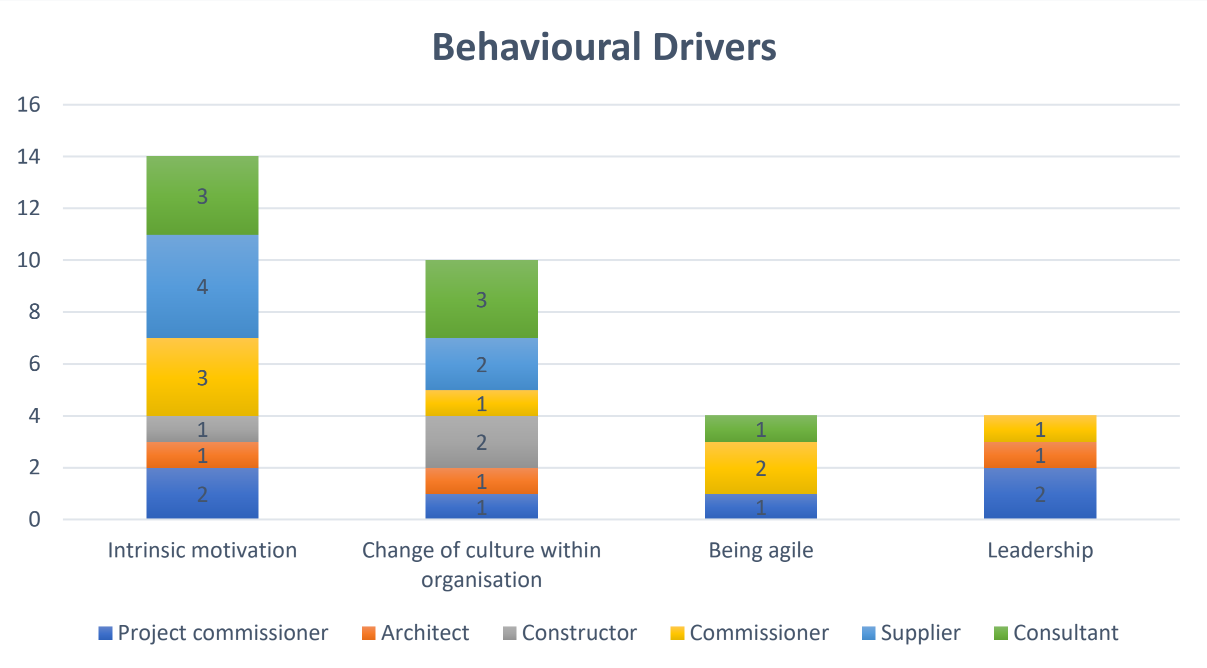
Change of culture within the organisation

Lastly, according to ten interviewees, the culture within an SME needs to change to be a driver for a transition towards circularity. A similar change of culture was seen amongst the interviewed SMEs operating linearly before. For this driver, two 1st order drivers could be analysed. These were 'creating a support base' and 'enhance enthusiasm for circularity'. Both were seen as essential factors for this driver. Interviewee 9 stated:

"I think it is important to take colleagues with you in your logic and keep it simple." (Interviewee 9, Constructor)

However, a change in culture was seen and experienced as a complicated task. As interviewee 5 (consultant) put it: "nothing is as complex as a cultural change". Nevertheless, the interviewees saw this driver as a catalyst in the transition. Especially when it could be set in motion by creating a support base. According to interviewee 3 (project commissioner), she experienced that such a support base made circularity a target and something colleagues wanted to work towards. Moreover, a cultural change could also be caused by bottom-up stimulation, whereby employees with the right mindset are needed to stimulate top leaders to make a change in SMEs. Three interviewees stated that bottom-up stimulation is very important. Interviewee 19 (supplier) said that his SME only wants to attract employees with the right ideology to provide insights to the top management. According to interviewee 3 (project commissioner), bottom-up stimulation is mainly needed because “we need to do as much as possible from all sides”.

Figure 25
Number of Interviewees mentioning a Behavioural Driver



4.5 Conclusion of results

To conclude this chapter, a few interpretive conclusions can be drawn to highlight the main results of this research. The main barriers (4.5.2) and drivers (4.5.3) will be discussed separately, whereby the division of barriers and drivers between the dimensions is also shown.

4.5.1 R-strategies

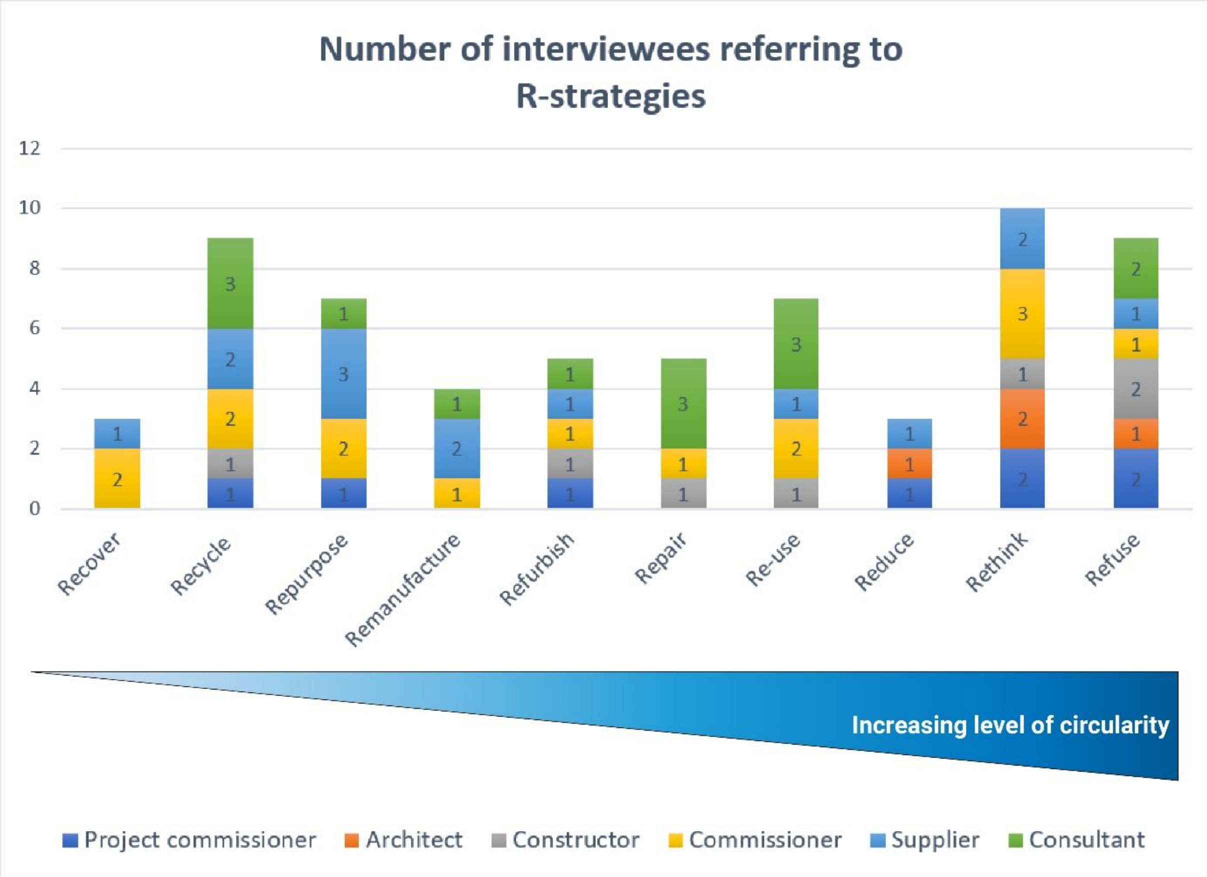
As can be seen in Figure 26, all ten strategies were mentioned by at least three interviews. In total, all interviewees referred to one of the ten strategies in the interviews. The strategy mentioned by most interviewees was ‘rethink’ which was mentioned by 9 interviewees, with ‘recycle’ and ‘reduce’ as second most referenced. On the other hand, ‘reduce’, ‘remanufacture’ and ‘recover’ were mentioned the least by 3 interviewees.

Only ‘refuse’ was mentioned by all interviewee groups, indicating that this strategy was deemed important by all interviewees. Although ‘rethink’ was mentioned by all interviewees, none of the four consultants saw ‘rethink’ as an important strategy. Three of the commissioners on the other hand found this strategy important.

When looking at the framework by Potting et al. (2017) in section 2.1.2.1, we can conclude that the strategy leading to the highest level of circularity, ‘refuse’, was mentioned by all interviewees. On the contrary, the strategy leading to the lowest level of circularity in the form of ‘recover’ was mentioned the least. This research interprets that the sector has incorporated a high level of circularity. Also, companies that have already transitioned towards CE are aware of what initiatives to implement.

This was also indicated by 'rethink', leading to the second-highest level of circularity, being mentioned by most interviewees.

Figure 26
Frequency of R-Strategies mentioned by Interviewees

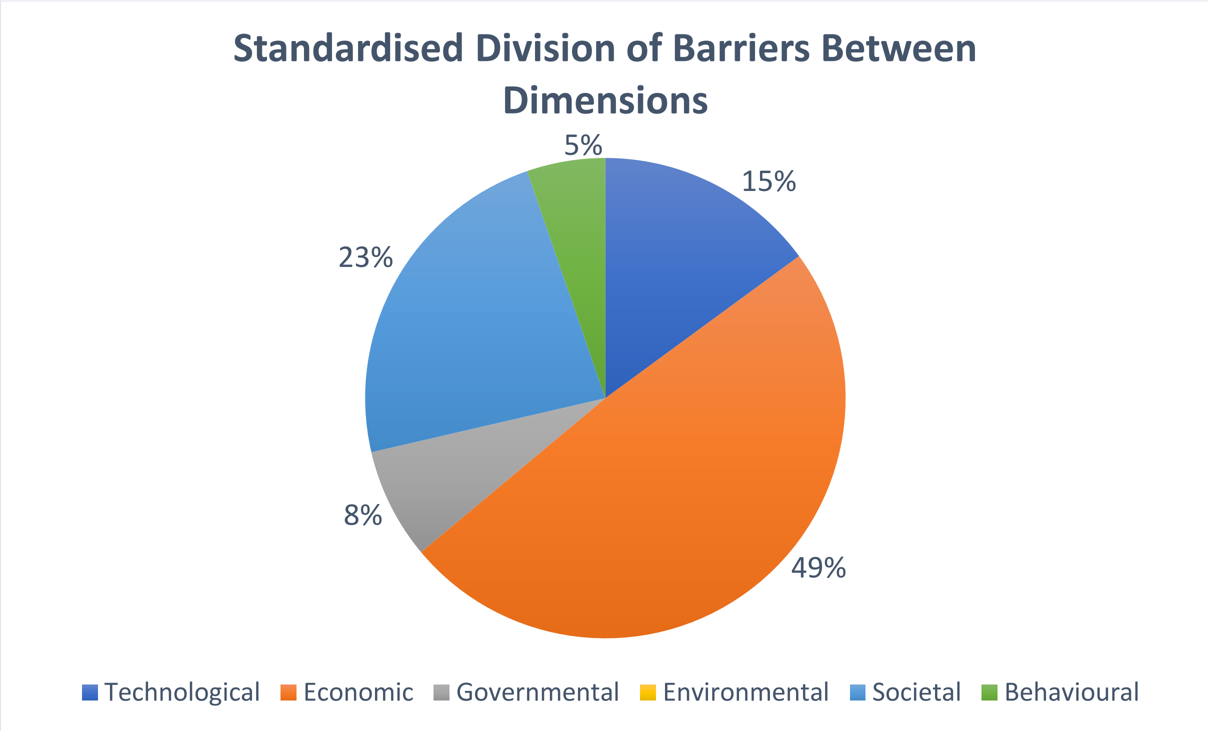


4.5.2 Main Barriers

To show the influence of each dimension, the number of barriers should be standardised for the sum of the number of interviewees mentioning a dimension. For example, the behavioural dimension included two barriers mentioned 14 and 3 times. The sum of 14 and 3 was multiplied by the number of barriers and divided by the total number of 'barriers*sum of interviewees'. The results of the correction can be seen in Figure 27.

Figure 27

Standardised Division of Barriers between Researched Dimensions



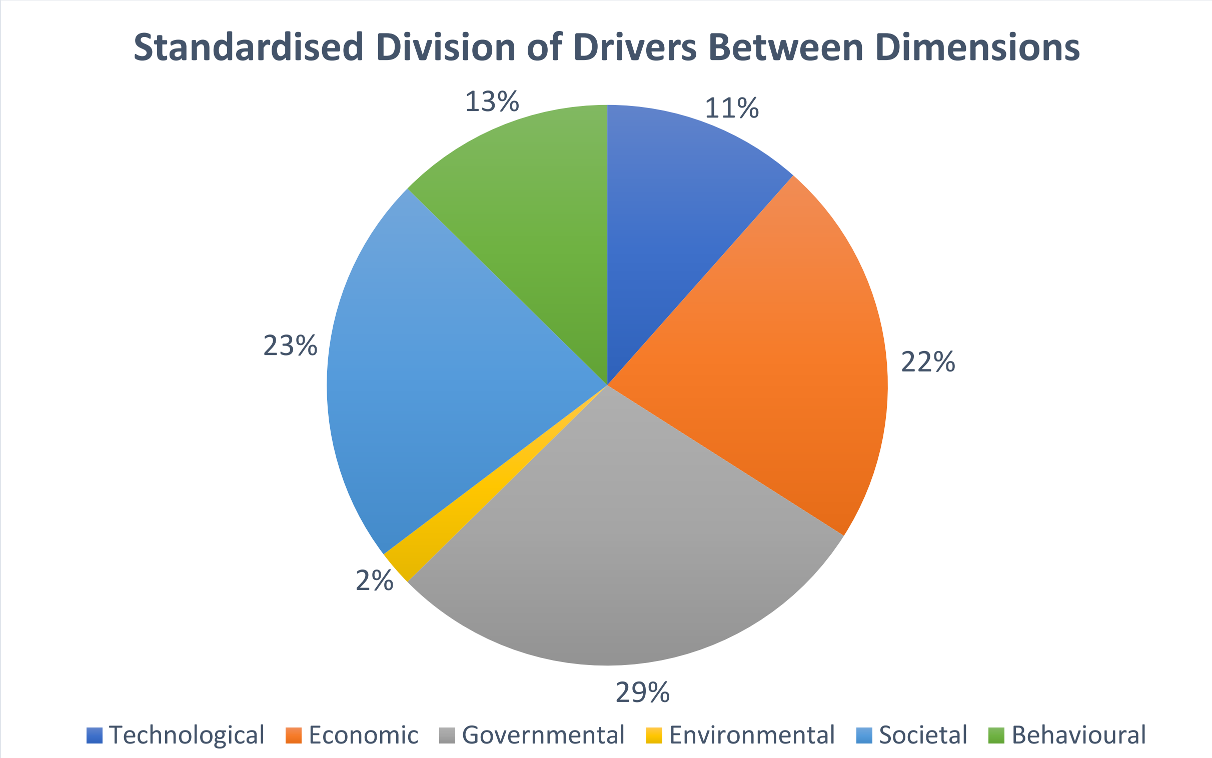
The economic dimension is most influential as it contained the most barriers (7) and was referenced by most interviewees (20). The significant influence of the economic dimension can be noticed in the graph with 49%, whereas the second most influential dimension only covered 23%. The least influential is the environmental dimension as it was referenced by the least number of interviewees (2) and contained only one barrier, meaning that its influence resulted in 0.5%. What can be concluded from these results, is that the interviewees see the economic dimension as the major obstacle for a transition by SMEs towards CE.

In general, 'financial risk', 'resistance to change', 'lack of awareness', 'difficulty to measure circularity' and 'regulation hindering circular innovation' were identified as the main barriers. A remarkable finding is that all these barriers are identified under different dimensions, making them the largest barrier in each dimension as well as the sector.

4.5.3 Main Drivers

A similar approach was taken to show the standardised division of drivers between the analysed dimensions. The results can be found in Figure 28. What can be noticed about this division, is that three dimensions have a highly similar influence. The governmental dimension has the highest influence with five barriers of which the sum of interviewees amounted to 58, leading to a 29% influence. Again, the environmental dimension had the least influence with only 2%. What can be concluded from these findings is that the interviewees see the government as most influential to overcome barriers and drive a transition by SMEs towards CE.

Figure 28
Standardised Division of Drivers between Researched Dimensions



In general, the drivers that were mentioned the most were 'technological advancements', 'new rules and regulations', 'collaboration', 'promoting circularity', 'intrinsic motivation', 'digital innovation' and 'creating awareness'. Again, the drivers come from mostly different dimensions, meaning that interviewees saw an important task for each dimension to drive the transition.

5. Discussion

In this chapter, the findings of this research, presented in section (4.2-4.4), will be discussed in context of the literature. Furthermore, the relationship between dimensions, the contribution to academic literature (5.4), limitations (5.5) and relevant areas for future research will be discussed (5.6).

5.1 Comparing Circular Initiatives

When comparing circular initiatives identified in this research to academic literature, we can acknowledge a few overlaps and two-way differences. Overlap was for instance present in ‘rethink’, ‘refurbish’, ‘remanufacture’ and ‘repurpose’. In terms of ‘remanufacture’, we can argue that using resources from construction components was seen as a crucial step towards circularity, especially when the strategies could not be applied. Only one initiative could likely be identified as remanufacturing is a very detailed process. In other instances, the Dutch construction sector can learn from identified initiatives, whereas in other instances initiatives are further developed in the sector compared to academic literature.

5.1.1 Lessons to be learned from academic literature

When comparing the initiatives mentioned during the interviews to other research, we could see that some initiatives from this literature could not be identified. In most instances, a possible explanation could be that these initiatives are harder to implement in practice but could nonetheless be required. An example of ‘refuse’ would be that refusing non-reusable materials was not mentioned in the interviews. Possible reasoning for this would be that materials such as concrete are still considered essential for construction, thus completely refusing to use them would not be beneficial. A second example relates to ‘repair’, where reparation of entire constructions was mentioned in other research, but not in the interviews. Therefore, this might be an excellent recommendation to SMEs in the construction sector. Commissioners, in particular, might be able to take on these projects and collaborate with architects and constructors.

Moreover, an r-strategy such as ‘reduce’ overlapped on all initiatives but was mentioned less frequently during the interviews. We could thus argue that although the initiatives were mentioned, more implementation is necessary to facilitate CE.

5.1.2 Further developed concepts

In contradiction to section 5.1.1, some concepts were mentioned which are implemented by SMEs but were not identified in the theory of this research. An example of this was the r-strategy ‘re-use’, whereby the literature only focussed on the re-use of components, whereas re-use of constructions was mentioned additionally during the interviews. The reason that this initiative has not been mentioned by other research is most likely because the innovation is brought to the market by the interviewed SME.

In terms of ‘recycle’, both the literature and interviewees agreed that, although the strategy is widely adopted, it is not the ideal strategy for CE. However, it could provide a function when the function of elements has come to an end. Whereas the interviewees made a distinction between using materials that could be recycled and using recycled materials, academic literature solely focused on the latter.

Similarly, ‘recover’ was seen as a last option by both the literature and interviewees, however, the interviewees contributed to this strategy by stating that recovery of energy can be considered in the design phase. Construction with wood would be preferable as it makes all r-strategies better applicable and allows for easier energy recovery. Nevertheless, recovering energy is seen as a last resort by most interviewees and it is therefore not necessary to fully focus on this strategy.

5.1.3 Contribution to academic literature

Apart from section 5.1.2, the results presented in section 4.5.1 need to be discussed. Figure 26 shows the division of r-strategies, how many interviewees referred to a strategy and which groups these interviewees came from. Academic literature has not provided a similar division for the Dutch construction sector or any other construction sector globally. This division shows that the main focus in the sector and in academic literature should be on middle strategies such as 'remanufacture', 'refurbish', 'repair' and 'reduce'. As most of these strategies overlapped fully with academic literature, this research argues that more initiatives should be researched in literature and implemented in the sector.

5.2 Comparing Barriers and Drivers

5.2.1 Technological Dimension

The four main barriers identified in this research are the 'difficulty of changing a linear supply chain', 'lack of a technological platform', 'finding materials fit for circularity' and 'difficulty of measuring circularity'. When we compare these to the barriers identified in the theory section of this research, we identify two relatively similar barriers in the form of 'lacking standardisation' and 'fragmented and linear supply chain'.

Interestingly, the two barriers 'technical challenges related to material recovery' and 'lack of adequate technology' were not identified in the interviews. A possible reason for this is that the interviewees worked in SMEs that already presented solutions to CE. Therefore, they acquired the adequate technology and knew that there were companies, of which '*NewHorizon*' was mentioned as a prime example, that could harvest materials from construction sites. Interviewee 15 (project commissioner) also specifically stated that adequate technology is present in the construction sector of the Netherlands, however, especially commissioners should know where to find the right partners.

Nevertheless, 'technological advancements' was seen as a driver for the transition towards circularity. However, these advancements mainly related to design solutions and learning from other sectors. The first 1st order concept mentioned here relates to the identified driver 'efficient designs' in academic literature. These designs should focus on fostering circularity in a later stage when the construction is taken down, instead of circularity at this exact moment. The technology present in the sector now focuses on incorporating existing construction in CE, whereas efficient designs would foster CE from the start of construction. The barrier 'development of enabling technology' identified in academic literature, is thus not of importance for the Dutch construction sector.

A similar reasoning can be applied to the driver 'digital innovation'. The current technology is already in place, but 'increasing efficiency' and 'digitalisation' is still considered important. This driver corresponds with 'web-based innovation' identified in the theory but is described more thoroughly through the 1st order concepts. 'New measuring methods' on the other hand, is not identified as a barrier in the academic literature but was considered important by the interviewees. Again, this would help to further develop technology that is currently in place, as the right projects can be targeted when circularity is measured correctly.

5.2.2 Economic Dimension

In both the theory and results of this research, the economic dimension contained the most barriers in the transition towards circularity. Section 4.5.2 already highlighted that barriers categorized under the economic dimension had undoubtedly the most influence. This ascendancy was mainly caused by the barrier ‘financial risk’, which was not identified specifically in academic literature. Nevertheless, the high ‘upfront costs’ or ‘investment costs’ were identified in the theory and during the interviews and were seen as one of the reasons for a financial risk. The combination of a financial risk and SMEs that see the transition as ‘not profitable’ leads to a general perception of economic insecurity. According to both the theory and this research, this keeps SMEs from making a transition.

Moreover, the ‘inadequate financial resources’ or ‘lack of resources’ were a substantial barrier as well. Currently, the SMEs can only charge 2 to 4% margins on their projects, leaving diminutive room for profit. From the perspective of this research, SMEs are therefore not able to finance circular initiatives with profits from linear projects, making the transition increasingly complex.

In terms of drivers, according to the interviewees, especially the market can perform pressure on SMEs when larger companies make the transition or when new start-ups or companies come into the sector. ‘Pressure from the market’ was thus seen as the most important economic driver, evoking change amongst SMEs because a financial incentive is created.

Another important driver corresponding with the theory are ‘new business models’. From the perspective of this research, a transition towards circularity is more than implementing circular initiatives and requires a shift in the entire economic system. Business models specifically, need to be targeted for circular initiatives to be implemented and to function in a desired manner. The business models that are mentioned in the form of ‘PSS’ and ‘long-lasting business relationships’ require a transition in doing business, rather than a transition in technology.

In the theory, two drivers were mentioned which could not be identified in the interviews. Both the ‘information metrics’ and ‘tools to measure the value of materials’ were not mentioned in the context of the theory. Information metrics in the theory referred to metrics that aid in implementing business models and although this was regarded as important by the interviewees, the metrics were not mentioned. Moreover, despite mentioning tools to measure circularity, tools to measure the value of materials was not mentioned. The main reason for this could be that these tools have been implemented in the sector already and now need to be made to good use. Therefore, tools such as ‘material passports’ and ‘buildings as materials banks’ could be seen as more important, as this would allow for re-use of the already valued materials.

5.2.3 Governmental Dimension

For the governmental dimension, the identified barriers corresponded a lot with the barriers found in academic literature. Both the researchers as the interviewees saw ‘hindering regulation’ and ‘obstructing laws and regulations’ as a major barrier for the transition towards circularity. A possible explanation was given when it was stated that governments often follow the market, instead of shaping a pathway. It is therefore very likely that the current regulations in most countries are not fit for a transition as CE is still a relatively new concept. To the two 3rd order themes, ‘regulation hindering circular innovation’ and ‘difficult to acquire permits for building land’, the same reasoning can be applied.

Moreover, a ‘lack of overarching legal system’ mainly applies to the ambiguity of ownership and lack of insurance possibilities. The legal system is simply not ready for CE, whereas the construction sector itself is already further developed. A similar barrier could be identified in academic literature regarding the ‘lack of regulatory mechanisms’.

In term of drivers, section 4.5.3 showed that the governmental dimension had the most influence. Although the barrier ‘lack of regulations and laws’ was only identified in the theory, the interviewees did mention ‘new rules and regulation’ as the most important driver. Although this would indicate that the Netherlands currently lacks these regulations, it was not specifically stated in the interviews. The governmental drivers would help to foster implementation by guidance, through ‘promoting circularity’, and support through ‘subsidies’. This shows that a lot of SMEs are still hindered in the transition because they still need the assistance to go through it. Moreover, like the technological driver of measuring circularity, the government should guide by setting up one measurement tool. From the perspective of this research, this measurement tool would provide control to the government of what they deem important in CE and would help them in providing subsidies to circular initiatives from section 4.2.

Lastly, the driver ‘regulatory reform’ from the theory connects to the earlier mentioned ‘new rules and regulation’ and ‘make current regulation stricter’. Again, the interviewees believed that governments would aid in the transition by facilitating a pathway for SMEs to follow. The main measures that are available to the government are rules and regulations, thus it comes as no surprise that the interviewees and academic literature see these drivers as most important.

5.2.4 Environmental Dimension

The least influential dimension for both the barriers and drivers is the environmental dimension. In academic literature, only one driver and no barriers could be identified, while this research derived one barrier and three drivers, which were only scarcely mentioned. A possible explanation could be that the environment cannot be influenced by society or ‘humans’ in general, which means drivers cannot be initiated. Moreover, transitioning towards CE would foster the environment, which could be the reason for the insignificant number of barriers.

The singular barrier mentioned in the interviews was ‘circular resource scarcity’. This would hinder SMEs that are currently transitioning towards circularity as there would be no resources to build with. This would pose a problem, mainly due to the vast increase in demand for circular construction. On the other hand, ‘scarcity of non-circular resources’ was seen as the major environmental driver, as this would foster the need for circularity of materials. From the perspective of this research, resource scarcity was a main driver for various interviewees despite not being mentioned specifically. Most circular initiatives arose from the fact that resources will diminish, while the demand for housing will grow.

The only driver mentioned in other research, was also identified in the interviews of this research as one interviewee suggested that we need ‘models to show the public the damage done to earth’. This driver was categorized under the environmental dimension as other metrics discussed in this research focussed on measuring circularity rather than environmental impact. You could argue that the models are a societal driver, however, in this case, the model influences society, while societal drivers come from within society.

5.2.5 Societal Dimension

What became more apparent in the interviews compared to academic literature, is that the transition towards circularity is more than a governmental, technological and economic shift but focuses strongly on society as well. Hence, society was seen as the second most influential in terms of barriers and drivers separately. The most influential barrier according to the interviewees is ‘lack of awareness’, which was not mentioned in other research. One of the two barriers related to this dimension in academic literature was ‘lack of interest, knowledge and engagement throughout the value chain’ which does correspond with the other identified barrier ‘lack of knowledge’. Both a lack of awareness and knowledge can be attributed to the early stage in which circularity currently is in the construction sector of the Netherlands.

A barrier not mentioned in other research as it was mostly attributed to the Dutch sector is 'conservative sector', meaning that SMEs stick to their way of collaborating and are comfortable with the hierarchical structure in place. This does match with the barrier in academic literature 'lack of collaboration between businesses' although the interviewees suggest that the right collaborations are lacking instead of collaborations in general. The interviewees do however see 'collaboration' as the most important driver, either through 'collaboration between businesses with similar vision' and 'collaboration on projects through all layers of the sector'. With the second 2nd order concept, the interviewees do suggest that the current collaboration between businesses in insufficient for CE and should thus further develop.

Two other overlapping drivers are 'networking' and 'support from demand network'. The first driver was regarded as important because sharing knowledge is crucial in the transition towards circularity according to the interviewees. Networking on for example platforms would help SMEs to overcome barriers such as the lack of knowledge, as they can learn from the knowledge of other SMEs.

Lastly, a barrier that was not mentioned in other research but considered important by the interviewees, is 'creating awareness'. Again, this driver will help to overcome the barrier 'lack of awareness', by providing education to students that will enter the construction sector and showing SMEs successful example cases of circular construction. It is thus the task of society to influence SMEs and help them in their transition.

5.2.6 Behavioural Dimension

The last dimension has the most significant overlap between academic literature and the results of this research, despite the lack of behavioural barriers in another research. First, the two barriers identified in this research were 'resistance to change' and 'afraid of risks'. Both barriers applied to either the owners or employees of the SMEs. It was argued by the interviewees, and confirmed by other research, that behavioural drivers are needed to overcome these barriers.

First, 'leadership' and 'intrinsic motivation' were seen as two drivers for the transition towards circularity. Both drivers would eliminate the resistance to change, whereas leadership would guide employees to withstand the fear of taking risks. Moreover, a 'change of culture within the organisation' could be identified in this research as well as in academic literature. Again, this could either be the result of leadership, or come from intrinsic motivation of employees to reduce resistance to change. What can be concluded from these barriers and drivers is that all members of an SME need to be willing to make the transition towards circularity, while also having the responsibility to influence other members. Interviewee 3 (project commissioner) described this as lighting a flame within colleagues to make the transition together. This shows that change within the SME is not only influenced by surrounding systems such as the government, the market or society, but also from within the SME itself

5.2.7 Contribution to academic literature

The results provided in section 4.5.2 and 4.5.3 also allow for further discussion. This research is the first in presenting a division between different dimensions as presented in Figure 27 and 28. This division of barriers and drivers allows for more specific implementation of measures and identification of barriers. We can argue that based on these results, the main initiative should be taken by the government as the most important dimension, with society as second most important. Moreover, the main barriers that are required to be targeted are those in the economic dimension.

5.3 Cross-Dimensional Relationships

The identified barriers and drivers have a far greater influence than within one dimension alone. In the theory (2.3.1) it was already stated that barriers and drivers cannot be limited to solely one dimension, which was also indicated in the model of Pomponi and Moncaster (2017) by peripheral arches and dashed lines in Figure 2.

This section aims to highlight the overarching influence of barriers and drivers and the relationship between barriers and drivers in different dimensions. Each relationship is indicated by a coloured number, which corresponds with a line in Figure 29, 30 or 31. Moreover, this chapter is not based on theoretical or methodological choices, for this reason it is included in the discussion. Also, as interviewees have not specifically mentioned the connection between barriers and drivers, this chapter allows for interpretation by the researcher and cannot be referred to as an analysis of results.

The first section (5.3.1) will describe the relationship between barriers, as some barriers are likely to be influenced by other barriers from different dimensions. The second section (5.3.2) will highlight how drivers from different dimensions relate to each other, whereas lastly, the third section (5.3.3) will highlight how drivers from one dimension can help to overcome barriers in a different dimension. Self-evidently, not all possible relationships can be discussed in this research. Therefore, the relationships that are presumed to have the most influence will be discussed.

5.3.1 Cross-dimensional relationships between barriers

Section 5.2 discussed the relationship between drivers and barriers in one dimension. However, cross-dimensional relationships between barriers also exist whereby barriers from one dimension can be the cause of barriers in another dimension or strongly influence them.

First of all, the technological barrier that it is hard 'finding materials fit for circularity' might be influenced by the barriers 'lack of knowledge' and 'lack of awareness' (societal) (**1**, Figure 29). When SMEs are not aware of future problems and only slightly know what problems might occur in the future, finding materials that are not affected by this thread is harder. Moreover, a lack of knowledge relates to the inability in the form of knowledge to find the right materials. Interviewee 16 (consultant) stated in relation to this that SMEs often do not know where to look.

Secondly, a lack of knowledge and awareness in the sector might also influence the individual 'resistance to change' (behavioural) which was identified by interviewees (**2**, Figure 29). Again, when employees are unaware of current climate problems and lack the knowledge to identify solutions, their resistance to change will preserve.

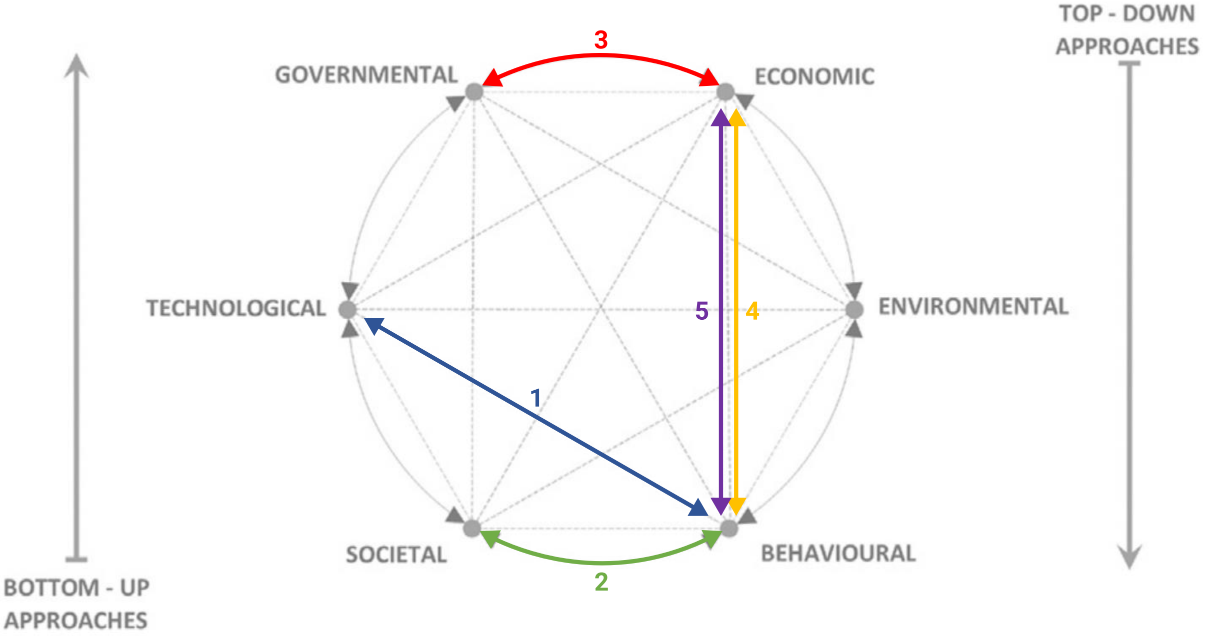
Thirdly, 'financial risk' was seen as the major economic barrier, for example caused by the 'high investment costs' and a 'lack of guarantee' on construction elements. Another cross-dimensional influence might come from the 'hindering regulation' (governmental), which makes it more difficult for SMEs to comply with standards and thus investment costs will rise (**3**, Figure 29). Current regulation does not protect SMEs willing to transition to CE, which might cause a vast increase in financial risk.

The financial risk on the other hand, might foster the fact that employees and owners of SMEs are 'afraid of risks' (behavioural), whereas you could also argue that the feeling of financial risk increases due to the fear of taking risks (**4**, Figure 29). Nevertheless, this research assumes that the two barriers enhance each other.

Lastly, the behavioural barrier 'focussed on short-term decision making' is fostered by the economic barrier that a substantial number of SMEs still 'profit from the linear economy' (**5**, Figure 29). Because the business models of these SMEs are still focused on a linear economy and they profit from it, the need to change long-term plans is not needed. SMEs will thus keep focussing on short-term decision making and the barrier is enhanced.

Figure 29

Cross-Dimensional Relationships between Barriers



5.3.2 Cross-dimensional relationships between drivers

Similar to the barriers, drivers from different dimensions could also enhance each other, leading to more impactful measures. This section seeks to shine a light on these relationships. The first four drivers come from the governmental dimension, which was already considered the most important dimension. This shows that the influence ranges further than the governmental dimension alone and even enhanced drivers from other dimensions.

These first governmental drivers, ‘subsidies’ and ‘setting up one measurement tool for circularity’, will most likely stimulate technological drivers such as ‘technological advancements’ and ‘digital innovation’ (**1**, Figure 30). Technological advancements are often hindered by a lack of financing and can thus be achieved when subsidies are provided. Moreover, digital innovation will also be encouraged as innovation using subsidies will be considerably simplified. The measurement tool on the other hand, will aid in providing guidelines in technological advancements, which SMEs considered hindered due to the large variety of tools. Technological advancements will thus be further developed when one measurement tool is created by the government.

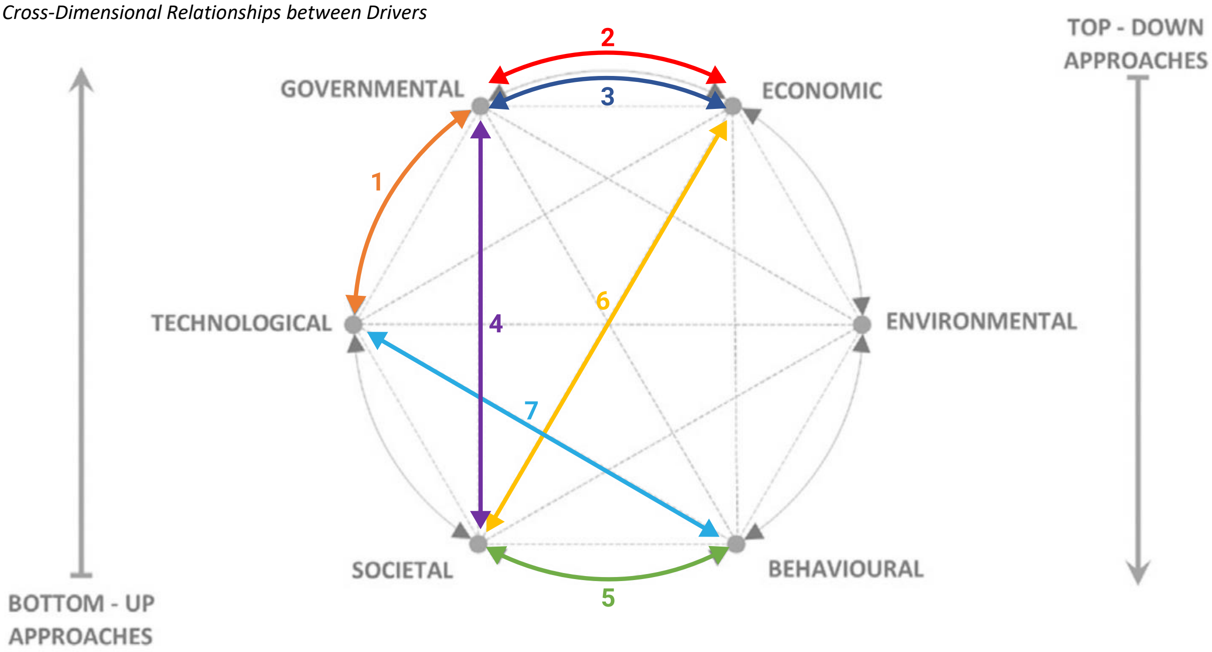
Moreover, the measurement tool will also allow SMEs to find new financing methods, therefore nursing the driver 'rethinking economic models’ (**2**, Figure 30). When one straightforward tool is presented, financing institutions such as banks can target truly circular projects and finance based on circular achievements. Connecting to this, ‘new rules and regulation’ (governmental) will also help in rethinking economic models as providing a guarantee on future value of materials and construction elements is greatly simplified (**3**, Figure 30).

As a last governmental driver, ‘promoting circularity’ will enhance the societal driver of ‘creating awareness’ (**4**, Figure 30). Very similar to the successful example cases, setting ambitions and providing a guiding vision will provide awareness to SMEs in their transition. When the government constantly displays successful businesses, other SMEs will become aware of the necessity to transition as they cannot see a different way of moving forward. Moreover, the guiding vision of the government will make SMEs aware of business opportunities. The driver ‘creating awareness’ will on the other hand strengthen the behavioural driver 'intrinsic motivation' because more SME employees are aware of the problem (**5**, Figure 30). This rise of awareness will most likely intrinsically motivate them to transition to CE. This intrinsic motivation will then further influence the implementation of 'new business models' (economic) which are needed to foster the transition (**6**, Figure 30). You could thus argue that a lot of drivers from different dimensions connect and enhance each other which makes it even more important than the first steps in the transition are taken.

Lastly, the behavioural driver 'being agile' will aid in the technological driver 'technological advancements' (**7**, Figure 30). A narrow range of interviewees saw being agile as an important driver because, during the transition, SMEs will face obstacles that need to be overcome. If they are agile in their behaviour, this will foster technological advancements as similar obstacles are faced.

Figure 30

Cross-Dimensional Relationships between Drivers



5.3.3 Cross-dimensional influence of drivers on barriers

The last relationships that require further discussion are those between drivers and barriers of different dimensions. Where the results presented the influence of each dimension separately, it is essential for this research to also discover how drivers from one dimension can help to overcome barriers in another dimension. It is therefore important to notice that the effect of drivers ranges further than their dimension.

When we analyse the results in section 4.5, we can identify the governmental dimension as the most influential as regards to drivers, whereas we also see an absence of barriers. This absence of governmental barriers shows that the government is aiming to promote circularity, which was acknowledged by the interviewees. On the other hand, as stated previously the economic barriers have a substantial influence on the transition. Firstly, it would therefore be interesting to see how governmental drivers can help to overcome these economic barriers. Secondly, an interpretation of other cross-dimensional influences on economic barriers is presented. Lastly, other dimensions and their cross-dimensional relationships will be covered.

First, the largest governmental driver 'new rules and regulation' will have a major impact on the largest economical barrier 'financial risk' (**1**, Figure 31). As other SMEs are demanded to transition to circularity and for example tax rates are shifted from labour to materials, the risk it takes to transition to circularity will reduce if not recede. Moreover, this will have an impact on the barrier 'not profitable' as SMEs suddenly are provided with an advantage as opposed to SMEs operating in a linear economy. Lastly, 'subsidies' will also help to overcome the 'financial risk' and 'lack of resources' as SMEs are provided with the resources for an initial investment that is not fully funded by the SME itself (**2**, Figure 31).

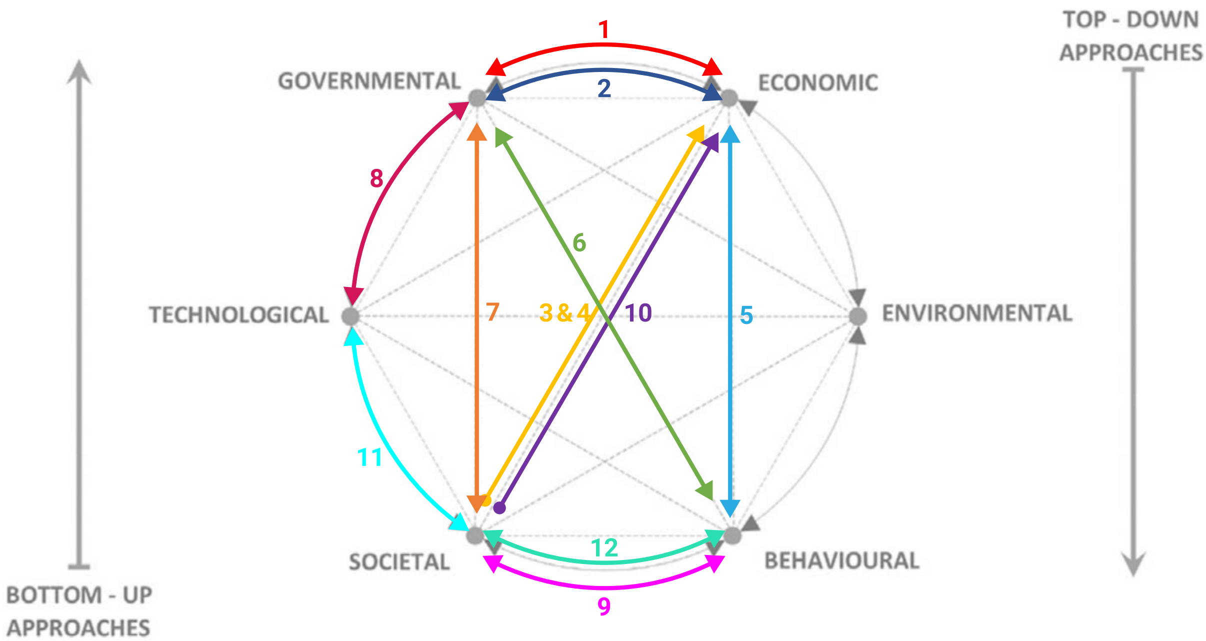
Drivers from other dimensions could also help to overcome economic barriers. The societal driver 'networking' can help SMEs to overcome the barrier 'place in the market still needs to be found' (**3**, Figure 31). Currently, SMEs often lack the knowledge to see what value their company can add to the market and how they can be profitable in a position in the market. When these SMEs network with other SMEs, they will learn from their experience, see what these SMEs strive for and how this could be applied to their business. Moreover, 'collaboration' (societal) between businesses could deal with the 'fragmented market' which was seen as a barrier by interviewees (**4**, Figure 31). As currently a lot of parties offer a similar service in the construction sector, having the same partners for more than a few years will help to develop the business. This also corresponds with the 'long-lasting business relationships' which was seen as an economic driver. Especially in the early stages, collaboration might also happen between parties still active in a linear economy. However, the interviewees did indicate that collaborating with businesses with a similar vision will help the SME more. A behavioural driver 'intrinsic motivation' can help to overcome the need to 'profit from a linear economy', mainly because the motivation of company leaders shifts from making profit to other goals such as doing good for the climate (**5**, Figure 31).

As the list of drivers that have a possible influence on barriers is extensive, this research will solely focus on the influence of the seven main drivers mentioned in section 4.5.3, starting with the main governmental drivers. First of all, 'promoting circularity' by the government will eliminate 'resistance to change' (behavioural) and the societal barrier 'lack of awareness' (**6**, Figure 31). When successful business cases are shown to SMEs, the behaviour of employees might change from being resistant to seeing a potential value in circularity. It is self-evident that employees and SME owners will also become more aware of possibilities and business opportunities. Also, a societal barrier that became apparent in the interviews was that the construction sector is a 'conservative sector', which can be overcome by 'new laws and regulation' (**7**, Figure 31). When these regulations force SMEs to change and guide them in doing so, the conservative parties will seek the path of least resistance, which is the pathway paved by the government. Thirdly, the government 'setting up one measurement tool for circularity' will aid in overcoming the technological barriers difficulty of 'finding materials fit for circularity' and 'difficulty of measuring circularity' (**8**, Figure 31). Although some interviews have argued that new measuring methods can come from SMEs and are thus a technological driver, a substantial amount wanted to attribute to an independent organisation such as the government. The government already aims to perform a role in this process by the platform CB23 with which they want to present the complete definition of circularity in the construction sector in 2023.

Similar to the promotion of circularity by the government, society can also perform a role in 'creating awareness' and thus eliminating the behavioural barrier 'resistance to change' (**9**, Figure 31). The same reasoning applies to this relationship for promotion of circularity. Furthermore, collaboration (societal) will help to overcome the economic barrier of 'lack of a technological platform' (**10**, Figure 31). Currently, the main problem arising from the lack of technology to find buyers and match them to future projects is aligning supply and demand. With collaboration, SMEs can establish long-term partnerships in which buyers are sure of suppliers whereas suppliers are sure of buyers.

A 'lack of knowledge' (societal) can be overcome by 'digital innovations (technological) whereby sharing knowledge online will provide SMEs with sufficient knowledge (**11**, Figure 31). As this information will include shared data such as material passports, but also a database for available circular materials, SMEs can acquire knowledge on elements and materials that could fit their business. Lastly, 'intrinsic motivation' (behavioural) can help to overcome, or at least reduce the impact of, many barriers, as it was often seen as an essential factor for an SME to transition. The most impact, however, can be generated by overcoming societal barriers such as 'short-term decision making' and 'lack of awareness' (12, Figure 31).

Figure 31
Cross-Dimensional Relationships between Barriers and Drivers



5.4 Scientific Relevance

This research has contributed to academic literature because it has provided new insights in the barriers and drivers of the construction sector of the Netherlands. As discussed in the introduction, the theory by Hart et al. (2019) is tested by comparing new results to their barriers and drivers, and differences are indicated when these were present. Moreover, a knowledge gap is filled as this research is only the second paper specifically focussing on barriers and drivers of SMEs in the construction sector of the Netherlands and only the first paper to focus on the Residential and Utility Buildings sector. This has led to the identification of new initiatives, and influential barriers and drivers. Different to the relevance discussed in the introduction, this is the first research that has identified the most influential dimensions or areas in the construction sector. Therefore, recommendations can be targeted more specifically to particular areas of research and allow for further research initiatives on this matter.

The contribution of this research reaches farther than one discipline alone, as it discusses barriers and drivers related to politics, economics, technology, and sociology. It provides observations that are relevant in each of these disciplines and can contribute to existing literature on this topic. Moreover, this research has shown that interdisciplinary research between these disciplines is of vast importance. As indicated in section 5.3.1, barriers in one dimension can enhance barriers in other dimensions substantially, meaning that measures in one area alone are insufficient. On the other hand, section 5.3.2 has shown that drivers can enhance each other as well, meaning that the biggest impact is made when researchers in different disciplines seek to work together. Lastly, section 5.3.3 has shown that initiatives in one dimension can help to overcome barriers in other dimensions. All three conclusions had not yet been identified in other research.

5.5 Societal Relevance

As discussed in the introduction, the aim of this research was to aid in the transition towards circularity and sustainable development as the construction sector is one of the most emitting sectors, while similarly contributing largely to the GDP of the Netherlands. This research has achieved this aim by providing the first insights into barriers and drivers that can be directly applied to SMEs of the Residential and Utility Buildings sector of the Netherlands. Moreover, this research has shown how different groups of society are required to interact with each other for economic benefit and the benefit of SMEs.

As this research has identified the most important barriers and drivers, as well as the most influential dimensions, the results can be applied to a practical recommendation presented in the conclusion (6.2). Due to this recommendation, processes within SMEs, the government and society can be optimised to facilitate the transition towards circularity.

As the most influential dimensions have been identified as well, this recommendation can be coordinated by means of strategic niche management (SNM). SNM refers to the process of managing niche formation processes through real-life experiments (Loorbach & van Raak, 2006). As the government is the most influential dimension, they can initiate these experiments by new rules and regulations, testing one measurement tool for circularity and subsidies. The main advantage of SNM is that social and technical aspects are aligned, leading to socio-technical change (Loorbach & van Raak, 2006). This research has shown that these two dimensions, especially when initiated by the government, can have a major influence on a transition in the sector. The results are partly embodied in technological advancements, whereas the experimental feature makes it possible to establish an open-ended search and learning process. SMEs will benefit from this as they can experiment with new innovations in a protected environment. Also, the open-ended learning process initiated by SNM will facilitate collaboration and networking, which were seen as two important societal drivers by SMEs. In the end, society benefits from SNM as well, as consumer wants are better aligned with supply (Loorbach & van Raak, 2006).

5.6 Limitations and Future Research

As with most studies, the findings of this research must be seen in light of some limitations. The first is the lack of a widely accepted definition for circular construction. This research-based the definition of circularity and circular construction on different research papers, but not one universal definition was found. Coming to a universal definition does not require future research, but rather a consensus between researchers.

Secondly, the interviews conducted for this study were mostly focused on circular SMEs in the construction sector as they have faced barriers and know what drivers have helped them reached the current state of business. However, this sampling may have resulted in sample bias. It would thus be advisable for future research to have a more extensive focus on non-circular SMEs and compare the results to the barriers and drivers identified in this study. Moreover, although saturation was largely achieved in barriers and drivers, the limited sample compared to the large sector could have resulted in incomplete initiatives implemented by SMEs. Future research could therefore also focus on a more elaborate sample focussing on consultants, as they are aware of multiple initiatives implemented by different SMEs.

Thirdly, the generalizability of the results is limited as full data triangulation was not achieved. Due to time constraints, the focus of this research was on transcribing and coding of interviews and analysing academic literature. A third form of data gathering was thus not incorporated in this research and would be advisable for future research.

The fourth limitation is the factor of interpretation, both in transcription and presentation of results. Interpretation in transcription was needed as the interviews were conducted in Dutch, whereas the quotes presented in this research are translated to English. Translation incorporates a factor of interpretation as a literal translation is often not possible. Therefore, a slight misinterpretation in quotation might have occurred. Moreover, the impact of barriers and drivers is based on interpretation and not tested. Due to the lack of data on scores of importance for these barriers and drivers, as interviewees were unable to provide these scores, their importance cannot be statistically proven. Future research could thus focus on testing the influence of each barrier or driver, by asking interviewees to score the presented results in this study.

Following on these limitations, a different approach of this research could have resulted in rival explanations. As discussed in section 5.4, the results of this research are interdisciplinary, which means that interviewing other stakeholders in society could have resulted in a different list of barriers and drivers. Now, the results show that actors in SMEs argue that the government is most influential when it comes to drivers, which might be the case as this relieves them from action towards a transition. However, this explanation can be excluded as the interviewees have indicated that their SME is taking action. Moreover, the environmental dimension has not been indicated as important for barriers and drivers, which could be the case as actors in SMEs are unaware of environmental problems. Again, this explanation can be excluded as interviewees have shown to be aware of environmental problems, although these problems were not the main barrier or driver for their transition towards circularity.

6. Conclusion

This research has aimed to answer the research question '*What are the barriers and drivers for implementing circular practices by Dutch SMEs in the construction sector of the Netherlands?*' by an analysis of academic literature and conducting interviews with Dutch SMEs. This has aided in answering sub-question 2 and 4, as sub-questions 1 and 3 have been answered in the theory section (2.5).

6.1 Summarizing the results

Firstly, the main circular initiatives were identified and categorized under R-strategies based on a framework by Potting et al. (2017). This aids in answering sub-question 2 '*Which R-strategies are implemented most frequently by SMEs in the construction sector of the built environment of the Netherlands?'.* The results have shown that the SMEs related to the interviewees have implemented initiatives that connect with strategies with high levels of circularity. 'Rethink' was seen as the major strategy, as most interviewees referenced to this strategy. It shows that rethinking design for circularity and which materials to use is a crucial part of the transition towards circularity. Moreover, 'recycle' and 'refuse' were identified as the second most important strategies. The results of this research have shown that although high levels of circularity have been achieved, especially strategies such as 'remanufacture' and 'repair' which are in the middle of the spectrum can be improved. In terms of 'repair', the SMEs can derive useful initiatives for academic literature, whereas for 'remanufacture' both SMEs and academic literature can improve.

Secondly, barriers and drivers could be identified from transcribed interviews, which were categorized under six dimensions following a framework presented by Pomponi and Moncaster (2017). This aids in answering sub-question 4 '*What barriers and drivers apply to the construction sector of the built environment of the Netherlands and have hindered or helped the implementation of circular initiatives?'.* The results have shown that the most influential barriers were 'financial risk', 'resistance to change', 'lack of awareness', 'difficulty to measure circularity' and 'regulation hindering circular innovation'. The economic dimension was seen to have a significant influence on the barriers to implementing circular practices and transitioning to CE. The most influential drivers were 'technological advancements', 'new rules and regulations', 'collaboration', 'promoting circularity', 'intrinsic motivation', 'digital innovation' and 'creating awareness'. In contrast to the barriers, the governmental dimension was most influential in terms of drivers for implementing circular practices.

When the barriers and drivers identified in this research were compared to those from academic literature, a lot of similarities could be seen. However, this research has also contributed to existing literature by providing new influential drivers and barriers. In term of barriers, especially the behavioural and economic barriers were undeveloped in academic literature. This literature has thus contributed substantially to this dimension with two major barriers. Also, because of the analysis of the influence of each dimension, the major strengths and weaknesses of the Dutch construction sector could be identified, leading to main areas of attention.

Moreover, this research has shown that the influence of drivers and barriers ranges further than one dimension alone. Barriers can enhance the impact of cross-dimensional barriers, whereas drivers act like cross-dimensional drivers. Also, drivers from one dimension can help to overcome barriers in another dimension, showing the impact of implementing a driver ranges further than its dimension alone.

6.2 Recommendations

Based on the results of this research the following recommendation can be made. The results have shown that governmental drivers can have a substantial impact on the implementation of circular initiatives and the transition towards circularity in the construction sector of the Netherlands. However, the results also indicate that the government of the Netherlands already performs a leading role in the transition and is willing to stimulate circular SMEs. It is thus advisable for the government to continue in this position by implementing four major drivers, through four leading actions.

First, new rules and regulations will force SMEs to transition either in the form of demand, for example by shifting tax rates from labour to materials, or by procedures such as a change in allocation of land.

Secondly, the government should continue its leading position by promoting circularity through setting ambitions, providing a guiding vision, and displaying successful businesses that have achieved the implementation of circular initiatives.

Thirdly, most SMEs have demanded an independent organisation to set up one measurement tool for circularity. The government should take on this role and be leading in setting up this tool.

Lastly, subsidies are considered important as they can have a major impact on the availability of financial resources for SMEs. As currently, the financial risk is the major barrier for SMEs, providing subsidies for circular initiatives will help them to make a transition and to choose a new direction. For the subsidies to be effective however, this research has shown that step three needs to be completed first, as the government must know which projects are truly circular before subsidising these projects.

Through SNM, steps one, three and four can be tested through experimentation. This allows the government to limit investments and test which method works best. Eventually, this method can be implemented in the entire sector to facilitate a smooth transition for all SMEs. SMEs will also benefit from this, as innovation and knowledge sharing is rewarded by the government in a protected environment.

6.3 Take-Home Message

This research has confirmed that circularity, and circular construction, is still a vague and undeveloped concept. Opinions on what circularity truly means differ and one measurement tool for circularity still needs to be developed. On the other hand, this study has shown that collaboration is of utmost importance. Not only was collaboration considered an important barrier, but the cross-dimensional influence of barriers and drivers has also shown that collaboration between disciplines is essential. We can therefore conclude that the transition towards circularity by the implementation of circular initiatives is not a task that must be left to SMEs alone. It is of radical importance that all actors in society contribute to this cause, either by providing changes in behaviour, support from society and providing financial support by considering circularity in construction projects.

Transitioning towards CE and implementing circular initiatives is vital for our planet and crucial to cope with resource scarcity in the coming years. With circularity, emissions of the construction sector will drop, while the influence on GDP will remain equal or possibly rise. When the drivers identified in this research are implemented, the barriers will be overcome and a transition towards circularity can be facilitated. However, only if all actors collaborate a solid foundation can be established.

7. References

Adams, K. T., Osmani, M., Thorpe, T., & Thornback, J. (2017). Circular economy in construction: current awareness, challenges and enablers. In *Proceedings of the Institution of Civil Engineers-Waste and Resource Management* (Vol. 170, No. 1, pp. 15-24). Thomas Telford Ltd. https://doi.org/10.1680/jwarm.16.00011.

Ajayabi, A., Chen, H. M., Zhou, K., Hopkinson, P., Wang, Y., & Lam, D. (2019). REBUILD: Regenerative buildings and construction systems for a circular economy. In *IOP Conference Series: Earth and Environmental Science* (Vol. 225, No. 1, p. 012015). IOP Publishing. https://doi-org.proxy.library.uu.nl/10.1088/1755-1315/225/1/012015.

Allacker, K., Mathieux, F., Manfredi, S., Pelletier, N., De Camillis, C., Ardente, F., & Pant, R. (2014). Allocation solutions for secondary material production and end of life recovery: Proposals for product policy initiatives. *Resources, Conservation and Recycling*, *88*, 1-12. https://doi-org.proxy.library.uu.nl/10.1016/j.resconrec.2014.03.016.

Allwood, J. M., Ashby, M. F., Gutowski, T. G., & Worrell, E. (2011). Material efficiency: A white paper. Resources, Conservation and Recycling, 55(3), 362-381. https://doi.org/10.1016/j.resconrec.2010.11.002.

Araújo, C. K., Salvador, R., Moro Piekarski, C., Sokulski, C. C., de Francisco, A. C., & de Carvalho Araújo Camargo, S. K. (2019). Circular economy practices on wood panels: a bibliographic analysis. *Sustainability*, *11*(4), 1057. https://doi.org/10.3390/su11041057.

Arora, M., Raspall, F., Cheah, L., & Silva, A. (2019). Residential building material stocks and component-level circularity: The case of Singapore. *Journal of Cleaner Production*, *216*, 239-248. https://doi-org.proxy.library.uu.nl/10.1016/j.jclepro.2019.01.199.

Arup. (2016). *The Circular Economy in the Built Environment*. Retrieved from: https://www.arup.com/-/media/arup/files/publications/c/arup_circulareconomy_builtenvironment.pdf.

Bao, Z., & Lu, W. (2020). Developing efficient circularity for construction and demolition waste management in fast emerging economies: Lessons learned from Shenzhen, China. *Science of The Total Environment,* 724, 138264. https://doi-org.proxy.library.uu.nl/10.1016/j.scitotenv.2020.138264.

Barriball, K. L. & While, A. (1994). Collecting data using a semi-structured interview: a discussion paper. *Journal of Advanced nursing*, 19, 328-335. https://doi.org/10.1111/j.1365-2648.1994.tb01088.x.

Bilal, M., Khan, K. I. A., Thaheem, M. J., & Nasir, A. R. (2020). Current state and barriers to the circular economy in the building sector: Towards a mitigation framework. *Journal of Cleaner Production*, *276*, 123250. https://doi.org/10.1016/j.jclepro.2020.123250.

Blomsma, F., Pieroni, M., Kravchenko, M., Pigosso, D. C., Hildenbrand, J., Kristinsdottir, A. R., ... & Li, J. (2019). Developing a circular strategies framework for manufacturing companies to support circular economy-oriented innovation. *Journal of Cleaner Production*, *241*, 118271. https://doi.org/10.1016/j.jclepro.2019.118271.

Bouwend Nederland. (2020). *Feiten en cijfers: kengetallen uit de bouw en infra*. Retrieved from https://www.bouwendnederland.nl/service/feiten-en-cijfers.

Brand, K.-W. & Jochum, G. (2000): Der Deutsche Diskurs zu nachhaltiger Entwicklung. Abschlussbericht eines DFG-Projekts zum Thema "Sustainable Development/Nachhaltige Entwicklung - Zur sozialen Konstruktion globaler Handlungskonzepte im Umweltdiskurs". München: Münchner Projektgruppe für Sozialforschung e.V.

Brütting, J., De Wolf, C., & Fivet, C. (2019). The re-use of load-bearing components. In *IOP Conference Series: Earth and Environmental Science* (Vol. 225, No. 1, p. 012025). IOP Publishing. https://doi-org.proxy.library.uu.nl/10.1088/1755-1315/225/1/012025.

CBS. (2019). *Sterke groei in steden en randgemeenten verwacht*. Retrieved from https://www.cbs.nl/nl-nl/nieuws/2019/37/sterke-groei-in-steden-en-randgemeenten-verwacht.

CBS. (2020). *Uitstoot broeikasgassen 3 procent lager in 2019*. Retrieved from https://www.cbs.nl/nl-nl/nieuws/2020/19/uitstoot-broeikasgassen-3-procent-lager-in-2019.

Chandra, Y., & Shang, L. (2019). Inductive coding. In Qualitative research using R: A systematic approach (pp. 91-106). Springer, Singapore. https://doi-org.proxy.library.uu.nl/10.1007/978-981-13-3170-1_8.

Choi, S., & Ng, A. (2011). Environmental and economic dimensions of sustainability and price effects on consumer responses. Journal of business ethics, 104(2), 269-282. https://doi-org.proxy.library.uu.nl/10.1007/s10551-011-0908-8.

Crawford, R. (2011). *Life cycle assessment in the built environment*. Taylor & Francis.

Debacker, W., Manshoven, S., Peters, M., Ribeiro, A., & De Weerdt, Y. (2017). Circular economy and design for change within the built environment: preparing the transition. *International HISER Conference on Advances in Recycling and Management of Construction and Demolition Waste*, 114-117.

Dryzek, J. S. (2013). The politics of the earth: Environmental discourses. New York: Oxford university press.

Ellen MacArthur Foundation (EMF). (2015). *Towards a circular economy: Business rationale for an accelerated transition*. Retrieved from https://www.ellenmacarthurfoundation.org/assets/downloads/TCE_Ellen-MacArthur-Foundation_9-Dec-2015.pdf.

Espinoza, A., Bautista, S., Narváez, P. C., Alfaro, M., & Camargo, M. (2017). Sustainability assessment to support governmental biodiesel policy in Colombia: A system dynamics model. Journal of Cleaner Production, 141, 1145-1163. https://doi.org/10.1016/j.jclepro.2016.09.168.

European Commission, 2015. Closing the Loop - an EU Action Plan for the Circular Economy, Com(2015) 614 Communication from the Commission to the Euro- pean Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. European Commission, Brussels.

Fernández, I., & Kekäle, T. (2005). The influence of modularity and industry clockspeed on reverse logistics strategy: implications for the purchasing function. *Journal of Purchasing and Supply Management*, *11*(4), 193-205. https://doi.org/10.1016/j.pursup.2006.01.005.

Fleischmann, M., Bloemhof-Ruwaard, J. M., Dekker, R., Van der Laan, E., Van Nunen, J. A., & Van Wassenhove, L. N. (1997). Quantitative models for reverse logistics: A review. *European journal of operational research*, *103*(1), 1-17. https://doi.org/10.1016/S0377-2217(97)00230-0.

Forsberg, A., & Von Malmborg, F. (2004). Tools for environmental assessment of the built environment. Building and environment, 39(2), 223-228. https://doi.org/10.1016/j.buildenv.2003.09.004.

Gallego-Schmid, A., Chen, H. M., Sharmina, M., & Mendoza, J. M. F. (2020). Links between circular economy and climate change mitigation in the built environment. *Journal of Cleaner Production*, 1-14. https://doi.org/10.1016/j.jclepro.2020.121115.

Geisendorf, S., & Pietrulla, F. (2018). The circular economy and circular economic concepts—a literature analysis and redefinition. *Thunderbird International Business Review*, *60*(5), 771-782. https://doi.org/10.1002/tie.21924.

Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2017). The Circular Economy–A new sustainability paradigm?. *Journal of cleaner production*, *143*, 757-768. https://doi.org/10.1016/j.jclepro.2016.12.048.

Geldermans, R. J. (2016). Design for change and circularity–accommodating circular material & product flows in construction. *Energy Procedia*, *96*, 301-311. https://doi-org.proxy.library.uu.nl/10.1016/j.egypro.2016.09.153.

George, D. A., Lin, B. C. A., & Chen, Y. (2015). A circular economy model of economic growth. Environmental modelling & software, 73, 60-63. https://doi.org/10.1016/j.envsoft.2015.06.014.

Gerlach, A. (2003). Sustainable Entrepreneurship and Innovation. Corporate Social Responsibility and Environmental Management, 29-30 June2003, Leeds, United Kingdom.

Ghaffar, S. H., Burman, M., & Braimah, N. (2020). Pathways to circular construction: An integrated management of construction and demolition waste for resource recovery. *Journal of Cleaner Production*, *244*, 118710. https://doi-org.proxy.library.uu.nl/10.1016/j.jclepro.2019.118710.

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner production*, 114, 11-32. https://doi.org/10.1016/j.jclepro.2015.09.007.

Gimenez, C., Sierra, V., & Rodon, J. (2012). Sustainable operations: Their impact on the triple bottom line. *International Journal of Production Economics*, *140*(1), 149-159. https://doi.org/10.1016/j.ijpe.2012.01.035.

Górecki, J., Núñez-Cacho, P., Corpas-Iglesias, F. A., & Molina, V. (2019). How to convince players in construction market? Strategies for effective implementation of circular economy in construction sector. *Cogent Engineering*, *6*(1), 1690760. https://doi-org.proxy.library.uu.nl/10.1080/23311916.2019.1690760.

Goyal, S., Esposito, M., & Kapoor, A. (2018). Circular economy business models in developing economies: lessons from India on reduce, recycle, and re-use paradigms. Thunderbird International Business Review, 60(5), 729-740. https://doi.org/10.1002/tie.21883.

Gravagnuolo, A., Angrisano, M., & Fusco Girard, L. (2019). Circular economy strategies in eight historic port cities: Criteria and indicators towards a circular city assessment framework. *Sustainability*, *11*(13), 3512. https://doi.org/10.3390/su11133512.

Guy, B., Shell, S., & Esherick, H. (2006). Design for deconstruction and materials re-use. *Proceedings of the CIB Task Group*, *39*(4), 189-209.

Haas, W., Krausmann, F., Wiedenhofer, D., & Heinz, M. (2015). How circular is the global economy?: An assessment of material flows, waste production, and recycling in the European Union and the world in 2005. Journal of industrial ecology, 19(5), 765-777. https://doi.org/10.1111/jiec.12244.

Hacking, T., & Guthrie, P. (2008). A framework for clarifying the meaning of Triple Bottom-Line, Integrated, and Sustainability Assessment. *Environmental Impact Assessment Review*, 28(2-3), 73-89. https://doi.org/10.1016/j.eiar.2007.03.002.

Hart, J., Adams, K., Giesekam, J., Tingley, D. D., & Pomponi, F. (2019). Barriers and drivers in a circular economy: the case of the built environment. *Procedia Cirp*, *80*, 619-624. https://doi.org/10.1016/j.procir.2018.12.015.

Heisel, F., & Rau-Oberhuber, S. (2020). Calculation and evaluation of circularity indicators for the built environment using the case studies of UMAR and Madaster. Journal of Cleaner Production, 243, 118482. https://doi-org.proxy.library.uu.nl/10.1016/j.jclepro.2019.118482.

Henrotay, C., Debacker, W., & Steinlage, M. (2017). How do current policies support a transition towards a circular economy in the built environment?. *International HISER Conference on Advances in Recycling and Management of Construction and Demolition Waste*, 227-230.

Hillebrandt, P. M. (2000). *Economic theory and the construction industry*. London: Macmillan.

Homrich, A. S., Galvao, G., Abadia, L. G., & Carvalho, M. M. (2018). The circular economy umbrella: Trends and gaps on integrating pathways. *Journal of Cleaner Production*, 175, 525-543. https://doi.org/10.1016/j.jclepro.2017.11.064.

Hopkinson, P., Chen, H. M., Zhou, K., Wang, Y., & Lam, D. (2018). Recovery and re-use of structural products from end-of-life buildings. *Proceedings of the Institution of Civil Engineers-Engineering Sustainability*, 119-128. Thomas Telford Ltd. https://doi.org/10.1680/jensu.18.00007.

Huang, B., Wang, X., Kua, H., Geng, Y., Bleischwitz, R., & Ren, J. (2018). Construction and demolition waste management in China through the 3R principle. *Resources, Conservation and Recycling*, *129*, 36-44. https://doi-org.proxy.library.uu.nl/10.1016/j.resconrec.2017.09.029.

Ijomah, W. L., McMahon, C. A., Hammond, G. P., & Newman, S. T. (2007). Development of robust design-for-remanufacturing guidelines to further the aims of sustainable development. *International Journal of Production Research*, 45(18-19), 4513-4536.

Iles, A., & Mulvihill, M. J. (2012). Collaboration across disciplines for sustainability: green chemistry as an emerging multistakeholder community. https://doi.org/10.1021/es300803t.

Joensuu, T., Edelman, H., & Saari, A. (2020). Circular Economy practices in the Built Environment. *Journal of Cleaner Production*, 124215. https://doi.org/10.1016/j.jclepro.2020.124215.

Kajikawa, Y., Tacoa, F., & Yamaguchi, K. (2014). Sustainability science: the changing landscape of sustainability research. Sustainability science, 9(4), 431-438. https://doi-org.proxy.library.uu.nl/10.1007/s11625-014-0244-x.

Kamer van Koophandel (KVK). (n.d.). What do the financial statements comprise?. *Kamer van Koophandel.* Retrieved from https://www.kvk.nl/english/filing/what-do-the-financial-statements-comprise/.

Kamer van Koophandel (KVK). (n.d.b). KVK-nummer: alles wat je moet weten. *Kamer van Koophandel*. Retrieved from https://www.kvk.nl/advies-en-informatie/bedrijf-starten-of-overnemen/kvk-nummer-alles-wat-je-moet-weten/.

Karhu, J., & Linkola, L. (2019). Circular Economy in the Built Environment in Finland-A case example of collaboration. *IOP Conference Series: Earth and Environmental Science* (Vol. 297, No. 1, p. 012024). IOP Publishing. https://doi.org/10.1088/1755-1315/297/1/012024.

Kazancoglu, I., Kazancoglu, Y., Yarimoglu, E., & Kahraman, A. (2020). A conceptual framework for barriers of circular supply chains for sustainability in the textile industry. *Sustainable Development*, *28*(5), 1477-1492. https://doi-org.proxy.library.uu.nl/10.1002/sd.2100.

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, conservation and recycling*, *127*, 221-232. https://doi.org/10.1016/j.resconrec.2017.09.005.

Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A., & Hekkert, M. (2018). Barriers to the circular economy: evidence from the European Union (EU). *Ecological Economics*, *150*, 264-272. https://doi.org/10.1016/j.ecolecon.2018.04.028.

Korhonen, J., Nuur, C., Feldmann, A., & Birkie, S. E. (2018). Circular economy as an essentially contested concept. *Journal of Cleaner Production*, 175, 544-552. https://doi.org/10.1016/j.jclepro.2017.12.111.

Lee, B., Trcka, M., & Hensen, J. L. (2011). Embodied energy of building materials and green building rating systems—a case study for industrial halls. *Sustainable Cities and Society*, *1*(2), 67-71. https://doi-org.proxy.library.uu.nl/10.1016/j.scs.2011.02.002.

Leising, E., Quist, J., & Bocken, N. (2018). Circular Economy in the building sector: Three cases and a collaboration tool. *Journal of Cleaner production*, *176*, 976-989. https://doi.org/10.1016/j.jclepro.2017.12.010.

Lieder, M., Rashid, A., 2016. Towards circular economy implementation: a comprehensive review in context of manufacturing industry. *Journal of Cleaner Productio,* 115, 36e51. https://doi.org/10.1016/j.jclepro.2015.12.042.

Longhurst, R. (2016). Semi-structured interviews and focus groups. In N. Clifford, M. Cope, T. Gillespie and S. French (Eds.), Key Methods in Geography (pp. 143-156). Thousand Oaks, California: SAGE Publications.

Loorbach, D., & van Raak, R. (2006). Strategic niche management and transition management: different but complementary approaches. Retrieved from http://hdl.handle.net/1765/37247.

Luciano, A., Cutaia, L., Cioffi, F., & Sinibaldi, C. (2020). Demolition and construction recycling unified management: The DECORUM platform for improvement of resource efficiency in the construction sector. *Environmental Science and Pollution Research*, 1-12. https://doi-org.proxy.library.uu.nl/10.1007/s11356-020-09513-6.

Mangialardo, A., & Micelli, E. (2017). Rethinking the construction industry under the circular economy: principles and case studies. *International conference on Smart and Sustainable Planning for Cities and Regions* (pp. 333-344). https://doi-org.proxy.library.uu.nl/10.1007/978-3-319-75774-2_23.

Munaro, M. R., Tavares, S. F., & Bragança, L. (2020). Towards circular and more sustainable buildings: A systematic literature review on the circular economy in the built environment. *Journal of Cleaner Production*, 121134. https://doi.org/10.1016/j.jclepro.2020.121134.

Murray, A., Skene, K., & Haynes, K. (2017). The circular economy: an interdisciplinary exploration of the concept and application in a global context. *Journal of business ethics*, 140(3), 369-380. https://doi.org/10.1007/s10551-015-2693-2.

Napolano, L., Menna, C., Asprone, D., Prota, A., & Manfredi, G. (2015). LCA-based study on structural retrofit options for masonry buildings. *The International Journal of Life Cycle Assessment*, *20*(1), 23-35. https://doi-org.proxy.library.uu.nl/10.1007/s11367-014-0807-1.

Nelissen et al. (2018). Transitieagenda Circulaire Bouweconomie. Retrieved online from: https://www.rijksoverheid.nl/documenten/rapporten/2018/01/15/bijlage-4-transitieagendabouw

Nußholz, J. L., Rasmussen, F. N., & Milios, L. (2019). Circular building materials: Carbon saving potential and the role of business model innovation and public policy. *Resources, Conservation and Recycling*, *141*, 308-316. https://doi-org.proxy.library.uu.nl/10.1016/j.resconrec.2018.10.036.

Núñez-Cacho, P., Górecki, J., Molina, V., & Corpas-Iglesias, F. A. (2018). New measures of circular economy thinking in construction companies. *Journal of EU Research in Business*, *2018*, 1-16. https://doi.org/10.5171/2018.909360.

Ollár, A., Femenías, P., Rahe, U., & Granath, K. (2020). Foresights from the Swedish kitchen: Four circular value opportunities for the built environment. *Sustainability*, *12*(16), 6394. https://doi.org/10.3390/su12166394.

Park, J., Sarkis, J., & Wu, Z. (2010). Creating integrated business and environmental value within the context of China's circular economy and ecological modernization. *Journal of Cleaner Production*, *18*(15), 1494-1501. https://doi.org/10.1016/j.jclepro.2010.06.001.

Pawlyn, M. (2019). *Biomimicry in architecture*. Routledge.

Pili, S. (2017). Experimentation of a Smart-Planning Approach for the Sustainable Renewal of the Building Heritage of Smaller Sardinian Historic Centers. *International conference on Smart and Sustainable Planning for Cities and Regions* (pp. 65-77). https://doi-org.proxy.library.uu.nl/10.1007/978-3-319-75774-2_5.

Pomponi, F., & Moncaster, A. (2017). Circular economy for the built environment: A research framework. Journal of cleaner production, 143, 710-718. https://doi.org/10.1016/j.jclepro.2016.12.055.

Potting, J., Hekkert, M., Worrell, E., & Hanemaaijer, A. (2017). Circular Economy: Measuring Innovation in the Product Chain. Available at. http://www.pbl.nl/sites/default/files/cms/publicaties/pbl-2016-circular-economy-measuring-innovation-in-product-chains-2544.pdf.

Raitu, C., Anderson, B. B., & Sfakianaki, E. (2015). Resource-efficient construction: Rethinking construction towards sustainability. *World Journal of Science, Technology and Sustainable Development*. https://doi-org.proxy.library.uu.nl/10.1108/WJSTSD-03-2015-0016.

Reh, L. (2013). Process engineering in circular economy. *Particuology*, 11(2), 119-133. https://doi.org/10.1016/j.partic.2012.11.001.

Reike, D., Vermeulen, W. J., & Witjes, S. (2018). The circular economy: new or refurbished as CE 3.0?—exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention options. *Resources, Conservation and Recycling*, 135, 246-264. https://doi.org/10.1016/j.resconrec.2017.08.027.

Rios, F. C., & Grau, D. (2019). Circular Economy in the Built Environment: Designing, Deconstructing, and Leasing Reusable Products. https://doi.org/10.1016/B978-0-12-803581-8.11494-8.

Rizos, V., Behrens, A., Van der Gaast, W., Hofman, E., Ioannou, A., Kafyeke, T., ... & Topi, C. (2016). Implementation of circular economy business models by small and medium-sized enterprises (SMEs): Barriers and enablers. *Sustainability*, *8*(11), 1212. https://doi.org/10.3390/su8111212.

Roberti, F., Exner, D., & Troi, A. (2017). Energy Consumption and Indoor Comfort in Historic Refurbished and Non-Refurbished Buildings in South Tyrol: An Open Database. *International conference on Smart and Sustainable Planning for Cities and Regions* (pp. 49-63).

Ruiz-Lozano, M., Navarro-Galera, A., Tirado-Valencia, P., & De Los Ríos-Berjillos, A. (2019). Can the cultural environment affect governmental transparency on sustainability? Useful measures for policy makers and practitioners. Local Government Studies, 45(4), 481-503. https://doi.org/10.1080/03003930.2018.1560271.

Shu, L. H., & Flowers, W. C. (1999). Application of a design-for-remanufacture framework to the selection of product life-cycle fastening and joining methods. *Robotics and Computer-Integrated Manufacturing*, *15*(3), 179-190.

Sieffert, Y., Huygen, J. M., & Daudon, D. (2014). Sustainable construction with repurposed materials in the context of a civil engineering–architecture collaboration. *Journal of Cleaner Production*, *67*, 125-138.

Springett, D. (2003). Business conceptions of sustainable development: A perspective from critical theory. *Business Strategy and the Environment*, *12*(2), 71-86. https://doi.org/10.1002/bse.353

Srivastava, S. K. (2008). Network design for reverse logistics. *Omega*, *36*(4), 535-548. https://doi.org/10.1016/j.omega.2006.11.012.

Stahel, W. R. (2016). The circular economy. *Nature*, *531*(7595), 435-438. https://doi.org/10.1038/531435a.

Stephan, A., & Athanassiadis, A. (2018). Towards a more circular construction sector: Estimating and spatialising current and future non-structural material replacement flows to maintain urban building stocks. *Resources, Conservation and Recycling*, *129*, 248-262. https://doi.org/10.1016/j.resconrec.2017.09.022.

Tazi, N., Idir, R., & Fraj, A. B. (2021). Towards achieving circularity in residential building materials: Potential stock, locks and opportunities. *Journal of Cleaner Production*, *281*, 124489. https://doi-org.proxy.library.uu.nl/10.1016/j.jclepro.2020.124489.

Walker, S., Coleman, N., Hodgson, P., Collins, N., & Brimacombe, L. (2018). Evaluating the environmental dimension of material efficiency strategies relating to the circular economy. *Sustainability*, *10*(3), 666. https://doi.org/10.3390/su10030666.

World Bank. (n.d.). *Urban population (% of total population).* Retrieved from https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS.

Yang, Q. Z., Zhou, J., & Xu, K. (2014). A 3R Implementation Framework to Enable Circular Consumption in Community. *International Journal of Environmental Science and Development*, 5(2), 217. https://doi.org/10.7763/IJESD.2014.V5.481.

Zanni, S., Simion, I. M., Gavrilescu, M., & Bonoli, A. (2018). Life cycle assessment applied to circular designed construction materials. *Procedia CIRP*, *69*, 154-159. https://doi-org.proxy.library.uu.nl/10.1016/j.procir.2017.11.040.

Zhijun, F., & Nailing, Y. (2007). Putting a circular economy into practice in China. *Sustainability Science*, *2*(1), 95-101. https://doi.org/10.1007/s11625-006-0018-1.

Zhu, Q., Geng, Y., & Lai, K. H. (2010a). Circular economy practices among Chinese manufacturers varying in environmental-oriented supply chain cooperation and the performance implications. *Journal of Environmental Management*, 91(6), 1324-1331. https://doi.org/10.1016/j.jenvman.2010.02.013.

Zhu, L., Zhou, J., Cui, Z., & Liu, L. (2010b). A method for controlling enterprises access to an eco-industrial park. *Science of the Total Environment*, 408(20), 4817-4825. https://doi.org/10.1016/j.scitotenv.2010.06.035.

van Buren, N., Demmers, M., Van der Heijden, R., & Witlox, F. (2016). Towards a circular economy: The role of Dutch logistics industries and governments. *Sustainability*, *8*(7), 647. https://doi.org/10.3390/su8070647.

van der Sande, L. (2019). In search of the barriers and drivers for the implementation of a Circular Economy in Dutch infrastructure projects.

Van Gils, A. (2005). Management and governance in Dutch SMEs. European Management Journal, 23(5), 583-589. https://doi.org/10.1016/j.emj.2005.09.013

van Leeuwen, S. Kuindersma, P. Egter van Wissekerke, N. Bastein, T. Vos, S. de Donkervoort, R. Keijzer, E. Verstraeten, J. (2018). Circulair bouwen in perspectief. TNO. Retrieved from https://repository.tno.nl//islandora/object/uuid:de7cb3d0-646c-4c5e-8f03-b1bbe240bcb0

Appendix I: Questionnaire

1. Could you briefly describe how your company/the company you work at, focusses on circularity in the construction sector?

2. Which circular initiatives has your company implemented?

3. From your point of view, what is the current state of CE in the construction sector in the Netherlands, specifically looking at the Residential and Utility building sector?

4. Why do you think this is the case?

5. What are the barriers to the implementation of initiatives?

6. Which changes can help to reduce [barrier]?

7. How could overcoming these barriers cause an acceleration in the implementation of circular initiatives?

8. What could be the drivers for CE in the construction sector of the Netherlands?

9. What are the most important barriers and drivers according to you from the list you have just mentioned?

Utrecht University

Appendix II: Informed Consent Form

INFORMED CONSENT FORM for participation in:

The Drivers and Barriers for a Circular Economy in the Built Environment of the Netherlands

To be completed by the participant:

I confirm that:

- I am satisfied with the received information about the research.
- I have been given opportunity to ask questions about the research and that any questions that have been risen have been answered satisfactorily.
- I had the opportunity to think carefully about participating in the study.
- I will give an honest answer to the questions asked.

I agree that:

- the data to be collected will be obtained and stored for scientific purposes.
- the collected, completely anonymous, research data can be shared and re-used by scientists to answer other research questions.
- video and/or audio recordings may also be used for scientific purposes.

I understand that:

- I have the right to withdraw my consent to use the data.
- I have the right to see the research report afterwards.

Name of participant: _________________________________

Signature: ___________________________________ Date, place: ___ / ___ / ____, ___________

To be completed by the investigator:

I declare that I have explained the abovementioned Participant what participation means and the reasons for data collection. I guarantee the privacy of the data.

Name: __________________________

Date: ___ / ___ / _____(dd/mm/yyyy)

Signature: