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The implementation of circular concrete in the Dutch construction industry

An explorative single-case study on the role of legislation in the implementation of circular concrete in the Dutch construction industry and the contribution to a circular economy

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PREFACE

The Master Thesis in front of you marks the completion of the Master's Business administration with the specialization in Strategic Management. This Master's degree also completes the double study programme Law & Management which started in September 2014. Last year I successfully completed the Law programme, after which this Master Thesis puts an end to my time as a student. The background of legal knowledge inspired me to write this Master Thesis from a legal perspective. Although I had no prior knowledge of the concrete industry, I enjoyed the opportunity to get a better picture of this specific industry and I learned a lot from it.

Although there were major plans to conduct a multi-country case study in order to compare a number of European construction industries, unfortunately I had to adjust these plans. In the spring of 2020, the world was faced with an unknown virus (CO-VID19) that turned the world upside down as the pandemic and strict quarantine lockdowns have limited this research. Nevertheless, I have been able to study the Dutch construction industry, of which the result lies in front of you. Even though the circumstances were not ideal, I am still proud that I succeeded. In the process of writing this Master Thesis I have been assisted by a number of people whom I would like to thank here.

First and foremost, I would like to thank Prof. dr. Jonker for his supervision of my Master Thesis. From the beginning you have enthused me about this subject and from that moment on I have experienced our cooperation as very pleasant. I have experienced the writing process as very instructive and conducive through your support and guidance, for which I would like to thank you. I would also like to thank the second supervisor in this writing process, drs. Koornneef. Thanks to your feedback, I have gained new insights, which has pushed this Master Thesis in an even better direction.

Second, I want to thank all the interviewees that made it possible to write this Master Thesis at all. Thanks to your participation in the interviews, I was able to receive the ins and outs of the Dutch construction industry after which the data could be analysed. Without your effort and shared knowledge, I would not have been able to complete this research.

Last but certainly not least, I would like to thank my family and friends for always being supportive in my time as a student. Because of your support and friendships, I have always felt at home in Sittard and Nijmegen. Thanks to you I was able to enjoy my student time the most.

Dion Wessels

Nijmegen, June 2020.

ABSTRACT

The world has been under the spell of sustainability for some time now. The social trend to do things better, more responsibly and more sustainably has also touched the Dutch construction industry. In this industry, linear concrete is the standard product that has been used for years. The climate objectives got people to start thinking about making the production process of concrete more sustainable: circular concrete. However, a major barrier to this transition lies in the fact that the legislation is outdated and is changing at a very slow pace. When circular concrete is to become the new standard in the construction industry, it will be necessary to investigate how the legislative obstacle can be overcome. Therefore, this research is conducted to answer the following research question: *How does legislation affect the implementation of circular concrete in the construction industry, contributing the transition to a circular economy?* An explorative single-case study is executed by means of semi-structured expert interviews and the data provided some enlightening findings. The construction industry has been analysed at the niche, regime and landscape level and has shown that the industry is a mixture of established and innovative companies interacting in a large network chain. Frontrunners are opposed by dominant companies that depend on rusted legislation and regulations focused on linear concrete, but the transition to sustainable concrete can be facilitated by landscape influences and technological innovations. Moreover, it has become clear that legislation is certainly not the only factor in speeding up the transition. It all starts with the mindset and awareness of the companies in the network chain, and the market actors must take over and implement the stimulating actions of the government. There are several knobs to turn if the innovation of circular concrete is to contribute to a transition towards a circular economy. This research contributes, among other things, to the theory of Multi-Level Perspective and the X-curve of Loorbach that a transition should not only be built up, but also should be scaled down. In practice, a collective sense of cooperation must be created, and the research provides handles under which circumstances circular concrete can become the new standard. It is recommended to scale up this research and to carry out a European comparison between construction industries through a multiple-country case study.

Key words: circular concrete, circular economy, legislation, Transition Management, Multi-Level Perspective, X-curve Loorbach

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‘’We cannot solve our problems with the same thinking
we used when we created them.’’

Albert Einstein, Physicist

1. Introduction

Worldwide, the use of material resources has been increased extremely due to an increased world population and its income (Adams, Osmani, Thorpe, & Thornback, 2017; Behrens, Giljum, Kovanda, & Niza, 2007). The cause of this phenomenon stems from the use of intensive linear activities that are depleting the earth's resources (Prieto-Sandoval, Jaca, & Ormazabal, 2018). Due to proliferating clues of the depletion of material resources, the call for a new economic model is receiving more and more attention (Ellen Macarthur Foundation, 2013). Additionally, the current economic model is showing extreme inefficiencies due to the use of primary production factors, labour and nature, resulting in the urgency to develop a new economic model (Heck, 2006). The search for a substantial improvement in resource performance across the economy initiated businesses to explore other mechanisms to reuse products or their elements and restore more of their material, energy and labour inputs (Ellen Macarthur Foundation, 2013). The reduction of using primary materials, the protection of material resources and the reduction of the carbon footprint has led to the concept of a 'circular economy' system (Adams et al., 2017; Ellen MacArthur Foundation & McKinsey & Company, 2014).

For many years we have worked in a linear economy where the whole system relies on supply and demand. Since the awareness is growing about the soon to be reached limits of the linear economy, there is simultaneously a growing need for a new system development that can provide standard goods and services for even more people (Bonciu, 2014). These sustainable developments are becoming increasingly important in the fight against pollution of the environment and waste minimisation (Prieto-Sandoval et al., 2018). Some features of this new system should preferably decrease the amount of waste and the usage of raw materials (Bonciu, 2014). A solution often referred to embody this new sustainability system is called the circular economy (Sikdar, 2019). Hereafter the circular economy shall be denoted by CE.

The interest in developing a CE did not go unnoticed by the European Union, when the institution first published the action plan for a CE (European Commission, 2015). In this report the European Commission explained the concept of a CE and the long-term contribution to the continent has been promoted: 'the transition to a more circular economy, where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised, is an essential contribution to the EU's efforts to develop a sustainable, low carbon, resource efficient and competitive economy. Such transition is the opportunity to transform our economy and generate new and sustainable competitive advantages for Europe' (European

Commission, 2015, p. 2). The European Environment Agency elaborated on this agenda item and its report mentioned that our current production and consumption systems are calling for fundamental changes focusing on reuse, repair, recycling, eco-design and the use of renewables (European Environment Agency, 2016). The action plan published by the European Commission emphasizes a long-term involvement at multiple levels to realize the CE (European Commission, 2015). That means that it relates to all the Member States, regions, cities, companies, and civilians. Against this background, the Dutch government also participated in the goals for a more sustainable CE, as the Dutch cabinet has launched the program 'The Netherlands circular in 2050' (Rijksoverheid, 2016). The Dutch cabinet is ambitious to realise a 50 percent decrease of raw materials (minerals, fossils, metals) by 2030 and in collaboration with social partners they have set objectives to solely use raw materials efficiently when they will be recycled afterwards without damaging emission into the environment by 2050 (Rijksoverheid, 2016). In this way, the Dutch government wants to outline a perspective for a future-proof, sustainable economy that will also facilitate future generations.

One of the most influential sectors contributing to the waste in the world is the construction industry (Gulghane & Khandve, 2015). Adams et al. (2017) have researched that the construction industry, being a very important economic industry using construction materials intensively, is generating the large amount of 821 Mt waste across Europe in 2012, being one-third of the total waste generated (Eurostat, 2019). As shown in Figure 1, the construction industry is responsible for 36.4% of the total generation of waste in 2016 (Eurostat, 2019).

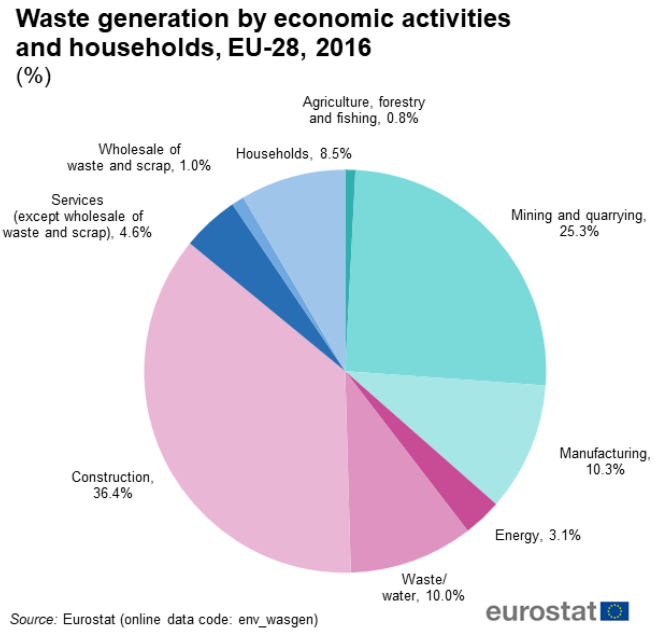

Figure 1: Construction industry waste (Eurostat, 2019)

According to the diagram presented above, construction waste is a serious problem causing the construction industry to have a large part in the contribution and existence of environmental problems (Gulghane & Khandve, 2015). All the waste materials that find their origin in construction and demolition activities and operations are known as Construction and Demolition Waste (CDW) (Pellegrino & Faleschini, 2016). CDW consists of numerous materials, including among others concrete, bricks, wood, glass, plastic, and the waste that arises from operations such as the construction or demolition of buildings, roads and infrastructure and maintenance (European Commission, 2019). Although CDW has been identified as a priority waste stream by the EU, the process of recycling and reusing CDW has a high potential to contribute to sustainable efficiency, since many components of the waste materials contain a high resource value (Adams et al., 2017; Pellegrino & Faleschini, 2016).

To dive deeper into the waste that the construction industry is generating and to tackle the problem of the depletion of natural resources and raw materials, it is wise to decompose CDW. Concrete is the most used material in buildings and recycling it decreases the depletion of natural resources and the dumping of waste (European Commission, 2014a). Research found that concrete accounts for 50-70% of the weight of the total CDW (Jin & Chen, 2019; Shayan & Xu, 2003; Tam, 2008). In many cases, concrete can be recycled after it has been demolished or it can be recycled at construction sites close to urban zones where it will be reused, which will result in a transport reduction saving costs and damaging emission (European Commission, 2014a). Since concrete waste embodies the majority of solid waste from construction, recycling concrete waste is the best starting point and opportunity to diminish the amount of CDW (Tam, 2008).

1.1 Circular concrete

Nowadays, with a current consumption of 1 m^3 per person annually, concrete is the most widely used material across the world (Gartner, 2004; Turner & Collins, 2013). When concrete is being produced, a lot of CO_2 gasses are emitted (Ding, Xiao, & Tam, 2016; Lieder, Asif, Rashid, Mihelič, & Kotnik, 2017; Turner & Collins, 2013). Consequently, due to the high interest in concrete production, the construction industry is accountable for approximately 7 percent of the worldwide CO_2 emission (Ding et al., 2016; Peris Mora, 2007). The industry of cement, being the key ingredient of concrete, is responsible for almost 5 percent of the current man-made CO_2 emission over the world (Hasanbeigi, Price, & Lin, 2014). Gartner (2004) states that the cement being used to produce concrete can be associated with less CO_2 emission if the processes are not directly involved with the use of fossil fuels or even solar-furnaces. There is general belief that the use of raw materials and energy should be reduced and the landfilling of CDW should be avoided and thus the

concept of recycling is suggested with the potential to resolve these proceedings (Ding et al., 2016). Against this background, these proceedings drive the research of recycling and reusing waste streams, resulting in innovative mechanisms to crush concrete waste into Recycled Concrete Aggregate (RCA) being widely used in the construction industry (Chen, Jin, Xu, et al., 2019; Ding et al., 2016; Xiao, Li, Fan, & Huang, 2012).

RCA can be obtained after the construction rubble, which is obtained from demolished structures, has been crushed and screened (Çakir, 2014). According to Lu et al. (2019), the innovative product of RCA can be used in various products: cement mortar (Li, Zhan, Lu, & Poon, 2019), pre-cast concrete blocks (Poon, Kou, Wan, & Etxeberria, 2009), road sub-base (Poon & Chan, 2006), asphalt (Paranavithana & Mohajerani, 2006) and minor concrete structures (Xiao et al., 2012). From an economical perspective, RCA serves as a valuable material for which a reuse market is already available and it is mainly attractive in densely populated areas (Pellegrino & Faleschini, 2016). Since the concept of circular concrete can be described by multiple terms, it is wise to make a distinction between various denotations. 'Old concrete' refers to waste concrete used to produce recycled aggregate (RA), 'recycled aggregate' is the aggregate produced by crushing old concrete and 'recycled concrete' stands for the new concrete prepared with the recycled aggregate (Katz, 2003). In this thesis, the concrete to be researched is the recycled concrete and shall be denoted by circular concrete (hereafter: CC). The mechanism of concrete waste recycling contributes to the sustainable development, since it supports the reduction of the negative environmental impacts of construction operations and activities (Jin & Chen, 2019).

1.2 Problem statement

Worldwide, the increased popularity for CC has led to a widely varied range of available applications (Jin & Chen, 2019). However, a deep understanding of the current status of CC in multiple countries or regions would support the advancement of useful, powerful and adequate strategies for improvement (Jin & Chen, 2019). Since CC contributing to a sustainable environment generated a lot of attention by the people that will benefit from a CE, logically governments and policy makers will introduce laws and regulations on the development. The CE in the Netherlands seems to be a hot topic. A lot of Dutch companies and organisations are consciously or unconsciously committed to this new economic model, as the Netherlands Environmental Assessment Agency reveals to count 85.000 'circular' activities that affect 420.000 jobs in 2019 (PBL, 2019). Although these numbers indicate an increase in the willingness for a transition towards a CE, the Dutch government simultaneously creates a number of obstacles due to their regulations, laws and restricting policies (Bastein, Roelofs, Rietveld, & Hoogendoorn, 2013).

Some of the barriers complicating the transition towards a CE stem from the governmental policies that are still focused on promoting an old economy (Rijksoverheid & Het Groene Brein, 2015). The Dutch government impedes the innovation of business models with its legal system, which depends on linear thinking (Jonker, 2012). Examples of linear thinking by the Dutch government are their financial incentives like the value added tax (VAT), stimulating the use of high materials, and the relatively high taxes on labour leaving materials relatively cheap (Allwood, Ashby, Gutowski, & Worrell, 2013; Kok, Wurpel, & Ten Wolde, 2013). Furthermore, the innovation policies are mainly focused on the incumbent companies and that impedes the development and exploration of new business innovation, indicating the lack of a circular vision integrated in laws and regulations (Kok et al., 2013). Another important barrier lies in the fact that the current tax system does not promote a CE, since it cannot succeed in rewarding companies that are willing to take the responsibility to initiate circular projects (Deloitte, KPMG, EY, & PWC, 2014; Rijksoverheid & Het Groene Brein, 2015). Additionally, on the European level there are also some barriers hindering the transition to a CE. The discussion about divergent definitions within the waste management policy and the lack of distinctness in the applications of waste management obstruct the change towards a more sustainable economic model (Rijksoverheid & Het Groene Brein, 2015; European Commission, 2014b). To put it briefly, at multiple levels there are obstacles hindering the transition towards a CE.

However, the transition towards a CE is not the only desired change that is impeded. The implementation of CC in the Dutch construction industry is also hampered by a number of other factors. To identify the bottlenecks in the production of CC, it is necessary to first discuss how the legislation in the Dutch construction industry is regulated. The legislation on CC can take multiple forms. In the Netherlands, the most important laws are regulated in the Building Decree 2012 (in Dutch: Bouwbesluit 2012) which contains regulations on safety, health (such as ventilation and daylight access), usability and energy efficiency of a building to be built (Sheridan, Visscher, & Meijer, 2003). Additionally, the Concrete Agreement is signed by multiple actors active in the construction industry in 2018. This agreement has been signed since the construction industry is capable of and willing to become more sustainable by working together more within the chain and with clients. In the Concrete Agreement, the target for the transition towards CC has been set by industry actors set on achieving 100% closed-loop recycling of all materials in the available concrete residues. There is no lack of objectives, but it turns out that it is not that easy to switch from linear concrete to CC.

Developments in the construction industry to carry out activities in a sustainable way are complicated by a few bottlenecks. For example, the process of 'circular building' is not yet based on a steady distribution of demand and supply, and current financiers are hesitant on the required innovations in the construction industry (Circulaire Bouweconomie, 2019). But the obstacle that impedes 'circular building' the most, is the requirement of new advanced policies and the adjustments of current legislation in order to remove barriers and stimulate the CE (Circulaire Bouweconomie, 2019). More and more companies assume that the use of CC can become the new standard in the construction industry, however the current legislation is restricting the possible applications of CC. For example, the concrete to be recycled has to meet certain quality requirements and quality guarantees (Frenay, Van der Poel, Van der Palen, & Broere, 2015). Building companies have to stick to the regulative guidelines, which obstruct the working space of these companies. Therefore, this paper contains research on the role of legislation in the implementation of CC and to what extent this role can improve the transition towards a CE.

1.3 Research objective and research question

The object of research in this thesis is the role of legislation stimulating the use of CC in the Dutch construction industry. Although a lot of information is available about the requirements for a transition towards a CE, there seems to be a lack of consensus on the use of CC. Chen et al. (2019) have discovered the gap in the discussion on applying CC: there is a need for standards, guidelines and legislation to specify the applications of CC in the construction industry considering its quality and property. Recycled concrete can act as the vehicle bridging the gap between CDW and applications of the waste during its life cycle, supporting the CE (Chen et al., 2019). Up to now, the progress of CC differs in various regions due to a lack of technology, insufficient legislations and the lack of coordinating waste transport (Lockrey, Nguyen, Crossin, & Cleaner, 2016). Therefore, the research objective is to gather knowledge about the current legislation of CC in the construction industry. Hence, the primary contribution of this thesis is gaining insight into the legislation and policy on the implementation of CC and the support of this innovation regarding the transition towards a CE.

Ultimately, it is interesting for the market players in the construction industry to strategically manage this legislative framework in their daily operations. As described earlier, useful and powerful strategies can benefit from regions and countries gaining more knowledge on the current status of CC. Organisations and businesses within the construction industry can adapt their activities to the current policy and possibly create a competitive advantage by taking the lead in the

transition towards the implementation of CC. Therefore, the research question to be answered in this thesis is:

How does legislation affect the implementation of circular concrete in the construction industry, contributing the transition to a circular economy?

This research question can be explained in twofold. First, it is necessary to map the legislation that has an influence on the implementation of CC. In the methodology chapter, the process for investigating the role of legislation on the use of CC in the Dutch construction industry will be elaborated upon. Second, the effect of the CC applications on the transition towards a CE will be discussed. It is an obvious and necessary choice for the construction industry to switch into a CE as this industry is responsible for more than one third of the total waste generated worldwide.

By answering the research question, a possible paradox can be explained. Since there seems to be a general agreement on the need to promote the wider use of CC, it should also be acknowledged that this product must meet the requirements for concrete applications set in relevant specifications for its particular use (Limbachiya, Koulouris, Roberts, & Fried, 2004). This can be seen as an apparently contradictory situation as it seems to go against our sense of logic or our intuition to pursue sustainability. However, the legislative policy can create a barrier for those companies and businesses following sustainable principles. According to Jonker and Faber (2015), in a changing economy it is probable that current institutions, legislative frameworks and fiscal measures provoke friction and will conflict with the upcoming new economy. Applied to the CC case, this innovation can put pressure on the established order and even more, the renewable technology can become the new ‘norm’ causing a transition (De Haan & Rotmans, 2011). If legislation policy may create an area of tension in the construction industry, the established order and emerging companies will have to adapt their strategic plans accordingly. This thesis will point out how legislation can affect the Dutch construction industry and whether an optimal environment can be created for implementing the innovative product of CC to a wider range in the construction chain.

1.4 Scientific relevance

Businesses experience growing legislative and peer pressure, from government and competitors, to fabricate and exploit more sustainable aggregates by decreasing the consumption of primary aggregates and by shifting to recycled or secondary aggregates (Pacheco-Torgal, Tam, Labrincha, Ding, & De Brito, 2013). This research intends to gain knowledge about the legislation on CC, which consequently forces businesses to think about implementing the innovative product. As described earlier, there is a knowledge gap within the construction industry about the standards,

guidelines, and legislation surrounding the implementation of CC. This research contributes to this knowledge gap by mapping how legislation affects the construction industry. Governments can also benefit from gaining a clear overview of the current legislative standards surrounding CC. A comprehensive study on the Dutch construction industry can provide insight into which legal policy fulfils a promoting effect on implementing CC. Additionally, the knowledge and further application of CC can be supportive to the CE. The Ellen MacArthur Foundation (2013) has drafted five basic principles underlying the CE, among which 'designing out' waste as an essential goal for the CE. A cause-effect relationship is assumed that the transition to CC in the construction industry leads to a reduction of CDW. The results of this research contribute to the discussion of various ways to support the CE.

Furthermore, the research on the transition to CC and CE will be conducted with the aim of imparting theoretical insights to science. Just as the research is carried out on two paths, two theories are generally linked to it. The transition to CC in the construction industry is put against the theoretical background of Transition Management and more specific the Multi-Level Perspective (Kemp, Loorbach, & Rotmans, 2007; Loorbach & Rotmans, 2006; Schot & Geels, 2008) and the X-curve of Loorbach will shine its light on the transition towards a CE (Bode, Buchel, Diercks, et al., 2019). The fact that this research is about a certain governance approach or policy model to realize a long-term sustainable development means it lends itself for Transition Management (Rotmans, Kemp, Asselt, & Geels, 2000). With regard to the X-curve of Loorbach, the theory offers a modern view of transitions showing that a transition not only needs to be built up, but it also needs to be scaled down. This research can contribute to these theoretical perspectives gaining insights in recent innovations in the construction industry.

1.5 Practical relevance

In general, the fast-growing economy and energy consumption are initiating serious environmental problems on both local and global levels (Peters, Weber, Guan, & Hubacek, 2007). A successful enforcement of a CE can tackle these environmental issues and source scarcity (Su, Heshmati, Geng, & Yu, 2013). Additionally, a CE can lead to global material savings of more than 70 percent compared to the current raw material extraction from common business models (Rijksoverheid & Het Groene Brein, 2015; Ellen Macarthur Foundation, 2013). Applied to the Netherlands, a CE can provide a total market value of opportunities worth €7.3 billion annually, which equals 54.000 jobs (Bastein et al., 2013). To achieve these goals, it is necessary to take collective steps into the right direction with changes in human behaviour by means of laws and regulations.

This thesis will provide a clear overview of requirements on legislation for implementing CC, being one of the most used materials worldwide, in the transition towards a CE. On top of that, the construction industry will benefit from these research results since it can point out the optimal application of CC in the industry. Within the buildings and public infrastructure, the efficient use of resources like concrete and the stricter landfill requirements will have positive effects on the CE: sustainable building practices, design requirements for deconstruction and higher resource efficiency for infrastructure (European Commission, 2014c). On the whole, the practical benefits from this research are not only noticeable on environmental and economical levels, but they could also contribute technical information to the construction industry on an under-utilised marketable product (Limbachiya et al., 2004). Furthermore, when the research results reflect the Dutch legislation regarding CC, companies in the construction industry can anticipate and strategically manage their activities in order to ultimately gain a competitive advantage.

1.6 Research outline

To conduct this research, various chapters will support the answer to the research question. The layout will be as follows. Chapter 2 provides the theoretical framework, based on Transition Management and the X-curve. More specifically, the theory of Multi-Level Perspective will be discussed. The framework of this theory will explain the lens through which the research is conducted and what levels can be determined in the construction industry. The methodology of this research shall be elaborated upon in chapter 3. Subsequently, a research analysis based on the theoretical frameworks will be conducted in the following chapter 4, after which the results of the research are presented in chapter 5. Ultimately, a conclusion shall be given in chapter 6. This final chapter will consist of an answer to the research question, contributions and limitations attached to the research and suggestions for further research.

1.7 Chapter conclusion

This thesis contains explorative research gaining insight into the Dutch legislation on the implementation of CC and the support of this innovation towards a CE. The innovation to use CC in buildings and houses instead of the polluting ‘grey concrete’ is a promising development that can lead to a sustainable transition. However, this development is restricted and hindered by the current obsolete legislation in the Netherlands. This is caused by a lack of consensus on the niche innovation of CC and the technological development of CC is being halted by inadequate legislation. This thesis provides a comprehensive overview of the role of legislation on the implementation of CC in the Dutch construction industry after which its impact on the transition towards a CE will be explained. In order to accomplish this objective, the transition theory of

Transition Management will first be discussed, in particular Multi-Level Perspective, expressing under what circumstances the innovation of CC can best be developed. This research also studies the effect of implementing CC during a transition towards a CE by means of the X-curve of Loorbach. These theoretical frameworks will be discussed in the following chapter.

2. Theoretical framework

The purpose of this chapter is to provide the theoretical lens through which the research will be conducted. The theoretical background relies on transition theories, more specifically Transition Management (Rotmans & Loorbach, 2008, 2009). Above all, the background of this thesis is the expectation that the construction industry will undergo a transition and subsequently CC will become the default material in the construction industry. The implementation of CC is an innovative development that requires help from multiple actors and levels to be realised in society. In the end, the aim for a technical innovation such as CC is to be support a sustainable development and to facilitate the transition towards a CE. Therefore, the concept of Transition Management (hereafter: TM) will be explained first in this chapter. Subsequently, the concepts of the Multi-Level Perspective (hereafter: MLP) will be discussed as the transition depends on multiple actors acting and operating on different levels. There will also be an elaboration on the institutional theory which is strongly related to the meso-level in the MLP. Finally, the X-curve of Loorbach will be discussed to form a clear overview on the theoretical framework of this thesis.

2.1 Transition Management

The development of CC is in its infancy and can potentially lead to a switch from the most used material in the construction industry. To demarcate this development, this research will be based on a few principles. The theoretical principles in the case of CC are derived from the belief that the use and implementation of CC is part of a bigger transition. In this context, transition theories have been used to explore systemic switches within large technical systems whose overall goal is the supply of energy (Geels & Raven, 2006), transport (Geels, 2012) and other societal utilities (Van Der Brugge, Rotmans, & Loorbach, 2005). One of these transition theories is TM, a fairly new theory, that is specifically useful in providing a theoretical foundation for the management of sustainable developments transitions (Rotmans & Loorbach, 2008, 2009). The concept of TM has been introduced in 2000 being a policy or governance approach which turned into a policy model to manage long-term desired change and sustainable development (Rotmans et al., 2000). The goal of TM is to deal with the complexity of steering activities by different actors, mechanisms and instruments and encouraging socio-technical activities in a common and desired direction (Kemp et al., 2007). This can be done by analysing the evolution of a transition on different levels and regulating the interactions between these levels through time. When the progress of a transition is monitored, different drivers and barriers, the improvement of its process, and social learning can be experienced thanks to the cooperation and interaction between different actors involved (Rotmans & Loorbach, 2009). More specifically, the drivers and barriers are relevant for this research, as the role of legislation on the implementation of CC is subject to investigation.

According to Kemp et al. (2007), each transition is made from processes of co-evolution involving changes in needs, demands, institutions, culture and practices. Geels and Schot (2007) express that a transition can be defined by changes from one socio-technical regime to another. Kemp et al. (2007) state that sustainable development requires radical changes in functional systems, radical changes in government policies and in current systems of governance. At the time, existing policy frameworks were not appropriate for dealing with social complexity and desired long-term change and this resulted in the need for a more open, adaptive and experimenting type of governance (Kemp et al., 2007). The reason why TM is chosen as the theoretical framework for this research lies in the fact that alternative social directions are explored in an adaptive and anticipatory manner when TM is used as a base (Kemp et al., 2007; Rotmans et al., 2000). In contrast to other governance frameworks, TM is best suited for this research as it is specialized in long-term sustainable solutions with explorative and design-oriented characteristics (Rotmans & Loorbach, 2008). Eventually, the Dutch model of TM has the ability to bridge the gap between top-down planning and bottom-up incrementalism. The construction industry has to balance between the old habits from the established order and the pathbreaking inventions from the innovative companies. TM tries to utilize innovative bottom-up developments in a more strategic manner by regulating different levels of governance and supporting self-organization by means of new types of interaction, learning processes and actions for radical innovations with sustainability advantages (Kemp et al., 2007).

2.2 Multi-Level Perspective

The key concept that functions as the root of the TM perspective is the socio-technical transition. According to Rotmans et al. (2000), a transition is a structural change in a societal system that is the result of a co-evolution of economic, cultural, ecological, technological, and institutional developments at different scale levels. With socio-technical transitions used as the fundamental base, the aforementioned different scale levels act as an important concept of Multi-Level Perspective in TM (Loorbach & Rotmans, 2006). The MLP is inspired by Rip and Kemp and makes a distinction between niches, regimes and the socio-technical landscape at the following three corresponding and interacting scale levels: micro-, meso-, and macro-level (Loorbach & Rotmans, 2006; Rip & Kemp, 1998). According to Geels and Schot (2010), levels can be described as heterogeneous socio-technical configurations that contain different approaches towards coordinating and structuring local practices, which implicates that levels also differ in stability and size.

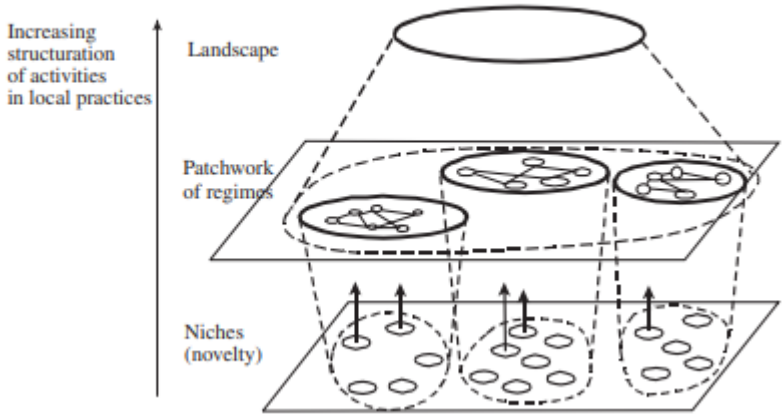

Figure 2: Multi-Level Perspective by Geels (2002)

According to Geels (2006), the macro-level is formed by the socio-technical landscape, which refers to conditions of the wider exogenous environment, which affect the socio-technical development. Examples of these developments are globalisation, environmental issues, and cultural changes. The macro-level consists of conglomerates of institutions and organisations, such as countries or organisations of states united (Rotmans et al., 2000). The socio-technical landscape is determined by slow changes in society at the macro-level (Loorbach & Rotmans, 2006). Given these points, the macro-level or landscape is the external context of a transition that enables or constrains the opportunity for the regime (meso-level) to change or transform. The macro-level can be used in the research, since the construction industry is feeling external pressure from climate issues that affects the environment of the industry.

The meso-level, also known as the regime, consists of systems of dominant organisations that perform in a stable manner such as companies, regulations, institutions, and supporting organisations (Geels & Schot, 2007). Loorbach and Rotmans (2006) state that the meso-level is filled in by social norms, interests, rules, and belief systems that manage the strategies from the companies, organisations, and institutions and that govern the policies of the political institutions. The meso-level is controlled by networks, communities and organisations (Rotmans et al., 2000). According to Geels and Schot (2007), the embodiment of the meso-level is the socio-technical regime, which is an extended version of the technological regime by Nelson and Winter (1982), that appoints shared cognitive routines in an engineering community and the development of technological trajectories. The socio-technical regimes can stabilize the existing trajectories by means of different methods: the routines blind the engineers to think outside-the-box, the regimes set the standards and regulations, and the regimes adapt to technical systems by investing in

infrastructure, machines and competencies (Geels & Schot, 2007). The theory of the meso-level or regime level can also play a role in the research on the legislative role in the implementation of CC, since the industry is familiar with stabilized routines and standards that have been governed by political policies.

As the rules have been mentioned at the regime level, it is useful to take a sidestep to explain the institutional theory being expressed by Geels (2004). He expresses that sometimes institutions can be wrongly referred to as (non-market) organisations, while institutions can best be described by standards, regulations and rules (Geels, 2004). He also claims that there is a recognized demand for a better conceptualization of the role of institutions as they support innovation and dynamic developments. Institutions can be defined as follows: 'institutions consist of cognitive, normative, and regulative structures and activities that provide stability and meaning to social behavior' (Scott, 1995, p. 33). According to Geels (2004), since the human being is not entirely free to act, attention is required for existing rules, regimes, and institutions as they determine constraining and enabling contexts for actors like individual human beings, organisations, and groups. By extension of aforementioned definition, Geels (2004) elaborates that regimes contain three types of rules: cognitive, regulative and normative rules. Cognitive rules are for example belief systems, guiding principles, objectives, innovation agendas and problem definitions. Regulative rules are for example laws, regulations, and standards. Normative rules are for example role relationships, values and norms concerned with human behaviour (Geels & Schot, 2010). These rules and regimes authorize a certain game, which is played out by individual actors, companies, public authorities, consumers, scientists, suppliers and so on (Geels, 2004). The background of this institutional theory can be useful for this research as it can explain the role of rules in the construction industry and it can possibly clarify how different actors within the industry will react to given institutions on the practical use of CC.

The micro-level, being formed by technological niches, is the place for radical innovations (Geels, 2006). The micro-level is about individual actors or technologies. At this level variations, deviations, and adjustments can emerge; for instance, a deviating method of governance or another social practice (Rotmans et al., 2000). On this micro-level, the status quo can be challenged by new ideas, alternative technologies and initiatives which are developed in so-called niches that function as a certain breeding ground for innovations (Loorbach & Rotmans, 2006; Rotmans et al., 2000). More specifically, a niche is a new structure or a small core of agents that emerges within a system and that joins a new configuration (Rotmans & Loorbach, 2009). Since the performance of radical innovations is initially low, the niches can provide protected spaces to shield them from mainstream

market pressure and selection (Geels & Schot, 2007; Kemp, Schot, & Hoogma, 1998). The micro-level is suitable for this research as construction companies in the construction industry desire space to innovate, but in doing so they are dependent on legislation from the regulatory authorities.

When a transition is being analysed, it is important to acknowledge the dynamics between the various levels of Multi-Level concepts as they can affect the development of the transition (Van Der Brugge et al., 2005). The potential innovation trajectories can be reinforced or restrained by positive or negative feedback loops and by alignments or misalignments between the macro-, meso- and micro-levels (Loorbach, Taanman, & Van der Brugge, 2008). Even more so, not only do interactions and linkages occur between the levels of institutions, regimes, and niche actors, because interactions and linkages can also exist within the separate levels. As with the between levels variant, the linkages also have an effect in twofold. Linkages within the levels can either encourage or restrain the breakthrough of niche innovations to the regime (Hofman & Elzen, 2010). This can lead to situations where regime actors are willing to work together for the opportunities of innovations or situations can occur where regime actors hold on to the status quo and even create linkages to prevent the niche innovations from taking their places within the regime. Since regime actors can have strategic considerations and apply these into real-life practices, it is wise to keep in mind that interactions happen between and within these three levels. Thus, the processes in a transition can be better interpreted when the actors and different linkages mapped via MLP. Hence, not only does this research investigate the external environment, the industry organisations, and the separate players within the construction industry, but also the interrelationships are analysed.

2.3 X-curve of Loorbach

TM is introduced in 2001 into the science-policy debate with a focus on sustainable development and complex society issues (Loorbach, Frantzeskaki, & Lijnis Huffenreuter, 2015). The TM theory proposed some generic principles stemming from decomposing complex sustainability challenges in a community as persistent issues. These principles laid the foundation for the experimental development of a variety of new instruments, strategies and actions to influence the pace and direction of sustainability transitions (Loorbach et al., 2015). Almost twenty years have passed since the introduction of TM and since the theory has gone through some changes, it is useful to take stock. In 2004, Rotmans founded the Dutch Research Institute for Sustainability Transitions (DRIFT). This is the leading research institute for sustainable transitions being directed by Derk Loorbach. DRIFT is (inter)nationally known for its unique perspective on TM, an approach in which scientific insights about transitions are translated into practical tools and steering instruments via applied action research.

In 2017, DRIFT has published a report with the state of transitions as the main subject in which patterns of building up and scaling down at five domains are presented (Loorbach, Lodder, Roorda, & Spork, 2017). The reason for this publication is that there has been an increase in change dynamics in various domains in recent years. This change dynamics is the result of a combination of social pressure (Paris Climate Agreement), internal tensions within ways of thinking and organizing and an increasing availability of feasible and competitive alternatives (Loorbach et al., 2017). One of these five domains that correlates best with this research is the CE. Therefore, this domain is chosen to take a closer look. Loorbach et al. (2017) described transitions as processes that do not only build up, but also scale down. The period of predevelopment can take decennia, but the actual transition takes up a relatively short but chaotic time. The underlying dynamics and patterns have been caught up in an X-curve that has been updated in 2019 by DRIFT (Bode et al., 2019).

Radical socio-technical innovations emerge, and the stabilized regimes turn against the system, making it increasingly vulnerable to disruptions. In the X-curve of transitions, a distinction is made between patterns of building up and patterns of scaling down that reinforce or counteract each other (Bode et al., 2019). This interaction takes place in a context of autonomous developments in demography, technology, economics, and politics that influence both patterns. The main message of the TM perspective remains that transitions cannot be managed or be forced in a pure manner, but transitions can be influenced in terms of speed and direction. There are five different phases that can be used as starting point for the societal debate on the state of the transition:

1. Phase of optimization and experimenting in which a system is functioning properly, and innovations are mainly focused on the advancement of the existing system.
2. Phase of destabilization and acceleration in which dominant systems get stuck, crises emerge, and the question arises of how long the current way of working and organising will last. Space for alternatives is provided but the resistance against change rises.
3. Phase of chaos and emergency in which dominant structures and routines partly disappear and apparently new solutions and structures reach the surface.
4. Phase of institutionalizing and scaling down in which the change is irreversible, new rules and structures emerge, and new power relationships are formed. Simultaneously, the losers of the game become visible, old structures are crumbling, and certain routines and patterns disappear.
5. Phase of stabilization and phase-out in which the former alternative developments are being detailed into the new established order. The old status quo is being phased-out, losses are taken and there is a time of acceptance.

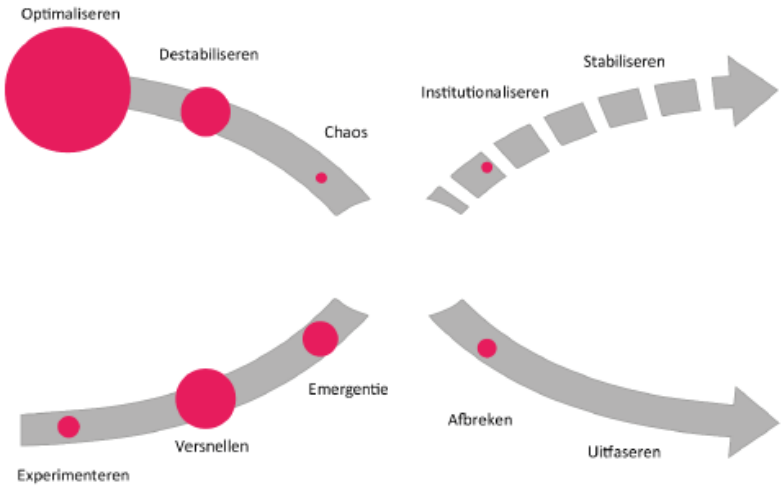

Figure 3: The state of transition towards a Circular Economy (Bode et al., 2019)

These five phases have also been tailored to the state of transition towards a CE. Although there is no such thing as 'the' CE, the linear process of make, use, and throw away, burn or release it in the air as CO_2 is reaching its limits (Bode et al., 2019). In 2015, it was a trend for many businesses, consumers and governments to be on the curve of the establishment and the emerging circular system was still small (Loorbach et al., 2017). Three years later, this trend was still applicable where the trend of experimenting has persisted throughout 1500 new initiatives featuring circular characteristics (PBL, 2019). At the policy level, a lot has been done to get the transition going by introducing transition agendas, implementation agendas and icon projects (Bode et al., 2019). The economy of servitization has gone through the phase of emergence, although the phase of institutionalizing is struggling to get a foot on the ground as the legislation is still focused on and geared towards the old linear economy. A painful message was delivered that the world became a little less circular in the period 2015-2018 as the majority of the players hold on to the phase of optimizing the linear system by means of efficiency (De Wit, Hoogzaad, Ramkumar, Friedl, & Douma, 2018). Raw materials are still cheap, and labour is expensive. Converting waste into energy has improved in the recent years, even though this is a very low-grade step in the current circular models for the repurposing of materials. The phase of chaos is not visible yet, although there are signals for chaos in the visible gap between ambitious objectives and daily practices. It is possible for companies and parties within an industry to feel the urgency in society for a certain transition but the insecurity increases whether the big investments have to take place or not (Bode et al., 2019). In the sector of waste, the Netherlands is slowly implementing the phase of scaling down existing structures which was caused by a ban on dumping abroad in 2019. The report by DRIFT also presents the fact that policy makers, scientists and other insiders recognize that the linear economy is under pressure but the transition to a CE is clearly not in the phase of acceleration.

To accelerate the transition there is a strong need for steering, focused on the establishment, the upcoming order and the linkages between these two parties (Bode et al., 2019). The establishment is attached to long-term investments and capital-intensive infrastructure that are blocking the development. The fiscal and financial legislation and policy such as taxes and fees hindering the circular business models, needs to be adapted. Simultaneously, the upcoming order has an important role to play in this area by indicating where change is needed in legislation and regulations. Promising technologies have been developed in the niches, but are not yet directly scalable or only applicable to few raw material flows (Bode et al., 2019). Overall, some aspects of the transition towards a CE reach the phase of emergency and chaos that is featured by insecurity and ambiguity. Regime parties feel the pressure to gain their profits out of linear polluting activities even though they have the capacity to develop new sustainable activities. Since steering can be difficult in this phase, it is important to emphasize that there is not just one CE, but it can be widely spread in society (Bode et al., 2019).

2.4 Chapter conclusion

In order to take into account the different backgrounds, levels and actors that affect the development and direction of the transition of CC towards a CE, the theoretical framework of this research is drawn up in threefold. These three theories are covered by Transition Management, the Multi-Level Perspective, and the X-curve by Loorbach.

First, TM explores the policy and governance approach to manage long-term desired change with a specific focus on sustainable development. The objective of this theory is to handle the complexity of a socio-technical transition by steering activities in a shared and desired direction. Different actors that play a part in the transition can be monitored and the progress, drivers, barriers, and social learning can be derived from this observation. Furthermore, the TM contains a useful tool to balance the bottom-up innovators and top-down planning for the establishment. The research on implementing CC in the construction industry can benefit from this tension field.

Second, the MLP differentiates niches, regimes, and the socio-technical landscape at respectively the micro-, meso-, and macro-level. The micro-level is the place where space and protection are provided to develop technological innovations that can challenge the regime. The regime or meso-level is controlled by networks and communities that rely on general interest, belief systems and rules. These rules are also rooted in the institutional theory by Geels (2004), which implies that cognitive, regulative, and normative rules are set within the regime level that can constrain or regulate the human behaviour. The institutional theory is important in the search for the role of legislation in the construction industry as it provides clarification as to why different actors in this

industry act on certain standards and guidelines about CC. One level above the meso-level is being filled by the macro-level or the socio-technical landscape. This level contains the external environment of a transition that enables or hinders the chances for the regime to change.

Third, the X-curve of Loorbach is pathbreaking as it involves and emphasizes the scaling down of a transition, besides the general idea that the development of a transition has to build up. Both pathways of building up and scaling down come together in the X-curve which is also applicable for the domain of a transition to a CE. The research institute DRIFT notes that the transition towards a CE is in the phase of young adulthood that is approaching the phase of chaos and emergency. To accelerate the process of the transition in the construction industry, the upcoming innovators can point out where they experience hinder from legislation and regulations which then allows the regime to adjust this legislation at its regime level. This also indicates the urgency of the inter- and intrarelationships between the different actors and levels connected to the transition towards a CE.

3. Methodology

This chapter will elucidate the methodology used in this research. Additionally, the descriptions and justifications of the research methods will be discussed. The overarching research objective and its accessory research approach, being semi-structured interviews with experts, will be elaborated upon first in this chapter. Second, the process of collecting data will be explained followed by an analysis. Finally, the last section debates the validity, the reliability, and the generalizability of the conducted research.

3.1 Research approach

The main objective of this thesis is to get a better understanding of the role of legislation influencing the implementation of CC in the construction industry supporting the transition to a CE. The primary contribution of this thesis is to gain insight into the legislation on the implementation of CC and the support of this innovation regarding the transition towards a CE. As expressed in the first chapter, there is a lack of consensus on the current development and use of CC. Hence, standards, guidelines, and (renewed) legislation are required to specify the applications of CC in the construction industry considering its quality and properties. To support these requirements, the following research question must be answered:

- *What role does legislation play in the implementation of Circular Concrete, contributing the transition to a Circular Economy?*

Similar to the fact that the research question can be addressed in twofold, the research approach follows this layout. Therefore, the impact of legislation on the implementation of CC will be investigated in the construction industry first and after that the effect of this innovation on the transition towards a CE is discussed. This order has been chosen since the movement of using 'green concrete' instead of 'grey concrete' may cause a transition in the search for a CE. The use and applications of CC is still in its infancy. As expressed by Blankendaal, Schuur and Voordijk (2014), further research in using recovered building materials is recommended, more specifically with respect to concrete. There is an urgent need to investigate some technological (quality, strength, repair) and economic (costs of life cycle) features of the concrete serving as an improved building material (Blankendaal et al., 2014). Although there are some aspects of concrete that need to be considered, in the end CC can serve the construction industry with the help of its economical, technical and environmental benefits (Liew, Sojobi, & Zhang, 2017). Before that, this research must map the new technological innovation of CC in its purest form. To do so, the choice for qualitative research is now further discussed, followed by an explanation of the explorative single-case study after which the choice for semi-structured interviews is explained.

First, this research is qualitative of nature, since this thesis is focused on the collection and interpretation of linguistic material which allows the researcher to make statements on a social phenomenon in reality (Bleijenbergh, 2015). As Bleijenbergh (2015) expresses, the empirical data in qualitative research can, among other things, be collected by the transcripts of interviews, field reports of observations and documents. In this thesis, the data will be found through conducting semi-structured expert interviews. Initially, the intention was to supplement these semi-structured expert interviews with desk research on the construction industry of other European countries, but the practical feasibility of this was blocked by quarantine lockdowns due to the CO-VID19 pandemic. The following paragraph deals with the consequential amendments that had to be made due to changing circumstances in more detail. The aim of these interviews is to gain a comprehensive view of how the construction industry works.

Second, a case study is an empirical method describing a contemporary phenomenon, based on a diverse set of data sources, in comparison with its real-world context (Eisenhardt & Graebner, 2007; Yin, 2017). Overall, a clear distinction between single-case studies and multiple-case studies can be made: the existence of a certain phenomenon can be best described by a single-case study (Eisenhardt & Graebner, 2007), whereas multiple-case studies are very useful in providing foundations for theory building (Yin, 2017). Multiple-case studies facilitate comparisons that can indicate whether some findings are applicable to only one case or if these findings consistently affect multiple cases (Eisenhardt & Graebner, 2007). Additionally, Yin (2017) mentions the further distinctive form of multiple-case studies, being the comparative case method: a technique that is about choosing a case of political interest, collecting information and data of occurrences of the case, to finally determine the common denominator of the occurrences of the phenomenon (Dion, 1998). From the start of this research, the approach has been to conduct a comparative multiple-country study, whereby the legislation and policies of four members of the European Union surrounding the implementation of CC will be compared. This cross-national comparison was chosen as the research approach for two reasons: the research is focused on what exactly the role of legislation on the implementation of CC is in these countries and the second reason is that there is not much control on the research context (Vennix, 2011). However, the changed circumstances of the CO-VID19 pandemic forced the researcher to adapt the research approach. As it has not proved feasible to compare the construction industries of Belgium, Germany and Liechtenstein, the focus has shifted to the explorative single-case study of the Dutch construction industry. The goal of this explorative research is to map the phenomenon and development of CC in the construction industry and thus lay the foundation for further research (Yin, 2017).

In this research, the case to be investigated contains the phenomenon of implementing CC in the construction industry. The intention is to study the role of legislation in this specific context, but the context may also be affected by other factors. As the legislation is discussed in detail and the boundaries between CC and the construction industry are still unclear, the case study is highly suitable for this research (Vennix, 2011). The sample has a relatively low number of respondents (n = 13), which implies that this research is mainly focused on how the phenomenon develops in the real-life context rather than making generalizable statements.

Third, the interviews to be conducted have a semi-structured character, meaning that they are semi-structured expert interviews. According to Clifford, French, and Valentine (2010), semi-structured interviews are verbal interchanges where the interviewer tries to elicit information from another person by asking questions. The semi-structured character arises from the prepared list of the interviewer leaving space and chances for the interviewees to further discuss issues they think are urgent. Although the semi-structured interviews are supposed to be open ended, they follow an overall script with a list of topics that can be realised by the use of an interview guide (Bernard, 2011). The interview guide (Appendix 1) ensures that the relevant topics will be discussed in the conversational and informal interview, whereby the guide can guarantee a certain structure. The choice for semi-structured interviews over structured interviews also depends on the fact that more information about CC can be generated when the interviewee's line of thought can be given free rein (Cooper & Schindler, 2013). The most important results of the interviews are used as quotes in the data analysis (Chapter 4). In order to validly record the interviews in audio, to quote the statements and to then incorporate them into this thesis, permission from the interviewees has been requested via a consent form (Appendix 2). The consent form was personalized for each interviewee and has been sent and returned by e-mail. To put it briefly, semi-structured expert interviews are selected for this research, since this method designs the broad strokes of the interview and it leaves space for the interviewee's interpretation.

3.2 Procedure data collection

In order to formulate a clear answer on the research question, it is necessary to contact the relevant persons and get information on the two main topics: the legislation on implementing CC and subsequently its effect on the transition to a CE. Hence, the interviewees are selected based on their knowledge about and experience with creating CC, more specifically the legislation regarding applications of CC. The leading criterium for this selection is that the interviewees must be directly or indirectly involved with the production of CC and preferably affected by the legislation from an authority. Examples of different actors involved with the implementation of CC: manufacturers of

concrete, directors of leading companies in the construction industry, scientists of concrete composition, and policy makers on the application and use of CC. The researcher attempted to conduct these interviews with people related to the CC innovation, who simultaneously know a lot about its effect on the transition towards a CE. A collection of semi-structured expert interviews with these kinds of actors provides comprehensive data through which the research question can be answered.

As stated in the previous paragraph, experts with a lot of knowledge and skills in the Dutch construction industry had to be found. In addition, it was also important to find interview experts who are in the middle of the transition towards a CE. Despite the limiting circumstances of the CO-VID19 pandemic, it was possible to conduct 13 expert interviews in the period March-May 2020. The researcher has assumed that the most detailed representation of the Dutch construction industry can be determined when several parties with different activities participate in the research. This variety is guaranteed by the fact that the following are involved in the research: from demolition companies to concrete suppliers and from building associations to experts in the Concrete Agreement. Although the number of respondents is relatively limited, the interviews have provided sufficient data to assess the development of CC and its effect on the transition to a CE. An overview of the experts interviewed is included in Appendix 3.

3.3 Procedure data analysis

Qualitative research analysis is a process in which existing or produced texts will be interpreted from an empirical research perspective by means of labelling concepts and their meanings in fragments of texts (Bleijenbergh, 2015). The process of labelling concepts within texts is called coding and its purpose is to select and unravel relevant fragments from huge quantities of text material (Bleijenbergh, 2015). Coding is the process of appointing numbers or symbols to answers from interviewees so that the responses can be grouped into a defined number of categories (Cooper & Schindler, 2013). According to Bleijenbergh (2015), qualitative research analysis consists of two ancient forms: on one side there is the inductive approach being a method whereby theoretical statements can be deduced from the empirical data, and on the other side there is the deductive approach being a method whereby the researcher is guided by theoretical expectations preceding the data collection and analysis. This research will be conducted via the inductive approach of coding since a new theory will arise from labelling concepts and their meaning instead of the event that an existing theory is tested. The process of coding will contain the steps of open coding, axial coding, and selective coding. Open coding is the process in which fragments in texts covering a certain concept will be labelled, axial coding is searching for connections between open codes and finding

overlapping themes, and selective coding is recognizing patterns in the social phenomenon by comparing themes (axial codes) among each other (Strauss & Corbin, 1998). Lastly, when the interviews have been conducted and the fragments of the transcribed texts have been coded, a translation will be made towards answering the research question.

3.4 Validity, reliability, and generalizability

Conducting the research from the perspective of a certain research procedure requires a methodological reflection to review the quality of the research. To measure the quality of a deductive research, there are three tools available: internal validity, reliability and generalizability (Bleijenbergh, 2015). These tools or tests can judge the quality of any given research design which is assumed to represent a logical set of statements (Yin, 2017).

Internal validity is the most important criterium to measure and judge the qualitative research (Bleijenbergh, 2015). According to Yin (2017), the internal validity involves the ability to measure what is desired and/or supposed to be measured. Firstly, one way to increase the internal validity is to use multiple sources of evidence, which contributes to the principle of triangulation (Yin, 2017). An application of triangulation in this research is that the data collected from the interviews are compared with secondary data, which in turn will increase the research validity (Yin, 2017). The more accurate the operationalization is conducted, the higher the chance that the measuring instruments are valid (Vennix, 2011).

Reliability is a test to measure whether the same findings and conclusions will be the result of a conducted research, if a future researcher takes the same steps and procedures described by an earlier researcher and conducts the same study once more (Yin, 2017). In other words, the research is reliable when the findings of a qualitative research are not distorted by accidental deviations (Bleijenbergh, 2015). In a reliability analysis the accuracy and consistency of a research procedure will be measured (Cooper & Schindler, 2013). According to Bernard (2011), reliability is about the recurrence of the same answer using an instrument more than once, where an instrument can be the question of an interview. In qualitative research, it is customary for researchers to replace the reliability by the verifiability of the data collection (Bleijenbergh, 2015). To ensure this verifiability of this particular single-case study, the selection of respondents, documentations, and transcripts will be reported in an understandable way in order that others can follow this research procedure.

External validity or generalizability of the results refers to the criterium that the findings must be able to be generalized to a bigger population (Bleijenbergh, 2015). According to Yin (2017), the test of external validity measures the extent to which findings from a certain case study can be

extended to wider situations that were not part of the original study. It is important to emphasize that this research is not intended to explore all possible aspects and features of CC but in particular the role of legislation on its implementation will be discussed. Furthermore, the main goal of this research is to develop ideas for further research as the research approach contains an exploratory single-case study (Yin, 2017). Therefore, a clear overview of legislation supporting or hindering the implementation of CC in the transition towards a CE would be a very desirable effect of this research given that other researchers can build on these findings.

3.5 Chapter conclusion

The goal of this chapter was to justify the research decisions for the thesis, being a qualitative research, in particular an exploratory single-case study conducted by means of semi-structured expert interviews. Since the development of CC is a certain phenomenon in the light of real-life context that is subject to legislation, the choice for a single-case study is made. This choice also depended somewhat on the limited possibilities offered by the consequences of the CO-VID19 pandemic. Because of the practical feasibility, it was decided to study the Dutch construction industry and how relevant players in this market respond to the development of CC and its effect on a CE. This topic can best be explored by means of semi-structured expert interviews, leaving space for the interviewee to elaborate on other relevant themes. Additionally, the procedure of data collection and data analysis have been elucidated in this chapter. Regarding the data collection, it is discussed that a varied pallet of experts was willing to participate in the case study. This will greatly benefit the research, as it will better represent the Dutch construction industry. Regarding the data analysis, it is discussed that the technique of coding has been applied to classify a large amount of data and to better organize the data for interpretation. Ultimately, the validity, reliability, and generalizability of the used research methods in this research are discussed.

4. Research analysis

The theoretical framework discussed in Chapter 2 is set up to analyse the complexity of activities and developments from different actors, levels, and instruments influencing a socio-technical transition towards CC. Within this field of multidimensional complexity, the role of legislation in the transition towards a CE is explored. This analysis gives an answer to the following research question: *How does legislation affect the implementation of circular concrete in the construction industry, contributing the transition to a circular economy?* Semi-structured interviews, based on the Multi-Level Perspective and the X-curve by Loorbach, were executed in order to gain an understanding of the socio-technical transition of CC and to discover the role of legislation in this transformation towards a CE. Overall, this chapter is designed to address all relevant themes recurring in the interviews by means of citations. First, the three analytical levels of the Multi-Level Perspective are analysed: the socio-technical regime, the socio-technical landscape, and the socio-technical niche. This order has been chosen since it is wise to first map the activities of the establishment at the regime level and subsequently the influences of the landscape and niche levels that integrate the transition. Second, the three factors influencing the transition towards a CE will be phrased. The transition is in fact dressed up by mindset, legislation and regulations, and market actors.

4.1 Construction Industry Regime

A crucial statement during the execution of the semi-structured expert interviews is the opinion that the construction industry consists of multiple companies in the same industry despite practicing different activities related to concrete. *'Het zijn meerdere bedrijven. (...)Het verduurzamen van beton betekent dat we kijken hoe we de CO_2 naar beneden kunnen brengen en hoe kunnen we meer circulariteit toevoegen aan beton. Ik ben een van de initiatiefnemers van [Betonvereniging]. Belangrijkste wat we doen is het binden van mensen in de hele keten. We hebben een keten-aanpak: alle betrokkenen bij de verwerking, productie en toepassing van beton aan tafel kunnen krijgen om te kijken hoe we dat project kunnen verduurzamen.'* (Interview 6). Two important elements are mentioned in the production of CC: the investigation of reducing CO_2 and the addition of circularity to concrete. The same expert reacted to the representation of the phenomenon that the construction industry can be compared to a network chain being connected by links: '*Ja, zo moet je dat zien. Opdrachtgever heeft meestal in 99/100 gevallen geen contacten met leveranciers, maar met de aannemers. Die voeren dat project uit. Die aannemer gaat naar zijn leverancier en die leverancier gaat weer naar zijn grondstoffenclub toe. Zo zit die hele keten aan elkaar verbonden. Zo moet je dat gaan stimuleren om met duurzamere producten te komen.'* (Interview 6). The way in which the chain is organised is also confirmed in another quote: *'Het is een zeer complexe sector, omdat daar*

veel verschillende typen producenten bij elkaar zitten, in de hele keten: van grondstof tot recyclers. En die zijn niet automatisch allemaal op dezelfde manier in de vernieuwing geïnteresseerd.' (Interview 3). Thus, a chain approach is praised to stimulate the market.

The construction industry consists of the following organisations: clients, contractors, suppliers, raw material processors, and demolition companies. All these companies have a different share and intention in the chain: the intention of a demolisher *'ik dacht: als ik in staat ben om daarin hoog in de waardeketen een nieuwe verbinding te maken, dus te zorgen dat dat beton wat vrijkomt bij de sloop niet vermengd wordt met andere materialen waardoor het waardeloos wordt, (...), heb ik in ieder geval een eerste stap gezet en dan maak ik ook daar iets nieuws mee. Dat is eigenlijk de reden waarom ik met beton begon'* (Interview 1), the contribution of a consultancy firm '*ik ben directeur/eigenaar van [Adviesbureau en kennisinstituut], een adviesbureau op het gebied van duurzaam bouwen en wij specialiseren ons volledig op het gebied van milieu-impact voor het maken, gebruiken en recyclen van bouwmaterialen en bouwproducten.'* (Interview 2), the activities of a production company *'ik werk bij [Betonproducent en leverancier], dat is een betonfabriek in Amsterdam-West. Omzet van 25 miljoen. Wij maken producten voor de industrie en voor de woningbouw en dat is allemaal pre gefabriceerd, dus wij zijn echt een productiebedrijf in het beton.'* (Interview 4) and the role of industry federations *'ik werk voor [Betonvereniging], een brancheorganisatie voor de cement- en betonindustrie. Eigenlijk is [Betonvereniging] een federatie waaronder weer verenigingen hangen. Dat is onder andere het [Cement- en betonvereniging], brancheorganisatie voor cementindustrie, waar ik het meeste werk voor doe.'* (Interview 8). These fragments indicate that the construction industry is filled with different companies and activities.

An expert interview with the director of an innovative demolition company made clear that the construction industry can be considered as a regime that creates barriers in the perspective of the market forces: *'In de technologie ervaar ik niet zozeer obstakels. De obstakels die ontstaan eigenlijk aan de andere kant, in de markt. Wat je ziet is dat de grote betonindustrie, wat een miljardenindustrie is, ook in Nederland. Die [gevestigde bedrijven] zitten al heel lang in die sector en die hebben zich op een bepaalde manier genesteld. En dat hebben ze heel slim gedaan, met allerlei typen afspraken. Onderling en met de markt. Ze hebben geografische ultieme spreiding aangebracht. Dus als je daar als nieuwe binnenkomer in komt en je weet niet precies hoe de hazen lopen, word je iedere dag weer verbaasd over hoe het toch kan zijn dat je steeds maar niet die opdracht krijgt.'* (Interview 1). This quote expresses a bottleneck in the market where the establishment is in control of the regime. The nestling of the routines and power from the establishment can deter the upcoming order. Following on from this, the role of Transition

Management and the effect of the Concrete Agreement have been stated by the chairwoman of the Concrete Agreement: *'Dat [Transitie Management] is een beetje de ouderwetse theorie. Koester de niches, die moeten groot en sterk worden en dan kunnen ze de regime actoren verslaan. In de praktijk werkt dat in ieder geval niet. Bij zoiets als het Betonakkoord, proberen we juist die niche actoren in een dusdanige positie te brengen, dat ze uit hun beschermde omgeving komen en juist met grotere spelers, die dan in die ontwikkeling mee moeten gaan, zorgen dat het opgepakt wordt. Want anders zijn we nu leuk iets leuks aan het experimenteren, maar dan wordt het nog niet toegepast. De grote uitdaging is juist zorgen dat dat wel gebeurt.'* (Interview 3). Although the relations within the regime thus create a bottleneck for frontrunners, the Concrete Agreement was introduced to break this obstacle. This fragment also discusses a difference between theory and practice.

The construction industry regime is in need of change and according to a policy officer the whole chain needs to adapt to this transition: *'Ja, ik denk dat je dat in heel de keten moet doen. Dus aan de andere kant zit de overheid, projectontwikkelaars, wie gebruikt er allemaal beton? En in heel die keten moet je samen die verandering tot stand brengen. Je hebt ze allemaal nodig.'* (Interview 7). The rules will have to be changed, but it will certainly not be easy to break the entrenched habits: *'ik begrijp van [respondent 5] dat de wereld van betonproducenten zo'n enorme lobby achter zich heeft. Net zoals de wapenindustrie in de Verenigde Staten. Zo sterk is die lobby ook in de cementindustrie. Dat is een dingetje om te doorbreken. Belangrijk dat daar echt de druk komt vanuit de markt. Alleen met recht kom je er niet. Met name ook omdat regels gewijzigd moeten worden, dan zie je dat er weer een sterke lobby vanuit die wereld is en dat vertraagt enorm. De markt als die eenmaal gaat vragen, die kan veel sneller handelen.'* (Interview 11). Since the lobby in the construction industry is as strong as the arms industry in the United States of America, it also remains important to strategically maneuver the companies in the market. By doing this, barriers can be dodged and competition between the industry actors shall be maintained: '*Terwijl het systeem ook moet veranderen. De markt moet veranderen. Mensen moeten op een andere manier gaan samenwerken. Dat beton moet op een andere manier uit gebouwen gehaald worden. (…) Je moet zorgen dat je niet geblokkeerd wordt en dat je kunt blijven concurreren.'* (Interview 1). These quotes indicate that the entire network chain needs to change, but the transition is being stalled due to the underlying lobby slowing down the change of legislation and regulations. It is possible that the effects of the external environment can contribute to this needed change.

4.2 Construction Industry Landscape

Being one of the levels of the Multi-Level Perspective, the macro-level or the socio-technical landscape is a collective term for external pressures such as climate change or globalization. Global concerns about CO_2 emission and climate change have increased and this has also led to sustainable objectives that affect the construction industry: *'dan [als de bouwsector zich circulair aanpast] halen we ons maatschappelijk doel dat we die CO_2 uitstoot in 30 jaar binnen de grenzen brengen, wat de planeet kan hebben. Dat is het einddoel. (...) Dat het gebruik van primaire grondstoffen ook afneemt, in elk geval halveert of zelfs meer. Dat voorkomt uitputting van natuurlijke voorraden, die echt opraken. Dat willen we ook voorkomen. 2 grote doelen. Klimaatimpact moet binnen de akkoorden van Parijs blijven en [de klimaatimpact] moeten binnen de grenzen van de planeet komen en we willen voorkomen dat we natuurlijke hulpbronnen uitputten en dat we het voor toekomstige generaties onbeschikbaar maken. Daar moeten we dus bewuster met onze grondstoffen omgaan. Die twee grote dingen moeten gebeuren in die transitie.'* (Interview 2). It can be deduced from this fragment that the climate targets and the use of raw materials, among other things, have an impact on the regime.

These sustainable objectives certainly relate to the construction industry since the main component of concrete, cement, is still responsible for a high footprint: *'Daarnaast is de footprint van beton heel slecht, 2 tot 8% van alle CO_2 ter wereld wordt veroorzaakt door beton, cement vooral dan. Nederland is dan al beter, we doen het beter dan de rest van de wereld, omdat we hier veel met reststoffen als hoogovenassen en vliegassen werken. Maar ook in Nederland wordt nog zo'n 4% van alle CO_2 uitstoot van de industrie veroorzaakt door cement en beton. Dat blijven enorme hoeveelheden CO_2, ik denk dus voor ons een belangrijke taak om te kijken hoe we dat kunnen verduurzamen.'* (Interview 6). This line of thinking is also endorsed by other interviewees, where the explanation for the amount of pollution depends on the volume of production: *'voor onze industrie is CO_2 wel een belangrijk issue. Want beton is en blijft een flinke bijdrage leveren aan de totale CO_2-emissie. (...) Wat mensen zich ook niet realiseren is dat dat komt door het enorme volume, hè. (...) Maar er wordt enorm veel met beton gebouwd. Per definitie heb je dan natuurlijk een forse CO_2-emissie.'* (Interview 8). Even though the most emission of CO_2 comes from the production of cement, the figures given in an interview point to the construction industry as a whole being a polluter: *'De cement, portlandcement heet dat, 1 ton Portland cement staat gelijk aan 1 ton CO_2 en dat staat gelijk aan 1,6 ton grondstoffen. Na het product elektriciteit van fossiele brandstof is cement het meest vervuilende product in de wereld. (...) Het is niet alleen cement, maar het is ook het maken van toeslagstoffen zoals zand en grind, het transporteren, en het plaatsen en het slopen. Alles bij elkaar (...) omvat dat al meer dan 7,1 miljard ton CO_2 van de hele betonsector.'* (Interview

5). The essence of these fragments shows that the polluting ingredient cement and the high-volume production play a significant role in the environmental impact caused by the construction industry.

At the end of 2019, a deadly virus called COVID-19 appeared in China and spread out over Europe in February/March 2020. The virus was declared a pandemic and forced quarantines turned everyone's daily lives upside down. This development was also discussed with the experts and they wanted to seize this corona-crisis as potential opportunities for sustainability: *'Ergens vind ik wel mooi aan de coronacrisis dat je wel beseft dat duurzaam beton een wereldwijd vraagstuk is en niet alleen in mijn fabriek speelt. (...) We hebben een klimaatuitdaging en die is groter dan wij in Nederland en ook groter dan Europa. Dus we moeten daar met elkaar wat mee en dat is volgens mij precies wat Corona wel met mensen doet. Je doet een collectief beroep op met elkaar verschijnen. Eén iemand in zijn eentje kan het niet. Je ziet ook wel dat de mensen die heel vervuilend zijn… iedereen vindt dat nu belachelijk en zegt ''oppakken die mensen''. Dat ontstaat wel uit de coronacrisis, een collectief gedrag. Dat doe je niet per se voor jezelf, maar wel voor kwetsbare mensen in je omgeving. Dus als je die lijn doortrekt naar duurzaamheid, kan het juist een fantastische kans zijn.'* (Interview 4). The global crisis does not only lead to a collective sense of belonging, but it also produces cleverness to adapt to the external environment: *'Dan worden mensen slim. Zie het coronavirus. Wat mensen allemaal niet aan slimmigheid verzinnen om hetzij een andere koers te varen, hetzij om nieuwe mondkapjes te maken… elke keer opnieuw gaat het erom: weet je de mensen achter het doel te krijgen, dan wordt inventiviteit aangeboord van heb ik jou daar. Dat is fantastisch.'* (Interview 13). From these quotes a side effect emerges that a pandemic can function as a driver for inventiveness. In addition, the polluting industries receive attention again.

4.3 Construction Industry Niche

Besides the regime level and landscape level, in Multi-Level Perspective the niche level, known as the place for radical innovations, plays an important role in the transition towards CC. There is a certain phenomenon going on in the construction industry that creates room for innovation: *'Het verschil tussen wat er technologisch kan en wat deze [risicomijdende] bedrijven aan het doen zijn, dat verschil wordt met de dag groter. Het gat tussen wat er kan en wat er gedaan wordt, wordt heel veel groter. Als dat groot genoeg wordt, gaan er nieuwe ondernemingen ontstaan door mensen die denken: ''dan duik ik in dat gat''. Ja, dat is eigenlijk wat hier gebeurt.'* (Interview 1). Legislation and regulations appear to play an important role in the emergence of this phenomenon, through both a causative role and a powerful role in changing it: *'Ik denk inderdaad (...) dat zodra regels in omvang teveel op die oude portlandcement is gericht, dan kunnen bedrijven die willen innoveren*

natuurlijk tegen bepaalde regels aanlopen waar ze last van hebben.' (Interview 11). Partly for this reason, the Concrete Agreement was signed in July 2018, after an earlier attempt in the form of a Green Deal by MVO Nederland failed: *'Er is een historie waarbij al eerder een Green Deal is afgesproken met de betonsector onder leiding van MVO Nederland. Dat liep niet helemaal goed, (...) dus toen heeft de hele betonsector, maar ook de opdrachtgevers, gezegd van: moeten we dit nou samen doen? Bij deze ontwikkeling was ik betrokken. Dat heeft ongeveer 1 jaar geduurd en dat heeft vervolgens geleid tot het Betonakkoord, dat is in juli 2018 toen bekrachtigd. Vanaf die tijd zijn we in uitvoering.'* (Interview 3). The Concrete Agreement was thus signed to facilitate a change.

The Concrete Agreement plays a crucial role in the development of upcoming companies implementing innovative ideas and practices. The chairwoman of the Concrete Agreement explains the underlying idea of the legislation: *'Mijn filosofie, die ik probeer toe te passen in het Betonakkoord, is dat er al een heleboel innovaties op de plank liggen en die al gewoon kunnen, waar de meeste nog niet mee aan de slag zijn, dat die nog moeten worden gepromoot (...) en die even alleen in de praktijk een keertje goed getest moet worden, daar zijn we nu goed georganiseerd mee bezig. (...) Dan heb je nog innovaties die nog verder gaan: innovatieve bedrijven die er nog een schepje op willen doen, want ze willen koploper zijn in de markt. Nou met die ga je dan nog grotere stappen zetten.* (Interview 3). The reason behind this idea is that the Concrete Agreement acts as a ceiling for the industry companies that have to go along with the circular flow: *'Niet iedereen wordt koploper en dat hoeft ook niet. Deel van de markt wordt koploper, een deel wordt early adapter, een deel wordt laggard, zoals het altijd gaat. Er blijven achter. Uiteindelijk dwingen we de achterblijvers met een eis, die moeten ook enigszins mee. Die gaan met de landelijke of minimale eis van bijvoorbeeld dat plafond van het betonakkoord mee, waar iedereen aan moet voldoen: dat is bedoeld om de laggards ook mee te krijgen. Dus echt achterblijven en niet meedoen vanwege de prijzen, dat mag dan niet meer. Dat sluiten we uit in dat systeem. En dan komt het hele peloton als een wielerwedstrijd in beweging. Koplopers vooruit, volgers erachter aan, peloton komt mee en de achterblijvers worden met een bezemwagen opgepikt. Die vallen uiteindelijk af.'* (Interview 2). In the end, this comparison of a cycling race with innovative leaders, a peloton and laggards runs like a thread through the expert interviews. The Concrete Agreement is focused on stimulating the whole construction industry to move towards a circular transition: *'[Het betonakkoord is] juist [gericht] op iedereen en we willen ook zorgen dat innovatieve bedrijven de leiding nemen in stappen die gezet moeten worden. Want zij zijn diegene die het in de praktijk toepassen. Ik ben juist bezig om te voorkomen dat we alleen maar op het peloton en achterlopers zitten. Dat is de wetgeving, daar wil ik juist meters in maken.'* (Interview 3). In the context of

interacting levels within the MLP framework, the niche level is stimulated by the Concrete Agreement to knock on the door of the regime.

An important observation in the search for CC is the fact that there is no such thing as a single product CC: *'daar wil ik over benadrukken dat er niet één soort duurzaam beton is. Het is altijd in ontwikkeling, dus als je een standaard maakt en je verheft dat tot standaard, dan ben je dus de standaard in beton aan het gieten en dan worden alle nieuwe innovaties weer geblokkeerd'* (Interview 3) and *'duurzaam beton kan voor elke toepassing weer anders zijn. Ook omdat je praat over (…) de levenscyclus analyse van een product en dat gaan van de grondstoffen tot het transport van grondstoffen tot de productie van beton tot het vervoeren van het beton, maar ook de verwerking- en afvalscenario's'* (Interview 6). Nevertheless, there are roughly three innovative practices of CC that contribute to the circularity of concrete as a whole in their own manner: the use of a SmartCrusher technology to recycle concrete, the process of geopolymer technology and the application of adaptive design.

4.3.1 SmartCrusher technology

The practice of the SmartCrusher is a promising technology to recycle concrete: *'Bijna al het beton krijgt een tweede toepassing, we gooien het niet weg want je mag het niet storten. Beton heeft een extreem lange levensduur. (…) Als het een keer weg moet, wordt het nu uitsluitend gebroken in 'betongranulaat', fijn gemalen tot korreltjes. Dat wordt voor grootste deel gebruikt als wegfunderingsmateriaal.'* (Interview 2). Other experts are also positive about the innovative development whereby the original concrete is recovered in sand, gravel and cement, but there is still work to be done: *'Met die SmartCrusher krijg je dat als een poeder fractie. Die poederfractie kan op zich wel weer in beton, maar eigenlijk moet dat nog een bewerking ondergaan, wil het echt een nuttige functie hebben in beton.'* (Interview 8).

Even though the SmartCrusher itself deserves the necessary improvements, the legislation is not yet geared to the innovative technology: '*Dat poeder kun je bijv. toepassen als vulstof in beton, maar hij [Ontwerper SmartCrusher] wil ook poeder toepassen als bindmiddel in beton. Ook daar is Europese regelgeving voor. De zogenaamde EN 197. En die nieuwe Europese regelgeving biedt op dit moment nog geen ruimte om dat soort poeders toe te passen. Maar ik weet wel dat er op Europees verband wel gewerkt wordt aan mogelijkheden om dat soort materialen geheel of gedeeltelijk als onderdeel van cement weer toe te passen. Dat is een Europees traject en die trajecten kosten echt jaren'* (Interview 9). The aforementioned standard EN 197 stipulates that only 30% of the gravel may currently be replaced by concrete granulate. The SmartCrusher shows a lot of potential in the niche level, but the legislation is still lagging behind: *'Je mag toch 30% gaan.*

Maar met die SmartCrusher verwachten we eigenlijk dat je tot 70% of zelfs 100% kunt gaan. Daar wordt op dit moment onderzoek naar gedaan en regelgeving voor ontwikkeld. Om dat dan ook te faciliteren.' (Interview 8). Even though the technology shows potential, it is being held back by delayed legislation.

4.3.2 Geopolymer technology

The production of concrete has been using cement as a binder for many years. Recently, technology has emerged in the construction industry whereby cement is replaced by industrial by-products as a binder. This is called the technology of geopolymer: *'Mensen praten nu over geopolymeren. Daar zit dus geen portlandcement, geen hoogovencement, dus geen cement in. Dus kan je dat niet toepassen in de bebouwde omgeving zonder een aantal dingen aan te kunnen tonen.'* (Interview 4). The technology of geopolymer that replaces the polluting product of cement can shake up the niche: *'Maar er zijn nu ook nieuwe dingen aan de hand. Richting andere betonsoorten ook zonder cement. Zijn we druk mee bezig en zijn we aan het stimuleren. Zogenaamde geopolymeer beton. Die gaat de zaak goed op stelten zetten.'* (Interview 5). Being developed in the niche level, the new technology can stir up the regime standards and routines.

The effects of the innovative geopolymer technology are noticeable on two fields. First, the innovation clearly shows that there is an area of tension between the established order and the innovative newcomers. *'Die innoverende bedrijven tasten natuurlijk de positie aan van de grote partijen, of kunnen dat aantasten op termijn. Geopolymeren is eigenlijk geen beton, want er zit geen cement in en het voldoet dus ook niet aan de regelgeving. Maar het wordt wel toegepast, omdat het voor de CO_2 uitstoot enorme voordelen heeft. Dat zijn dan producten die door de bestaande orde in de hoek worden gezet, gediskwalificeerd. (...) Ze [de gevestigde bedrijven] willen het niet helemaal afbranden, maar ondertussen proberen ze het wel natuurlijk tegen te houden. Want het tast hun marktpositie aan, dat soort innovaties. Ze [de gevestigde bedrijven] zijn van het portlandcement en in geopolymeren zit geen portlandcement, dus op termijn kan dat een probleem zijn. De cementindustrie is natuurlijk wereldwijd geregeld met heel grote partijen die heel dominant zijn. Dan tasten nieuwkomers hun positie aan.'* (Interview 6). Second, the technology has to deal with the obstacle that it is initially more expensive to apply as a client. *'Als je kijkt naar geopolymeren beton, dat is een stukje duurder dan normaal beton. Opdrachtgevers zijn toch bereid dat te betalen, ook omdat het die CO_2 reductie meehelpt. Dus er zit ook een verdienmodel aan en dat moet ook. Duurzaamheid is niet duurder, in principe. Zeggen we altijd. Maar een innovatie zoals geopolymeren, dat is in het begin wel duurder, maar zodra het mainstream wordt, zal dat ook vergelijkbaar worden met traditioneel beton.'* (Interview 6). So, it turns out there are still a few

bottlenecks and challenges attached to the development of an innovation in this niche. In this case competition, market position and economic considerations play a role in the development of the innovative geopolymer technology.

4.3.3 Adaptive Design

Concrete is basically a product that can last a very long time, so there are innovative companies that respond to this characteristic. A common application of CC, observed during the expert interviews, is the process of adaptive design: *'Wat nu sowieso al kan is adaptief ontwerpen. Dus je maakt een kantoorgebouw, maar ik hou er rekening mee dat het wellicht over 50 jaar woningen worden. Dus dat ik daarmee in mijn ontwerp al dusdanig voorzieningen meeneem zodat een transformatie soepel kan gaan. Dat is iets wat nu al probleemloos kan.'* (Interview 8). It is clear from the cited interview that there is not one specific product of CC, but adaptive design embraces a lot of potential in realizing objectives for the transition in the construction industry. *'Dan blijft de vraag wat we verstaan onder circulair beton. Wat ik zei, het is van belang dat er geen afval gecreëerd wordt en dat er geen schaarse en kritieke grondstoffen gebruikt worden. Zoals het overheidsbesluit 2016 duidelijk aangaf, daar voldoet beton al aan. Dan is de enige echte milieuwinst die je kan boeken, is het niet méér beton maken dan noodzakelijk is. Dat doe je door adaptief te ontwerpen en demontabel te bouwen. Dat zijn de opties voor de toekomst.'* (Interview 8). The method of adaptive design mainly contributes to the CE as it has an emphasis on recycling. *'Je hebt in feite een circulaire economie, daar kun je heel veel over zeggen. Ik wil dat we ons beperken in de materiaaltoepassing: we moeten zo veel mogelijk hergebruiken. Je moet uiteindelijk zorgen dat het weer hernieuwbaar is, zodat het straks demontabel weer toe te passen is. Circulair beton heeft in feite al een leven gehad, die valt onder de categorie hernieuwbaar. (...) Dus, zorg dat alles demontabel is waardoor je het ergens kan oppakken en dan ergens anders weer kan toepassen. Dat je het een nieuw leven kan geven via een andere woning of ander project.'* (Interview 10).

Even though adaptive design has great potential to be a suitable solution to make concrete more sustainable, there are still certain obstacles causing friction: *'Je zorgt dat het heel makkelijk afbreekbaar is en zo herbruikbaar, zoals bijvoorbeeld modulair bouwen. Dat zijn dingen die spelen in de ontwerpfase. (...) Industrieel bouwen gaat over precisie, materialen nauwkeuriger en efficiënter gebruiken. Je kunt daardoor ook modulair beter bouwen. Er zijn heel veel mogelijkheden om dat te doen, maar er zijn blijkbaar veel redenen en hindernissen die dat in de weg staan. Dat zijn er niet enkelen, maar heel veel tegelijk. Die grijpen allemaal op elkaar in, die maken dat een hele boel in elkaar gehecht is en niet veranderd.'* (Interview 13). It is therefore important at the

design stage of the production process to anticipate the state and the function of the concrete building or application in the future.

In this paragraph, the three MLP levels of regime, landscape and niche are further explained and how they are interpreted by the construction industry. These levels and their interactions can be summarized and visualized in the following figure 4:

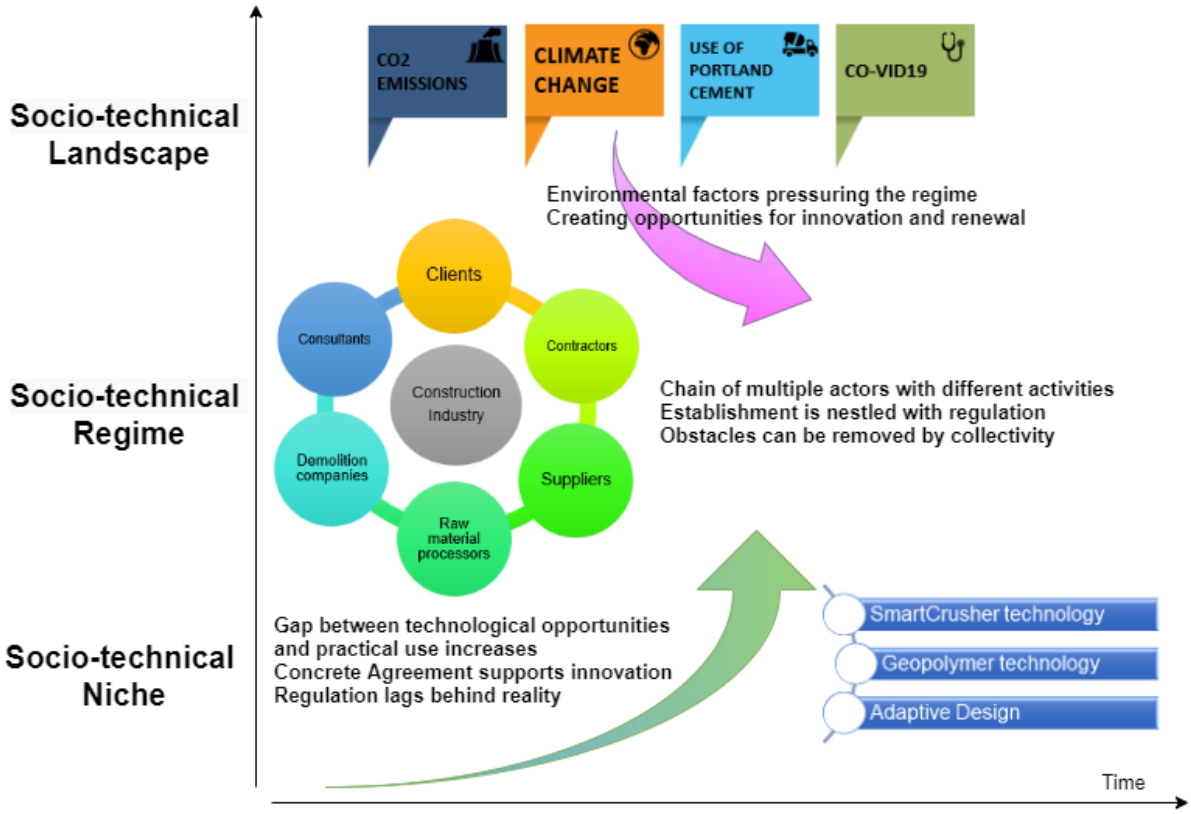

Figure 4: Multi-Level Perspective on socio-technical transitions (inspired by Geels, (2002))

4.4 Factors for the Transition

It appears that the transition of CC in the construction industry interacts on several levels. However, the process of change can be encouraged by drivers and impeded by barriers. There are also certain triggers and points of attention that need to be considered to facilitate the sustainable transition towards a CE. Comprehensively, there are a number of factors that affect the course and flexibility of this transition. These factors can be clustered into three main categories, namely *mindset*, *legislation and regulations* and *market actors*. These groups of factors consist of subfactors of which one cannot specific whether they are barriers or drives, but they affect the transition in their own way. In order to keep the analysis accessible and organized, some subfactors have been underlined.

4.4.1 Mindset

Many interviews have shown that the entire transformation is initiated by a certain mindset. This mindset can also be expressed in terms of necessary responsibility, social awareness, inner motivation, or urgency. *'Ik denk dat maatschappelijk gezien een grote noodzaak is om de productie van cement vooral te verduurzamen en daarmee beton duurzamer te krijgen. (...) We zouden het hergebruik en recyclen van beton moeten verdedigen, wat ook gaande is. Veel aandacht voor. Dat gebeurt nu nauwelijks. Industrie zelf heeft daar in al die tijd weinig oog voor gehad. Gemiste kans. (...) Het gaat écht om de mindset, ja. Ik ken zat mensen bij gemeentes die dat graag willen doen in hun aanbestedingen, maar durven niet.'* (Interview 2). These statements are complemented by the idea that sensemaking should arise among the organisations involved: *'Het is inderdaad zo dat stap 1 bij alles wat je hoopt dat bedrijven oppakken aan duurzaamheidsgebied, dat dat getriggerd wordt doordat men inziet om welke reden dan ook, dat het noodzakelijk is. De eerste stap is altijd bewustwording. (...) Er zijn wel 20 redenen waarom mensen voor zichzelf er ook zin aan kunnen geven. Sensemaking in organisation. Daar werken bedrijven ook veel mee. Dat is de eerste stap waarop je mensen meekrijgt.'* (Interview 3).

In one of the interviews the open question was asked of what is required to accelerate the transition in the construction industry. The respondent answered as follows: *'Puur de mentaliteit. Als wij als bouwers maar zorgen voor genoeg vraag naar de toeleveranciers, dan gaan de toeleveranciers er wel voor zorgen dat het er komt.'* (Interview 10). In the same context, an expert in CE was asked what is needed in particular to further develop the transition: *'Urgentie is wel iets wat breed gevoeld moet worden wil er überhaupt beweging gaan ontstaan. Als er eenmaal beweging is, heb je weer nieuwe problemen. Elke fase heeft zo zijn nieuwe problemen. Urgentie is nu het allerbelangrijkste. Urgentie hangt hier samen met het besef dat een belangrijk deel van onze milieuproblemen [klimaatverandering] en de kern van heel veel vraagstukken is terug te voeren op verspillende omgang met grondstoffen.'* (Interview 11). Urgency can thus create broad support.

Since the inner motivation derives from strategic considerations of a person or organisation, it is logical that there are different visions of the transition. For example, certain companies may have their reasons for ignoring the movement: '*ik ben voorzitter van de brancheorganisatie van de [bouwgroep] en ik probeer dat [circulaire beleid] bij onze leden wel zo veel mogelijk te stimuleren. Maar als zij eigenwijs zeggen dat ze zich daar niet in gaan verdiepen, omdat het ze tijd kost of ze hebben daar geen zin in… Er zijn veel redenen om het niet te doen, want het kost tijd. Dat moet je willen.'* (Interview 10) and in contrast to other cases, in particular the market leaders, the reasons for a transition do not even need to be clarified: *'er zijn wel motieven om in dit soort ontwikkelingen*

mee te gaan. De koplopers zijn ook vaak intrinsiek gemotiveerd om met duurzaamheid aan de slag te gaan. Omdat ze dat gewoon in zichzelf hebben, omdat ze daar ook met duurzaamheid bezig zijn.' (Interview 6).

In this paragraph it has become clear that the mindset is a recurring theme through many expert interviews. The driver can take different names, but they all serve as a starting point for initiating a transition. Depending on the noses pointing in the same direction, the transition can be accelerated.

4.4.2 Legislation and regulations

This research is focused on the role of legislation in the practical applications of CC in the context of a sustainable transition within the construction industry. One of the most striking statements about legislation is that there is almost no legislation in the construction industry, only norms and standards imposed by the market: *'We hebben eigenlijk bijna geen wetgeving. Op dat gebied. Dus de overheid stelt niks verplicht. (...) Wat we wel hebben is regelgeving, zo noemen we dat. Dat zijn door de sector aan zichzelf opgelegde regels, die gebaseerd worden op norm-afspraken, afspraken die in normatieve documenten worden vastgelegd. In Nederland hebben we NEN, het Nederlandse norminstituut. Dat beheert de normen voor Nederland. (...) Dat stelsel van normen is belangrijk, maar het is geen wet!'* (Interview 2). This regulative system of norms is characterised by a positive side: *'[Die normen worden] zorgvuldig bewaard want ze gaan over beton, constructieve veiligheid, dus dat een gebouw of brug niet instort. Weersinvloeden kan weerstaan, allemaal in normen geregeld. Positieve van normen.'* but the negative side lies in the fact that the voluntary nature of a norm is not reflective in practice: *'iedereen is eraan verslaafd en werkt ermee. Het is wel vrijwillig, maar in de praktijk is het heel moeilijk om met al je ketenpartners, opdrachtgever, je onderaannemer, je constructeur, afspraken te maken buiten de normen. Mag wel, maar dan moet je alles dus wel aantonen. Heel ingewikkeld en kostbaar. In de praktijk is een norm dus wel vrijwillig maar je kunt er bijna niet omheen.'* (Interview 2). Thus, the construction industry mainly operates on behalf of regulations and not on legislation. The following scheme is an overview of the key norms and standards.

Norm/ standard	**Description**	**Role or experience**
MPG (Environmental Performance Buildings)	*MPG values. Environmental performance buildings. In the Building Decree. It has been in it since 1 January 2018. It says that you have to calculate the total environmental impact of your building when applying for a permit. All kinds of software have been developed for this purpose. Then a number comes out: euro number per m2 per building. That is the environmental damage caused by your building. Behind this is a calculation model, the MKI value calculations of all kinds of different building materials.* (Interview 1)	*It is a button the government can turn. So, they introduced those MPG values with a value of 1. That is so extremely high that all building permit applications comply with that. (…) High introduction so the market would not resist. Then they put that value in and they turn that knob year in, year out and lower that number every time*. (Interview 1) *This is a way for the government to ensure a minimum level of performance in terms of sustainability of construction works throughout the country. It now stands at 1.0. If they tighten it to 0.8, 0.6 or 0.4, it automatically forces everyone to produce more sustainable. As a law, that is the ultimate control tool for the government.* (Interview 2)
MKI (Environmental Cost Indicator)	*The MKI environmental cost indicator, an overall indication of how sustainable your product is, we can calculate it all for our product, we take care of it, all MKI data of our product show on delivery on the delivery note. And we agree that we all make sure that the MKI goes down by a few percent each year and you are not allowed to deliver above a certain value. Then you are no longer allowed to participate. Then the playing field will be level for everyone. It is a pricing model, it is agreed nationally, so it is not a law, it is just a national agreement with each other that we all follow the same pricing system.* (Interview 2). *[With the MKI] you can set the requirements or show what the environmental costs are of your material, of your process, of your building. And that means that in the future you will increasingly look at sustainability in terms of MKI in addition to the award price of buildings/constructions*. (Interview 9)	*That ceiling comes down gradually every year and that is the same for everyone and everyone knows about it and you can focus on that. And then in competition you can decide for yourself when you take steps, as long as you meet the ceiling, that is the condition. Then we will all at least make that transition. That ceiling will then automatically come down at a speed that will enable us to meet our targets in 2030 and 2050 and that we all make that transition together. So, that has become the Concrete Agreement.* (Interview 2) *There are quite a few hooks and eyes on it, but in principle it is a prefix of which friend and foe say: let us do it this way. It provides clarity in what we do and how we do it. And how we ask it out.* (Interview 9)
Certificates	*When producing concrete, we must demonstrate that we comply with civil engineering legislation and regulations. We do this in a system of certification, so we are externally verified. This means that we supply concrete with a certificate, and we can only obtain that certificate if we strictly adhere to that legislation. That is why we adhere to it. We supply that concrete in accordance with the European standard. That is externally verified, so we have to comply with those regulations.* (Interview 9) *C2C is a trademark certificate. An authority that ultimately stands for a certificate, just like the KOMO stands for a certificate that our tiles also have to comply with. Certain quality, not so much durability. Just like DIN, which is also a certificate. There are thousands of them. ISO 9001, ISO certificates. Some are about the production of a product, some are focused on sustainability. BREEAM certificate has to do with the energy consumption of a building. There are a lot of them*. (Interview 12)	*Normally you have to prove this yourself with investigations into your concrete type, reinforcement, construction, but now you do not have to if you keep to the agreements we have laid down in the standards. Then you can omit 80% of the investigations, because then you can assume that if you adhere to the standards, then that is settled. That makes working a lot quicker and cheaper. Otherwise, all builders would have to have much larger research institutes if they had to demonstrate and prove whenever they built a new building. These standards are very important for that. (...) Working outside the norm, which you have to do when you want to innovate, you are obliged to adhere to the system, even if it is temporary for 5 or 10 years. So, working outside the norm is complicated, complex, and expensive. We are aware that this impedes innovation.* (Interview 2) *Certification is actually a retreating government. So, certification is a model in which the market corrects itself. So, in principle I think that the government should not interfere with certification until certification leads to market foreclosure. And that is what is happening here. Here, the market is correcting itself, but that is happening in such a way that new entrants are being blocked. Then I think the government should intervene.* (Interview 1)

Building Decree 2012	*What you see, of course, is that those testing companies, those auditors, who come to see if you comply with the rules… those rules were once established by trade unions, house builders, contractors, trade unions, governments perhaps. The Dutch Building Decree. That whole world has led to cement having to comply with those laid down quality requirements. Or sustainability requirements.* (Interview 12) *This Building Decree also specifies the requirements that our materials must meet. This is the requirement we also set for the quality of circular concrete. This means that the certificates must be supplied with it and that we can also demonstrate to the client that this concrete simply meets the requirements of current times and legislation and therefore the Building Decree.* (Interview 10)	*Everyone looks at the Buildings Decree and we have to comply with it. But the Buildings Decree also provides some escape routes for innovation. If you can demonstrate that it provides the same performance, a client should be able to do the same.* (Interview 6)
Concrete Agreement 2018	*This Concrete Agreement actually has 2 important pillars. The first pillar is the reduction of CO_2 throughout the chain. The second pillar is the stimulation of circularity. And the Concrete Agreement includes producers, suppliers, contractors, clients, and the government. And in any case, we try to achieve a significant reduction of CO_2 by the year 2030 at the latest, linked to concrete construction and an increase in the amount of circularly applied concrete.* (Interview 9)	*In the Concrete Agreement you also have the Friday consultations: these are the most important government bodies such as the Directorate-General for Public Works and Water Management, ProRail, Government Buildings, the large and small municipalities, which hold consultations to see whether they can make proposals at a national level, make agreements to indeed make those intended objectives of CO_2 and circularity possible. This is also very important for us to know because the government often has a leading, guiding and sometimes also a legislative role to haggle over certain matters. And thus, also to make the entrepreneurial risk acceptable.* (Interview 9)
CO_2 Tax (future)	*That taxation will definitely come, but we do not know exactly what it is going to look like. So, that is going to cost us money and I already put in my contract to builders that I reserve the right that if there is a CO_2 tax on cement, I reserve the right to pass that on to the customer. Because that is going to come, I already know that. I cover myself contractually for this, but I prefer to avoid it. (...) That is when the game really starts.* (Interview 4)	*The biggest incentive is CO_2 taxation. It has to come! There are already companies that are doing it. DSM already uses an internal CO_2 tax. Because they say, 'we need to prepare for this'. (...) In the Netherlands we should take the lead and already introduce this CO_2 tax for building materials. Then you will see what a big shift will take place between the materials that emit CO_2 and the materials that store CO_2. So, that is the big, most important instrument: the CO_2 tax.* (Interview 5)

Figure 5: Overview Norms and Standards for implementing CC

The system of setting standards and norms thus arouses different opinions, but the biggest barrier to these norms and standards is the pace at which it moves with society: *'Aangezien de bouw standaardisering als basis heeft van al het handelen, wat ook wel begrijpelijk is in de sector, en het eindeloos lang duurt voordat een standaard weer ietsje is aangepast, ben je al weer een paar jaar verder om die standaard aan te passen. Ik zit ontzettend te worstelen met enerzijds de juiste institutionele structuur die maakt dat standaarden een manier vooruit zijn, en wij moeten ook standaarden gebruiken, maar anderzijds zijn ze ook belemmerend voor het tempo.'* (Interview 3). This statement expresses the paradox for CC: the norms and standards can initiate and steer a transition towards sustainable concrete, but simultaneously the tempo of these institutions impedes the process.

4.4.3 Market actors

At this point, it has been shown that the mindset and regulation contribute in their own way to the transition towards CC. An important link that is added to this, is the way the market handles the transition. It is not just about feeling the inner motivation or standardizing norms in the construction industry, but it is also relevant who or what takes the responsibility and stimulating role in this socio-technical transition, how entrepreneurs spread their innovative drive and whether the collective's behaviour is desired. In other words, the relevant subfactors in the market consist of the *responsibility of the government, entrepreneurship,* and *collectivity.*

The common thread running through many interviews was that the government has the stimulating role that can activate the market. If the instructing party, the commissioning company, or the client includes circularity in the contract, the market can be put in motion. *'Ik denk dat die [instituties] buitengewoon belangrijk zijn, want een overheid is toch altijd een entiteit die voorbeelden kan stellen en zaken kan afdwingen om dat zo maar eens te noemen en die het mogelijk maken om een transitie verder door te voeren. Wat je vaak ziet bij ontwikkelingen in dit kader is dat de overheid vaak het voortouw neemt en de rest volgt.'* (Interview 9). This statement is supported by another respondent emphasizing the leading role of the government: *'de overheid is de game-changer. Die kunnen zeggen van ''we gaan dit doen en zorg maar dat de markt dit gaan doen''. Dus door de gemeente, provincies en nationaal kan er gezegd worden van ''wij willen alleen maar duurzaam bouwen, dubbel duurzaam''.* (Interview 5). The chairwoman of the Concrete Agreement claims that the main responsibility lies with the commissioning parties: *'Niet de overheid, maar de opdrachtgevers. Zowel de publieke, als de private opdrachtgevers. Want zij zijn degene die de uitvraag in de markt doen. Dus als die zeggen 'wij willen die en die prestatie geleverd hebben', dan moeten aanbiedende partijen dat kunnen leveren. Dat is wat mij betreft het belangrijkste sturingsmiddel, waar ik mee werk.'* (Interview 3) and in this context the government is one of the biggest clients for the construction industry: *'De overheden zijn heel belangrijke inkopers van beton: 40% van alle beton in Nederland wordt ingekocht door overheden. Dus als zij daarmee aan de slag gaan, dan kun je heel snel stappen maken richting meer circulariteit en minder CO_2.'* (Interview 6). The government thus carries the responsibility for stimulating circular contracts in the construction industry in order to initiate the transition towards CC.

When the market is set in motion, it is up to the entrepreneurs to think innovatively about how strategic benefits can be achieved. Entrepreneurs may face uncertainty in this process: *'In het begin heb ik er wel een paar keer aan getwijfeld. Omdat ik een andere koers vaar en twijfel of ik wel de juiste keuzes heb gemaakt, want dat valt écht niet altijd mee. Het betekent namelijk dat je tot*

waanzinnige innovatietrajecten kan komen, maar die blijken na 1,5 jaar hard werken en veel investeringen niet te kunnen concurreren met het lineaire gebied.' (Interview 1). In addition, it is important that entrepreneurs make economic considerations in the context of risk management in order to justify their choices: *'Zo'n aannemer zegt: ik moet een miljoen investeren voor een nieuwe manier om mijn beton te recyclen, maar als ik dat doe, gaat mijn MKI 30% omlaag en daarmee ben ik in staat om voor mijn beton 2% betere prijzen te krijgen. Dat doe ik waarschijnlijk 3 jaar lang met een voorsprong op de rest, dat is een bepaalde waarde op mijn volume en dat kan ik afwegen op die miljoen investering.'* (Interview 2). Although the government has a steering role, it can also create a sense of security for people who jump into the deep: *'De overheid heeft vaak een leidende, sturende en soms ook wetgevende rol om bepaalde zaken af te dingen. En daarmee ook het ondernemersrisico acceptabel te maken. Dus uiteindelijk praten we over een verandering, over ontwikkelingen die uiteindelijk ook de bedrijfsvoering betreft. En als de overheid daar achter gaat staan, is het risico om bepaalde investeringen te doen, om bepaalde beslissingen te nemen in je product/procesvoering/bedrijfsvoering dan een stuk makkelijker.'* (Interview 9). In the interview with the inventor of the SmartCrusher a comparison is made with planting a seed: *'Ik heb dat zaadje geplant, daar komt nu een heel klein plantje uit. Er staan allemaal mensen omheen die schaduw maken, die zorgen dat mijn plantje niet harder gaat groeien. Dus ik ben al die schaduwmakers tegen de schenen aan het schoppen en te omzeilen. Eén ding weet ik zeker: uiteindelijk gaat dit plantje groot worden of ze nou blijven staan of niet!'* (Interview 1).

There are a number of important factors that can set the market in motion, but the collective essence of the transition has yet to be addressed. It is relevant to mention that several buttons can be pressed and steering instruments can be used to activate the market actors. *'Je hebt fundamentele barrières die te maken hebben met wet- en regelgeving, economische prikkels, dingen die de rijksoverheid kan doen of Brussel. Dat gaat heel traag. Dus als je dat weliswaar beoogt, maar er rekening mee houdt dat het niet zo snel gaat als het moet, dan moet je dus gaan werken met een transitie aanpak waarbij je alle barrières in het betonsysteem allemaal met die partijen verandert. (...) We zijn wel bezig met een type standaarden, maar dan via voortschrijdende standaardsetting, we zijn bezig met innovatie op een bepaalde manier, we zijn bezig met opdrachtgevers die uitvragen moeten doen, prestatie-eisen moeten stellen, we zijn bezig met die betonketen om die in een andere denkwereld te krijgen, dus gemotiveerd te krijgen. Dat zijn allemaal knoppen.'* (Interview 3). A policy officer agrees with the rationale that the transition requires action from all parties concerned: *'Wij zijn natuurlijk als overheid wel een grote partij, dus wij kopen veel in. (...) Als wij heel veel circulair inkopen, dan hebben wij daar een grote rol in. Alleen als je echt gaat kijken over circulair beton,*

dan maakt één gemeente niet het verschil. Dan zul je dat met meerdere partijen op die manier moeten gaan doen.' (Interview 7). All things considered, the government fulfils an essential role, but it is the market players themselves who decide whether the rules of the game will be made more sustainable. *'De overheid is wel belangrijk, maar dat is elke speler. De werkelijke veranderingen gebeuren in de samenleving, niet in Den Haag. Maar het is wel zo dat jouw onderwerp spelregels wel in Den Haag voor een belangrijk deel worden gemaakt en die conditioneren van wat er wel/niet mogelijk is. Die maken welk spel er gespeeld worden en welke uitkomst is wel bereikbaar en welke niet. (...) Focus op wet- en regelgeving, à la, maar besef dat er andere hindernissen van andere signaturen zijn die hierop ingrijpen. En de overheid is daarin dus een belangrijke speler, maar nogmaals de overheid maakt zelf geen beton.* (Interview 13). In sum, these fragments combined lead to the transition approach where every actor and factor involved is needed in order to make a change. This not only applies to the stimulating role of the government, but also the market players need to adjust their practices into CC. Furthermore, the collectivity also shows that regulation is not the only determining factor in this process. All three factors can be summarized and visualized in the following transition model:

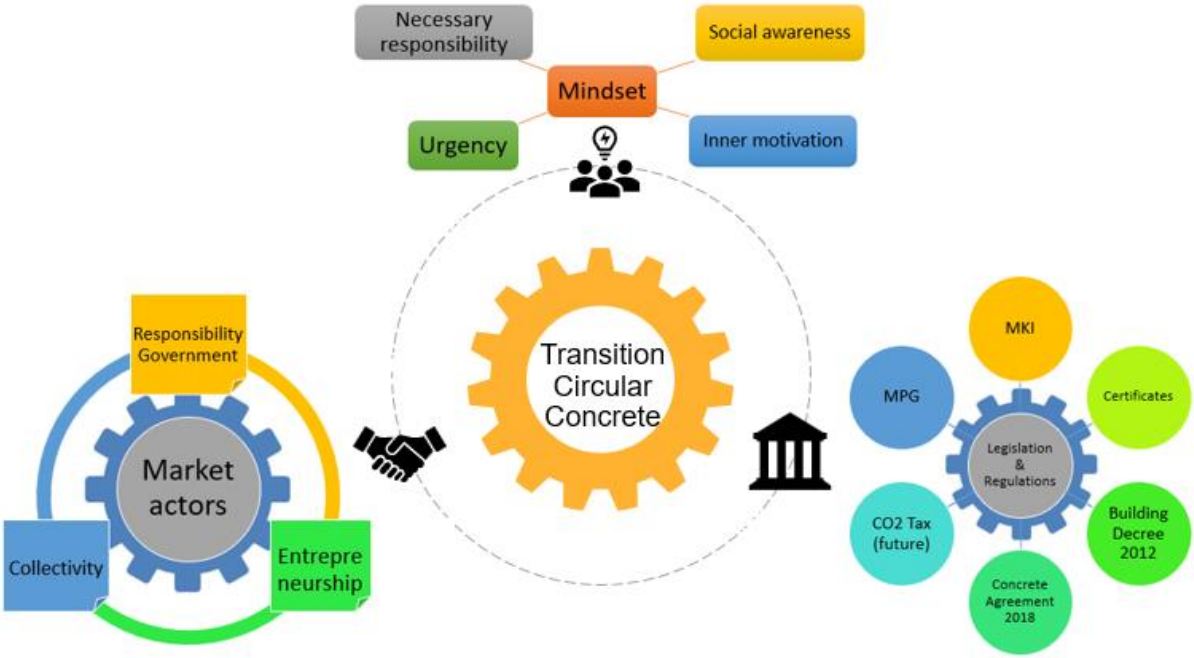

Figure 6: Factors Transition towards Circular Concrete

4.5 Chapter conclusion

In this chapter the data from executed semi-structured interviews is analysed from two perspectives: the MLP on the construction industry on one hand and three main factors influencing the socio-technical transition of CC on the other. The interviews revealed that legislation is definitely not the only factor in need of attention, hence the analysis consists of a comprehensive overview.

The construction industry is viewed as a network chain full of different actors and interests with a common goal: reducing CO_2 and adding circularity to concrete. The regime is characterised by a noticeable area of tension between the establishment and the upcoming order which creates a barrier for frontrunners to implement innovations. This barrier emerged as the strong lobby behind the establishment slows down the current legislation. In this way the transition is being held back. However, the landscape level can exert environmental pressures on the routines of the regime in the form of climate issues, saving raw materials and effects from a pandemic in spring 2020. In addition, the regime is corrected by the niche level, being a breeding ground for a few innovative technologies. These innovations are supported by the Concrete Agreement 2018 which takes away fundamental barriers in order to move the whole industry in the right direction of a sustainable transition.

In addition to the three industry levels the socio-technical transition can also be approached by three main factors influencing the speed and direction of the transition: mindset, legislation and regulations, and market actors. First, the transition is primarily triggered by the mindset and mentality among the people. It all starts with a social necessity creating the urgency to change ancient traditions to use linear concrete. The point of view from people and organisations in the industry can raise or hinder the initial phase of the transition. Second, with regard to legislation it has appeared that the regime is controlled by norms and standards. Although these regulations cannot be judged in general, some rules function as a key governmental tool to tighten the development of the transition. This is also confirmed by the third factor: the market actors play a crucial role in the course of the transition. The government owns the stimulating and legislative role in the process, but this can only be applied when entrepreneurs dare to innovate and when the chain as a whole starts to move.

5. Research results

The main objective of this thesis is to get a better understanding of the role of legislation influencing the socio-technical transition of CC and subsequently what effect this innovation will have on the transition to a CE. This chapter combines the received data from the semi-structured expert interviews, including the dynamics and operations in the construction industry, with the theoretical frameworks of TM, in particular MLP, and the X-curve of Loorbach. In other words, this chapter explains how the socio-technical transition of CC implemented in the construction industry can best be framed by the MLP background, whereas the contributions of this innovation towards a CE transition can best be framed by the X-curve of Loorbach. In this way, the research has led to a number of findings in twofold.

First, the MLP framework is used to gain a better understanding of the multi-dimensional levels that are ingrained in the construction industry. The external pressures from the landscape on the regime as well as the internal pressures from the niche on the regime explain how the socio-technical transition of CC can be facilitated. A clear understanding of the construction industry regime and what effects it experiences, is necessary to explore the role of legislation in the transition of CC and to explore the optimal circumstances in order to facilitate such a transition. Second, the X-curve of Loorbach is used to explore the role of the socio-technical transition of CC in the construction industry towards the development of a CE. The theory of Loorbach examines how the transition of CC will affect and contribute to a CE. Hereby, particular emphasis is placed on the desired mechanisms of building up and scaling down.

5.1 Construction industry as a network chain

The Multi-Level Perspective (MLP) provides a framework by distinguishing the socio-technical niche, regime, and landscape at the following three corresponding and interacting scale levels: micro-, meso-, and macro-level. The niche level is considered the place for radical innovations, the regime level consists of dominant organizations that perform in a stable manner on the basis of nestled legislation and regulations, and the landscape level can be viewed as the external environment creating conditions for the transition scope. The development and pace of the transition depends on potential innovation trajectories that can be reinforced or restrained by positive or negative interactions between the MLP levels. In other words, in order to analyse the socio-technical transition of CC in the construction industry, it is required to map the dynamics within and between the levels of niche, regime and landscape. Lessons can be learned from this analysis and suggestions can be made to steer the sustainable transition.

A very important observation about the construction industry is that the industry operates as a large chain network connecting multiple organisations with different activities and interests. The network is often driven by the client or the public tender that is requesting a construction project that is picked up by the contractor. In this way, the mechanism is very similar to a market providing supply and demand. However, other players claiming their place in the level playing field are construction companies, concrete suppliers, raw material processors, consultancy firms and/or demolition companies. As a result, the activities range from demolition of buildings, supply of concrete, advice on the contracts, and extraction of raw materials. The billion-dollar industry is characterised by the establishment that is nestled in the regime with its routines, customs, and standards. At the same time, this ingrained nature provides the biggest barrier for upcoming companies willing to implement CC practices. However, external factors from the landscape put pressure on the regime to change the established practices of linear concrete and gets the whole network chain think about the potential of CC.

5.1.1 Environmental landscape pressures on regime

First, the external pressures from the landscape context that affect the construction industry most is the global concern on CO_2 emission and climate change. These environmental issues have touched the construction industry and sustainable climate objectives have also had an impact on the construction industry regime. The global political aim to reduce CO_2 emission is shaped in the Paris Climate Agreement 2020-2050 and this puts pressure on the construction industry to stay within the boundaries. All different actors within the industry will have to commit to the decarbonising process of the industry and this embraces an important trigger for the sustainable transition in the industry.

Second, the factor from the landscape that the regime commands to change is the requirement of reducing the use of raw materials. The construction industry is one of the biggest polluters in the world due to the high footprint of Portland cement and the enormous volumes of concrete. Nearly 8 percent of the global CO_2 emission is caused by concrete, more specifically its main ingredient (Portland) cement. Moreover, it needs to be realized that the enormous amount of pollution is caused by the construction industry due to the high volumes. These environmental pressures have got the regime thinking about adapting their standards into more sustainable practices. Therefore, consideration is being given to replace the use of Portland cement as the main ingredient of concrete or to implement alternative applications to reduce the large volumes in concrete projects.

Third, in the spring of 2020 a deadly virus called CO-VID19 was elevated to the status of a pandemic. Although it has no direct medical effects on the construction industry, the forced quarantine periods do however lead to a greater focus on pollution and a sense of solidarity raises the inventiveness of the community. The global disease highlights the climate challenge and is identified as a source of opportunities for drastic change.

In sum, the external factors coming from the environmental landscape pressuring the regime to change are CO_2 emission, climate change, the use of raw materials and the pandemic of CO-VID19. These global concerns have indirect or direct effects on how the construction industry functions and in which direction the regime is heading.

5.1.2 Technological niche pressures on regime

Besides the pressures from the landscape, the niche level also influences the regime level. A niche can function as a breeding ground for innovations in order to challenge the status quo (regime) with new ideas, alternative technologies, and inventiveness. With regard to the construction industry, its phenomenon is observed that the space is growing between the technological opportunities and how much of the potential practices are used. The reason for this gap is that the current legislation and regulations are focused on old practices including Portland cement and therefore some experts claim that the legislation is lagging behind current developments. In order to bridge this gap, a collection of building companies, contractors, and concrete suppliers came together and signed the Concrete Agreement in July 2018.

The Concrete Agreement is crucial in the development of new technologies as well as the facilitation of current technologies that still need a proper market introduction. Observations about the target group of the Concrete Agreement and the different roles of regime actors made clear that the comparison with a cycling race provides an accurate representation of the actors in the playing field. There is a group of frontrunners who want to bring a lot of innovative technologies into the market, there is a group of chasers who also claim to be engaged in CC, then comes the peloton that moves along with the mainstream practices and lastly there is a group of laggards who consciously or unconsciously drop out of the race. The Concrete Agreement is focused on every part of the game in order to stimulate all actors in the construction industry to implement sustainable practices.

Another eye-opener in this research is the observation that there is no such thing as one product of CC, but the whole chain can adapt their activities in order to extract, produce, use, and recycle concrete in a sustainable manner. Roughly taken there are three promising technologies contributing to the transition of CC. First, the technology of the SmartCrusher breaks the original concrete in a

granulate of sand, gravel and cement and these recycled products can be reused in applications of concrete. Second, the technology of geopolymer concrete is an example of replacing the polluting Portland cement by industrial by-products. In this technology the binder of cement is thus replaced by sustainable by-products which contributes to the process of decarbonisation. Third, in order to reduce the amount of concrete in building projects, the application of Adaptive Design is a much-quoted technique of recycling. In essence, the technique is about anticipating the future function to prevent the concrete structure from having to be demolished. This is one innovation to reduce the volume of concrete in the construction industry.

Although these are promising methods for implementing CC, they have to deal with (overlapping) barriers and obstacles. For example, the legislative obstacle that only 30% of the gravel may now be replaced by concrete granulate, whereas this can easily be scaled up by the SmartCrusher. This obstacle causes friction for frontrunners as the potential cannot be fully exploited. In addition, the area of tension between the establishment and the upcoming frontrunners is reflected when a technology like geopolymer concrete enters the market. The new technology does not use Portland cement, the ingredient on which the billion-dollar industry is based. The fact that the establishment feels threatened as the frontrunners gain a market position implies a barrier for companies to jump in the deep as the establishment tries to counteract the innovations. The regime is pressured by promising technologies from the niche level and barriers can be overcome when the CC practices become mainstream.

In sum, the regime consists of established companies adhering to their linear practices but both external landscape pressures and niche technologies can push the regime into a socio-technical transition by pointing out that these linear practices can be executed much more sustainably.

5.2 Transition towards circular economy

The socio-technical transition interacts on the regime, landscape, and niche level. The expert interviews also indicate that there are three main factors that influence the speed and direction of transitions: mindset, legislation and regulations, and market actors. Although these factors apply to the socio-technical transition to CC, they have deep resemblance with triggers, drivers, barriers, or obstacles for the transition to a CE.

5.2.1 Mindset triggers the phase of experimenting and acceleration

First, a recurring theme for stirring up a transition is the mindset of people and organisations. This theme is also known by other terminology such as necessary responsibility, social awareness, inner motivation, and urgency. One of the first triggers for sustainable activities to start up is the sense of necessity. From society comes the common feeling of needing to work in a more sustainable way

and therefore the construction industry is also affected. However, several different interests and intentions play a role in the construction industry due to the variety of activities. The first step to move everyone in a sustainable direction is to create awareness or sensemaking in organisations. For some frontrunners, this awareness is self-evident as they have the inner motivation to operate sustainably, whereas other companies are harder to move because they believe it is too costly or because they simply do not want to join the transformation. In addition, the landscape pressures such as CO_2 reduction and saving on raw materials can create the urgency for the construction industry regime.

In the context of the X-curve of Loorbach, the mindset or mentality also claims a spot on the curve. Although the main message from Transition Management (TM) is that a transition cannot be forced or managed, the X-curve shows that the course of a transition can be steered or accelerated. The X-curve consists of two intersecting lines with five interconnected phases. The mindset of people and organizations in the construction industry to implement CC can be classified into the first phase of optimization and experimenting and into the second phase of destabilization and acceleration. With regard to the first phase in the X-curve, the mindset or necessary responsibility to feel that change is needed belongs in the phase of experimenting. The establishment holds on to their linear practices when simultaneously an inner motivation is growing at a small scale such that the old habits need to be adapted. With regard to the second phase in the X-curve, the mindset plays a role in such that it can accelerate the movement towards implementing CC. In this phase the dominant regime system gets stuck, the people are wondering how long the current activities will last and the process is accelerated by experimenting frontrunners showing that it can be done better, more sustainable, and more responsible.

5.2.2 Regulations restrain further development

An important finding early on in the research was the observation that there is no legislation on CC per se, but that the construction industry system is dominated by regulations. These regulations are defined as self-imposed regulative rules nestled in the construction industry, which are based on normative agreements that are laid down in normative documents. In the Netherlands, the most important institute to arrange these regulations is the NEN, the Dutch Normalisation Institute. It is a neutral cooperation that has the objective to facilitate and develop norms and standards. The experts emphasize that this system of imposing standards creates support and foundation for an operating industry, but it has not been elevated to the status of a law. Although the system is widely supported, a positive and a negative side is highlighted. The positive experience with standards is that they are carefully drawn up and thus guarantee the safety of concrete structures. On the

negative side, experience has shown that the voluntary nature of norms is not reflected in practice. This makes it difficult to apply and try out other sustainable practices outside of the agreements with other market parties. So, even if the market can regulate itself in the form of norms and standards, at the same time it is limited in its possibilities by its own system.

The theory has shown that a transition is not only a co-evolution of economic, cultural, and technological developments, but institutional development also plays a role. In this context, the institutional theory can be used to clarify the role of institutions in a socio-technical transition. A misunderstanding that needs to be cleared up is that institutions are seen as non-market organisations, when in fact they are best described as standards, regulations, and rules. The institutions in the construction industry can be approached by two perspectives. They claim a spot within the regime level on one hand and they can influence the speed and direction of a transition by means of the X-curve of Loorbach. Before addressing this, it is first useful to show six relevant institutions in the construction industry in the following scheme:

Type institution	**Description**	**Role or experience**
MPG (Environmental Performance Buildings)	*MPG is a calculation that measures the environmental impact of a building on the basis of used materials. Since 2013, this calculation has been included in the Building Decree 2012 (section 5.2) and can therefore be required when submitting the environmental contract. Since January 2018, the limit value for the MPG is <1. The MPG is dressed using a calculation model of the MKI.*	*MPG acts as the ultimate control tool given that it can be adjusted annually to move the market. When the government turns this rotary knob, all market players are automatically steered to produce more sustainably, otherwise they will not win the contracts for building projects.*
MKI (Environmental Cost Indicator)	*MKI sets requirements and shows what the environmental costs are of your materials, of your process and of your building. This implies that many building companies will increasingly look at sustainability in terms of MKI in addition to the award price of contracts.* *MKI expresses the environmental impact of a product in euros. In weighs all relevant impacts that occur during a product's life cycle and adds them up to a single score.*	*MKI, as known as the shadow price of a product, is an easy way to compare and communicate the environmental impact of building products or projects.* *A ceiling is attached to the MKI to ensure that everyone gradually moves along in the transition to meet the sustainable targets in 2030 and 2050.*
Certificates	*The certification system ensures that producing companies demonstrate that they comply with civil engineering legislation and regulations in their producing process. The companies are verified externally, and they can only obtain a certain certificate if they strictly adhere to that legislation.*	*The big advantage is that companies save time, money, and effort of research of they comply with the certificates. It saves a lot of work from your own research institutes if the certificates guarantee the necessary quality. Certification is actually a model with a retreating government, in which the market corrects itself. However, newcomers are blocked because it is expensive and complex to work outside the norm.*

Building Decree 2012	*The Building Decree 2012 contains regulations for safety, health, usability, energy efficiency and the environment. All buildings must meet these requirements. The decree has been drawn up in consultation with the building sector. It consists of, among others, construction companies, contractors, architects, and policy makers from townships.*	*Everyone looks at the Building Decree 2012 and we have to comply with it. But this regulation also provides some escape routes for innovation. This implies that you can do business with a client if the building company can demonstrate that it provides the same performance.*
Concrete Agreement 2018	*The Concrete Agreement emerged from a collaboration between producers, suppliers, contractors, client, and the government who collectively pursue two objectives: reducing CO_2 and stimulating circularity in the industry. It is a highly respected institution to develop and facilitate innovations.*	*The regulations also facilitates rounds of consultation on Fridays: the most important government bodies such as the Directorate-General for Public Works and Water Management, ProRail, large and small townships hold consultations to see whether they can make proposals at a national level in view of the objectives.*
CO_2 Tax (future)	*There is prediction and speculation about the form a future CO_2 Tax. This will cost the market parties money and some companies already include a right of reservation in their contracts to builders to pass this tax on to the client.*	*The CO_2 Tax is seen as the biggest trigger the government can use for the sustainable transition. Experts suggest that the Netherlands cabinet should take the lead in this and introduce this tax already for building materials. The expectation is that there will be a big shift from emitting CO_2 materials to preservative CO_2 materials.*

Figure 7: Institutions affecting the transition of CC

The paragraph on legislation and regulations has shown that it is difficult to assess the role of this factor in the transition unambiguously. This difficulty lies in the fact that the institutions may have different effects in the practices of concrete. However, there is a general opinion that the current norms and standards stand in the way of sustainable development because of the lengthy process of change. From the MLP perspective, the regime continues to adhere to existing regulations as niche innovations are hampered by the slow pace of change. With regard to the X-curve of Loorbach, the implementation of legislation is mostly related to the fourth phase of institutionalizing and scaling down. The governmental tools such as MPG and MKI are eminently the embodiment of a sustainable transition that needs to be built up and scaled down. These institutions are slowly eroding the old linear practices, and they are simultaneously creating space to apply the better, more sustainable, and more responsible CC in the industry.

5.2.3 Market actors should form a collective

The third main factor that plays a crucial role in the course of the socio-technical transition of CC is the approach of the market actors. Repeatedly, the concluding theme in the interviews was about what is really required to take a giant step towards implementing CC in the construction industry. In other words, what mechanisms need to be put into place if the movement to CC is to really take off. In almost all interviews it was found that the government plays an important role in legislation, but that it is mainly the market that has to pick it up. In order to clarify this mechanism, three underlying themes have been chosen to contribute to this market approach: the responsibility for the government, entrepreneurship and collectivity.

The government is the game-changer. In fact, this statement can be based on three reasons. First, the government has such a guiding and leading role in society that it controls certain phenomena within a market by means of national power. Second, the network chain of the construction industry consists of all kinds of interconnected parties: clients, contractors, suppliers, and construction companies. As a client, national and local authorities often buy 40% of all concrete in the Netherlands, which gives it a very important stimulating role in the search for CC. Third, the government fulfils an exemplary function in which the interests of society must be represented by the government in a sustainable transition.

In addition to the phenomenon that the market must be set in motion by government action, a sustainable transition also depends heavily on entrepreneurship. As soon as the government and the market mechanism come up with the rules in which the game can be played, it is up to the innovative entrepreneurs to see opportunities and respond to them. Some obstacles for entrepreneurs to jump into the deep end relate to them daring to make a change, the extent to which the government provides safety and the considerations of risk management. It is uncertain for innovative frontrunners whether they will be able to return their current investments with new sustainable activities. A characteristic comparison is the planting of a seed by frontrunners, in which the establishment tries to shade its development. Eventually, the frontrunner will have to persevere to grow into a full-fledged plant in order to receive a respected position in the market regime. With regard to the X-curve of Loorbach, entrepreneurship can contribute to the first two phases of a transition towards a CE. Entrepreneurs can initiate the phase of experimentation, after which a phase of acceleration can be reached when several entrepreneurs with creative practices shake up the regime. The guts to implement sustainable practices can affect the speed and direction of the intended transition.

While others emphasize the role of legislation, the role of clients and the influence of innovations on the socio-technical transition, it is also very important to bring the entire construction industry into a different way of thinking. The framework of MLP has shown that the construction industry is characterized as being a network chain with multiple parties and interests. The fact that broad support must be created by the entire industry also applies to local and regional authorities. It will not be sufficient to create a movement by getting one township on board, but more townships will have to join the transition. Even before the interviews were conducted, the assumption was already made that priority was given to the collective sense in the industry in order to move the transition in the right direction, but this idea was explicitly emphasized in the interviews. The noses must point in the same direction, which means that everyone in the chain must be urged and moved to undergo

the transition. Hence, the collectivity covers the whole transition period in terms of the X-curve of Loorbach. It is not possible to determine when a transition will come to an end because of constant development, but commitment and cooperation are crucial factors to light and hold the running fire of the socio-technical transition towards a CE.

5.3 Chapter conclusion

This chapter is used to establish a link between the theoretical frameworks from MLP and the X-curve of Loorbach and the received data from the expert interviews. The MLP framework has explained how the construction industry regime is subject to external landscape pressures and technological niche innovations. The X-curve of Loorbach provides clarification on what factors have an influence on the speed and direction of the socio-technical transition in the construction industry.

Against the background of MLP it is explained that the construction industry regime is a network chain of different actors and interests. A lot of money goes into the industry which is characterized by a nestled establishment being a barrier for upcoming companies to make a change. However, the regime is influenced from two sides to make changes in daily practice. External landscape pressures fulfil the first level that makes the regime think about better, sustainable, and responsible activities. The regime level is driven by phenomena from the external environment: the process of decarbonisation, climate change and the consequences from a pandemic put pressure on the construction industry. In addition to the landscape pressures, the niche level also puts pressure on the establishment by technological niche innovations. The Concrete Agreement is a cooperation of different leading parties in the construction industry that stimulates the punching power of the niche technologies. Although there is not one single product of CC, a few promising technologies can implement sustainable techniques into the production process. The biggest barrier for these niche innovations relate to the outdated regulations that are still focused on the linear concrete practices. Eventually, the landscape and niche pressures can affect the construction industry to move in a sustainable direction.

The X-curve of Loorbach has also proved to be a useful tool or framework to map and analyse the transition towards a CE. There are three main factors that include the ability to steer and accelerate or impede the transition in the construction industry into a CE: mindset, regulations, and market actors. The term factor has been chosen because the concepts do not necessarily fall under the category of drivers, barriers, triggers, or obstacles, but they are a mix of them.

First, the mindset is all-important for the start of the first two phases of the X-curve. The regime practices can only be improved when the people feel the inner motivation in their minds to make a change in the current economy. People's mentality can ensure that the current regime system gets stuck as the people wonder how long the current activities will last and the process is accelerated by experimenting frontrunners proving that a better way of acting is possible. Second, on the factor legislation it can be said that it is covered by self-imposed rules that the market has set itself. The regulations, norms and standards that are used in the construction industry are considered to be the institutions on which the industry relies. There are a few institutions that the government can use as the ultimate steering tool. For example, the MKI calculates the environmental impact of a concrete building; it is introduced in the market with a certain ceiling value and gradually this value is tightened to move the market into sustainable actions. Although the general obstacle of slow changing regulation dominates the industry, these institution tools are the most important manner to get the market moving. Third, the market actors must take the government's stimulating intentions on board and participate collectively in the pursuit of a more sustainable society. In order to succeed in the transition towards a CE, which is not as obvious as it sounds, the whole network chain in the industry needs to feel the urge to implement CC. The parties need each other, entrepreneurs must dare to seize opportunities and the whole chain must be drawn in the movement towards a CE.

6. Conclusion and discussion

This thesis is an explorative research on the role of legislation in implementing CC in the construction industry. To investigate this phenomenon, the socio-technical transition of the implementation of CC in the industry is analysed in order to study the effects of this transition towards a CE. The knowledge gap lies in the fact that less is known about the legislation and regulations that can govern the applications of sustainable concrete in the construction industry. Hence, the primary contribution is gaining insight into the role of legislation on the implementation of CC and the support of this innovation regarding the transition towards a CE.

In this final chapter, the answer to the research question is given. The chapter begins with an introduction of the background research for this thesis. After that, the findings of the research data will be summarized followed by an answer to the research question. Afterwards, the theoretical and practical contributions of this research will be elucidated. Finally, the last part of the thesis covers the practical implications, the methodological implications, and suggestions for further research.

6.1 Background research

The Dutch government aims for a CE in 2050. By 2030, the use of primary raw materials must be reduced by 50 percent. Some efforts are already being made to make our economy circular: rubble from construction serves as a foundation under roads and we are reusing paper and plastic. However, not all chains are sustainable and safely closed yet. In addition, the Netherlands and the rest of the European Union are firmly committed to an emission-free economy in 2050: from fossil to sustainable. This calls for serious and economically viable alternatives to the fossil fuels on which the current economy is almost entirely running. This has several advantages of which the lower CO_2 emission is the most important. To achieve this, however, the current system will have to be renewed.

A CE should be seen as an economic system designed to maximize the reusability of raw materials, products and human talent and minimise value destruction. A CE makes use of other chains in addition to its own. The concrete industry is a good example of this. Concrete is the most widely used building material worldwide. Concrete is reliable, inexpensive, and non-combustible, and concrete structures have a very long lifespan. However, the main ingredient in concrete is cement which is one of the most polluting products in the world. Therefore, there are already a few applications of CC. An example that also clarifies the cooperation between other chains is the use of by-products: by-products from other production processes are used to replace the cement in concrete. Another example is the application of reusing concrete granulate as a raw material as it is produced at the end of its life after demolition and crushing.

Although some sustainable ideas are being introduced in the market, there is always room for improvement. It is better to design a concrete structure in such a way that future changes in use are considered as much as possible. It is also better to design a demountable concrete structure of which the elements can be reused. Furthermore, techniques are being developed to break down concrete into gravel, sand, and cement stone powder in order to reuse the powder. All these developments claim to contribute to the further greening of concrete, in addition to the developments to further reduce CO_2 emission. A problem related to this development is that companies like to label their activities as circular. Sustainable labels seem to become the new standard in a changing world, but the presence does not always cover the reality and some companies pretend to operate sustainable when in fact they only make a small contribution to the green world.

Legislation can set strict rules for concrete practices in the construction industry for the purpose of creating order in the sector in which people and organisations claim to be sustainable whether appropriate or inappropriate. However, the general opinion is that legislation does not keep up with the transition towards sustainability. This also implies the knowledge gap with regard to regulations and legislation that govern the possibilities and opportunities for construction companies to implement CC. Therefore, the role of legislation is being studied in this thesis and how the regulations and rules can contribute to the implementation of CC. The ultimate aim of introducing CC in the construction industry is to contribute to the objectives of a CE for society.

6.2 Research question

Against aforementioned background research, this thesis is an explorative research on the role of legislation on CC in the construction industry and its effect on the CE. There is a knowledge gap within the construction industry about the standards, guidelines, and legislation surrounding the implementation of CC. Furthermore, less is known about the effects of CC in the transition towards a CE. Hence, this thesis aims to give a comprehensive answer to the following research question: *How does legislation affect the implementation of circular concrete in the construction industry, contributing the transition to a circular economy?*

Above all, the background of this thesis is the expectation that the construction industry undergoes a socio-technical transition and subsequently CC will become the default used material in the construction industry. The development of CC is in its infancy and can potentially lead to a switch from the most used material in the construction industry. The research is conducted along two paths: the first path addresses the implementation of CC as a socio-technical transition and the second path addresses the contribution of this sustainable product towards the transition into a CE.

First, in order to analyse and demarcate the socio-technical transition of CC, the theory Transition Management (TM) is used to provide a frame within which the development can be explained. In particular, the Multi-Level Perspective (MLP) is an important concept for TM as it distinguishes the regime level, the niche level, and the landscape level. Second, in order to determine the effects of the sustainable product of CC on the transition towards a CE, the X-curve of Loorbach is used. In the X-curve, a distinction is made between patterns of building up and patterns of scaling down that reinforce or counteract each other in the context of an underlying transition.

Transition Management (TM)

TM is a relatively new theory that is specifically useful in providing a theoretical foundation for the management of transitions focused on sustainable development. A transition can be defined by the shift from one socio-technical regime to another regime. Sustainable development requires radical changes in functional systems and changes in government policy and in current systems of governance. The goal of TM is to handle the complexity of steering activities by different actors, mechanisms and instruments and encouraging socio-technical activities in a shared and desired direction. It looks at how the transition is evolving on multiple levels and how the groups of people within these levels respond to this. When the transition is monitored on the level of progress, social learning of drivers, barriers and other factors can be experienced thanks to the cooperation and interaction between different actors involved. The construction industry is balancing between the old habits from the establishment and the pathbreaking inventions from the innovative businesses. Therefore, TM tries to utilize innovative bottom-up developments in a more strategic way by regulating different levels of governance and supporting self-organization by means of new types of interaction, learning processes and actions for radical innovations with sustainability advantages.

Multi-Level Perspective (MLP)

The MLP elaborates on the principles of TM with the following definition of a transition: a structural change in a societal system that is the result of a co-evolution of economic, cultural, ecological, technological, and institutional developments at different scale-levels. The MLP makes a distinction between three interacting levels: niche level (the place for radical innovations), regime level (incumbent organisations that perform in a stable manner on the basis of nestled legislation and regulations), and landscape level (the external environment). These three levels are also used to reflect on the construction industry in order to understand the evolution of the socio-technical transition of CC in the industry.

The *socio-technical regime* takes centre stage and it consists of a whole network chain of different actors, various activities, and differing interests. The industry is dominated by clients, contractors, suppliers, raw material processors, consultancy firms and construction companies. By nature, market forces are triggered when the client asks for a building project that the contractor can try to bring in. The construction industry is mainly dependent on the establishment, a group of companies that has elevated its own linear way of producing concrete to be the standard approach. This situation of nested routines and habits causes a huge barrier for upcoming companies to implement and introduce their new innovative technologies in the market. However, a principle of MLP is to view the levels as interacting configurations and with this in mind, the regime can be triggered by the influences of the landscape level and the innovations from the niche level.

The *socio-technical landscape* refers to conditions of the wider exogenous environment, which affect the socio-technical development. The construction industry is mainly triggered by a foursome of external pressures in the environment: the emission of CO_2, climate change in general, the use of raw materials and the CO-VID19 pandemic. The global political aim to reduce CO_2 emission is shaped in the Paris Climate Agreement 2020-2050 and this process of decarbonisation pressures the regime. At the same time, climate objectives due to the global issue of climate change influence the regime. Furthermore, the construction industry is one of the biggest polluters in the world due to the high footprint of Portland cement and the enormous volumes of concrete. The regime is forced to think about alternative raw materials and alternative applications to reduce the concrete volume. The last and probably the most surprising factor is the CO-VID19 pandemic. The pandemic is leading to great inventiveness to implement change strategically. In sum, the four environmental factors are a trigger for the regime to implement more sustainable practices.

The *socio-technical niche* acts as a breeding ground for innovations in order to challenge the status quo (regime) with new ideas, alternative technologies, and inventiveness. There is a growing gap in the regime between technological opportunities and what is applied in practice. This gap is mainly caused by the focus on outdated legislation for linear concrete products. In order to overcome this barrier, a leading group of clients, construction companies and townships came together to sign the Concrete Agreement in 2018. This legislative partnership is crucial in the development of new and current CC technologies. The target group of this agreement can be divided into the following categories: frontrunners innovating the regime, chasers tracking these innovations, peloton moving along with the mainstream and laggards who are left behind. The Concrete Agreement plays a crucial role in getting the laggards on board and a supporting role for frontrunners who innovate on their own initiative. The ultimate goal is to have the entire industry produce CC.

An important observation in order to answer the research question is that there is not one single product of CC, but all operational activities in the industry should be made more sustainable and responsible. However, there are three technologies indicating how the innovations can improve the circular practices in the industry: the SmartCrusher regains the sand, gravel and cement from the original concrete in order to recycle the concrete in new applications, the geopolymer technology replaces the polluting Portland cement by industrial by-products, and the process of Adaptive Designs anticipates the future functions in the design phase of concrete. Generally seen, there are two major obstacles for the further development of these innovations: legislation allows only 30% of gravel to be replaced by concrete granulate and the tension between the establishment and upcoming companies stands in the way. The establishment feels in fact threatened in its market position by the innovative companies that are gaining ground. In sum, incumbent organisations adhere to their linear practices but both external landscape pressures and niche technologies can push the regime into a socio-technical transition by pointing out that these linear practices can be executed much more sustainably.

Factors on the X-curve of Loorbach

It should be noted that during the research the observation came to light that legislation is not the only factor that triggers the transition of CC towards a CE. In addition to legislation, the mindset and market actors also appear to play a crucial role in the transition. Hence, all relevant factors that can influence the transition as trigger, driver, barrier, or obstacle receive attention in the background of the X-curve of Loorbach. This curve came about a publication from DRIFT, the Dutch Research Institute For (Sustainability) Transition. Recently, DRIFT published a report with the state of current transitions in which the process towards a CE was also discussed at length. Loorbach described transitions as processes that do not only build up, but also scale down. The patterns and dynamics of both paths are involved in the following X-curve of Loorbach:

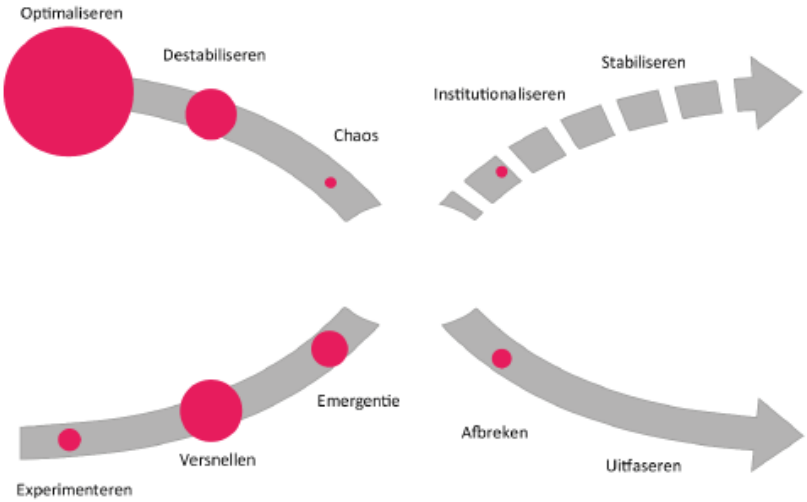

Figure 8: The state of transition towards a circular economy (Bode et al., 2019)

The diagram shows that the transition can be classified in five phases. The bottom line is that transitions not only need attention to be introduced, but it also requires management to scale down the existing regimes. In addition, it is important that a transition cannot be enforced, but can be adjusted and steered into the right direction. Against this background, the three factors are determined that have the most impact on the direction and pace of a transition towards a CE.

First and foremost, it is crucial there is a necessary responsibility, an inner motivation and/or shared awareness within the construction industry to initiate a transition towards a CE. Something can only happen in daily practice when the mindset is focused on sustainable change and improvement. Although this may seem logical at first glance, it is more difficult than expected because of the diversity of actors and interests in the construction chain. The first task for the industry is to ensure that all noses are pointing in the same direction to start a transition. Considering the X-curve, the mindset is linked to the first two phases of a transition. The establishment holds on to linear practices when simultaneously an inner motivation is growing at a small scale that the old habits need to be changed. The dominant regime system gets stuck as the people are wondering how long the current activities will last and the process is accelerated by experimenting frontrunners showing that CC can be produced better, more sustainable, and more responsible. In sum, the mindset of people and organizations is the prominent trigger for the transition towards a CE.

Second, the legislation seems to consist mainly of self-made rules that are considered to be norms and standards. Although they guarantee the safety of buildings, the rules are not entirely voluntary. Since the regulations cannot be judged in general, a brief overview of the most relevant regulations in the industry is presented:

Type institution	**Brief description**	**Main effect**
MPG	Calculation that measures environmental impact of a building	Ultimate control tool to steer the market sustainably
MKI	Environmental impact in euros	Ceiling of shadow price is updated annually
Certificates	Verification system to ensure product's quality and safety	Saves time-consuming and expensive investigations
Building Decree 2012	General law for safety, health, and usability of the building industry	Broad support that also creates room for innovation
Concrete Agreement 2018	Partnership of leading companies to stimulate circularity and reduce CO_2	Supports innovations on national level
CO_2 Tax (future)	Future tax charged to the customer	Biggest trigger to accelerate sustainable transition

Figure 9: Institutions affecting the transition of CC

The institutions mainly have a delaying effect on the transition towards a CE because of the lengthy process of change. With regard to the X-curve of Loorbach, the governmental tools such as MPG and MKI are the embodiment of the fourth phase of institutionalizing and scaling down. These institutions are slowly eroding the old linear practices and they are simultaneously creating space to apply CC in the construction industry.

Third, an important step that needs to be taken is for the market actors to put the government's stimulating actions into practice. The government itself is a major buyer of concrete and can ensure that circular aspects are included in the enquiry, which needs to be implemented by the rest of the construction chain. In addition, entrepreneurs can be supportive when risk management does not constitute an obstacle to sustainable innovations. Entrepreneurs can initiate the phase of experimentation in the X-curve, after which a phase of acceleration can be reached when several entrepreneurs with creative practices shake up the regime. In conclusion, the coming together of the collective network chain in the construction industry will still have the most conducive effect on the speed and direction of the transition. If the whole industry works together with the same objectives, the shift to CC as the standard concrete will be made to contribute to a CE.

6.3 Theoretical implications

Before the research was carried out, the intention was to make both theoretical and practical contributions to science. The aim of this research is to contribute to the scientific ideology that prevails in the field of socio-technical transitions, but it also intends to offer new insights into real-life practices in the construction industry. Ultimately, research must be cited to bring about improvements in society.

With regard to the theoretical contribution, this research has yielded new insights in the field of MLP and the X-curve theory of Loorbach. First, the MLP offers a framework that puts the idea forward that the level playing field consist of a niche, regime, and landscape level. The levels can be described as socio-technical configurations that contain different approaches towards coordinating and structuring local practices, but despite these different views it is useful to study the dynamics between them. The MLP propagates the principle that structural change can take place in a nested hierarchy when the interactions of the niche level and the landscape environment are included in the transformation. This research has shown that the general trend for decarbonisation, the issue of raw materials and the consequences of a pandemic can have an impact on the existing regime to change their habits. In particular, the fact that a worldwide health crisis can lead to inventive opportunities is pathbreaking. Instead of applying a survival mechanism, an industry can benefit from people coming up with new ideas in a drastically changed environment.

Furthermore, the theory of MLP is complemented by the phenomenon that legislation can have a delayed effect on the influence of niches on the regime. In addition, the institutional theory is enriched with the knowledge that legislation can be outflanked by mindset and market actors. Second, the relatively new theory of the X-curve of Loorbach has been studied. A structural change needs to include the fact that a transition requires a path of building up and scaling down. Although the X-curve is a fairly new concept, it has shown that this theory fits together perfectly with some governmental tools used in the construction industry to steer the sustainable transition. In addition, the new X-curve theory benefits from the findings that some factors relate to multiple transition phases rather than a one-sided classification.

6.4 Practical implications

With regard to the practical contribution, this research has shown that the transition to CC is most likely to succeed if each link in the chain provides the right mindset and actions in the transformation. Furthermore, the research advocates for an active attitude from all the market actors, innovative entrepreneurs, and frontrunners to stir up the regime practices. Although the government has an important role to play from above, it is certainly advisable and recommended not to wait for legislation to change very slowly, but for the construction companies to take the initiative themselves, working together and urging partners to build circularly. It sounds like a cliché, but the interviews have strongly emphasized that really the whole construction chain has to believe in and work towards the change if the climate targets are to be met. With the help of the shared mindset, adapted legislation on current innovations and an organised chain, CC can replace the polluting concrete and become the new standard.

6.5 Methodological implications

During the execution of the research, a number of implications have occurred that have made the course of the study more difficult. This subchapter mentions a few implications.

First, as already mentioned in the findings, the CO-VID19 crisis also had an impact on this research. The pandemic took over the world in early 2020 and led to some countries integrating a quarantine lockdown as a prevention policy. The biggest implication for the conduction of the research is that the interviews had to be conducted digitally or by telephone. Although this saves travel time, a major disadvantage is that respondents cannot be physically interviewed, and the true dynamics of an interview are lost. In addition, the experience of conducting the interviews is not the same when receiving the answers via a telephone or monitor. Nevertheless, 13 interviews were able to take place and sufficient material was obtained to make valid statements about the phenomenon of CC.

Second, due to the fact that interviewing was used as the qualitative research method, the researcher's subjectivity was put to the test. As the research progressed, some findings surfaced. However, in this phase it was necessary to maintain a helicopter view in order not to cling to certain knowledge gained. Nevertheless, the progressive insight has been useful in addressing certain aspects in the remaining interviews. Another research value that may be called into question is the generalizability due to the number of interviews. Despite the practical feasibility due to the CO-VID19 crisis, 13 interviews have been conducted but whether this is sufficient to reach general conclusions remains to be seen. More respondents could have guaranteed this generalizability.

Third, the approach at the beginning of this research was to make a European comparison by analysing and comparing the construction industries of some Northern-European countries. However, the lockdowns due to the CO-VID19 crisis threw a spanner in the works and it proved impractical to make this comparison. This limitation is also linked to the language barrier. This, however, feeds the suggestions for further research.

6.6 Suggestions for further research

As already discussed, the purpose of this thesis was to conduct a multiple-country case study of construction industries. The qualitative research methods would then consist of interviews and desk research that combined would lead to an overview of two European countries that have already focus on and implemented applications of CC and two European countries that have not yet started the transition. This approach stemmed from the following research gap. The Dutch inspection for the Ministry of Housing, Spatial Planning and the Environment conducted a research on German building practices in the Netherlands and its report expresses that these activities have to meet up with the standards of DIN-1045-1 (VROM, 2006). This report also states that the relationship between the Dutch and German legislation in the construction industry has never been investigated. Adding to that, a research on the restricting effect of legislation by institutions regarding the CE also expresses the need for cross-regional comparisons (Ranta, Aarikka-Stenroos, Ritala, & Mäkinen, 2018). As this proposed research can contribute to the knowledge of the topic and indicate which policies are suitable for the implementation of CC, it is recommended to conduct a multiple-country case study as further research. Another interesting topic that came up during the interviews was the suggestion to introduce some kind of database on quality, years of use, place of origin and current state. The use and analysis of data has taken a huge leap forward in recent years and some experts recommend that it should also be introduced into the construction industry. As an extension of adaptive design, it would useful to investigate whether a database of concrete structures is feasible and conducive to produce concrete even more sustainably.

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Appendix 1: Interview Guide

1. Introductie voor de geïnterviewde

Door de groei van de wereldbevolking en haar inkomen gebruikt de mens wereldwijd steeds meer materiaal als hulpbronnen. Het naleven van een lineaire economie zorgt ervoor dat veel hulpbronnen uitgeput raken en daardoor is er een grote vraag naar een nieuw economisch model, waarbij het gebruik van grondstoffen en hulpbronnen wordt verminderd: een circulaire economie. De ontwikkeling van deze duurzame economie is nodig tegen de vervuiling van de omgeving en verspilling van afval.

Een van de grootste sectoren die bijdragen aan vervuiling en verspilling is de bouw sector. In 2016 is ruim 36% van de totale vervuiling afkomstig uit de bouw, genaamd de construction and demolition waste (bouw- en sloopafval). Wanneer dit afval nader onderzocht wordt, blijkt dat het grootste bestanddeel van dit afval beton is. Aangezien beton het grootste aandeel heeft in bouw- en sloopafval, is het juist nodig om dit product circulair te maken. Echter, de invoering van circulair beton wordt belemmerd door huidige wet- en regelgeving. Mijn thesis gaat over de rol van wetgeving omtrent de implementatie van circulair beton.

Er is al een en ander bekend over circulair beton en er is bereidheid om over te stappen naar deze duurzame ontwikkeling, echter belemmert onder meer de Nederlandse regering de implementatie hiervan via beleid en wetgeving. Om de toepassingen van circulair beton te versoepelen, zijn er verbeterde standaarden, richtlijnen en wetten nodig. Daarmee kan de ontwikkeling van circulair beton ook bijdragen aan de transitie naar een circulaire economie. Op dit moment zijn er nog variërende opvattingen over het gebruik van circulair beton door een gebrek aan technologie, onvoldoende wetgeving en een gebrek aan coördinatie van afvaltransport.

Tegen het licht van twee transitie theorieën probeer ik in mijn thesis te onderzoeken wat de rol van wetgeving is op de implementatie van circulair beton. Circulair beton zijnde een duurzame ontwikkeling kan worden aangemerkt als een technologische niche-innovatie, die een belangrijke rol kan spelen in de switch naar een circulaire economie.

2. Bijdrage van de geïnterviewde

U kunt mij enorm helpen met mijn onderzoek door tijdens het interview inzicht te geven over uw kennis en raakvlak met toepassingen en de productie van circulair beton dan wel uw mening over de wetgeving omtrent circulair beton. De vragen zullen onder andere gericht zijn op het product circulair beton op zichzelf en over de wet- en regelgeving die een effect heeft op het gebruik van circulair beton in onze samenleving. Daarnaast kunt u benoemen hoe u denkt over de bijdrage die

circulair beton kan hebben op de transitie naar een circulaire economie. Al met al ben ik vooral benieuwd naar de belemmerende en/of bevorderende werking van beleid en wetgeving op circulair beton. Uw interview is uiterst belangrijk voor mijn onderzoek, waarvoor ik u graag wil bedanken.

3. Semigestructureerde vragenlijst

Vanuit het oogpunt van de research methode om semigestructureerde interviews te houden, wordt hierna een lijst met relevante vragen opgesomd. De bedoeling is dat elk persoon voor het interview een algemeen idee verkrijgt van de achtergrond van het interview. Vandaar dat de introductie van de Interview guide ook per e-mail wordt verstuurd naar de geïnterviewde voordat het interview wordt afgenomen. Deze e-mail wordt ook begeleid met de benodigde 'informed consent-verklaring'. Daarnaast is het mogelijk dat er van onderstaande lijst wordt afgeweken in verband met de verschillende werkgebieden van de geïnterviewden. Echter, de volgende vragenlijst zal grotendeels worden nagelopen:

<u>Algemeen</u>
- Voor welke organisatie werkt u en wat zijn de operationele activiteiten van het bedrijf?
- Welke functie vervult u voor de organisatie?

<u>Vragen met betrekking tot Circulair beton</u>
De vragen zijn bedoeld om een beeld te schetsen over de ontwikkeling van circulair beton op zichzelf.
- Wat is uw relatie of connectie met circulair beton?

- Hoe kijkt u aan tegen circulair beton? Vindt u het een positieve ontwikkeling?

- Ervaart u obstakels en/of onbenutte kansen met betrekking tot circulair beton?

Mijn thesis heeft als doel om te onderzoeken wat de rol van wetgeving is op het implementeren van circulair beton. Hierbij is het nodig om te weten hoe relevante personen de wetgeving over circulair beton ervaren. Wetgeving zoals Bouwbesluit 2012 en Europese Eurocodes.
- Wat kunt u zeggen over de rol van wetgeving op het gebruik en toepassingen van circulair beton?

- Bent u van mening dat de wetgeving aanpassing behoeft om optimaal gebruik van circulair beton te stimuleren? Zo ja, op welke manier moet de wetgeving gewijzigd worden?

<u>Vragen met betrekking tot de Circulaire economie</u>
Circulair beton kan een bijdrage leveren aan de transitie naar een circulaire economie. De ontwikkeling kan namelijk worden aangemerkt als duurzame innovatie.

- Wat wordt in uw ogen bedoeld met een circulaire economie?

- Bent u van mening dat er een belangrijke rol is weggelegd voor circulair beton in de switch naar een circulaire economie?

Mijn thesis gaat uit van twee transitie theorieën, waarbij wordt verondersteld dat een transitie een aantal systematische veranderingen inhoudt (innovaties) die de links tussen bedrijven, organisaties en instituties kunnen herstructureren.

- Welke actoren zijn volgens u van belang om een transitie te bewerkstelligen?

- Denkt u dat duurzame (technologische) innovaties de ruimte moeten krijgen om zich te ontwikkelen of juist gereguleerd moeten worden door de overheid?

Circulair beton kan worden gezien als technologie niche, waarbij het uiteindelijk de bedoeling is om 'normaal beton' te vervangen.
- Denkt u dat circulair beton een radicale verandering nodig heeft of dat het zich ontwikkelt via een langzaam proces?

- Denkt u dat het van belang is om niet alleen duurzaam beton in te voeren, maar dat de afbouw van bestaande praktijken ook aandacht verdient?

<u>Vragen met betrekking tot de invloed van circulair beton op de circulaire economie</u>

- Wat zijn de ideale omstandigheden voor circulair beton om een circulaire economie te stimuleren?

- Vindt u het wenselijk dat de Europese Unie zich bezighoudt met de regels en richtlijnen van het gebruik van circulair beton?

- Verwacht u dat circulair beton in de bouwsector de nieuwe standaard kan worden?

<u>Afsluiting</u>
- Heeft u nog vragen en/of aanvullende opmerkingen in het kader van mijn onderzoek?

Appendix 2: Consent Form

Radboud Universiteit

TOESTEMMINGSVERKLARING

Naam onderzoek: ***Master Thesis Interviews Circulair Beton***
Verantwoordelijke onderzoeker: ***Dion Wessels***

Verklaring deelnemer
Ik heb uitleg gekregen over het doel van het onderzoek. Ik heb vragen mogen stellen over het onderzoek. Ik neem vrijwillig deel aan het onderzoek. Ik begrijp dat ik op elk moment tijdens het onderzoek mag stoppen als ik dat wil. Ik begrijp hoe de gegevens van het onderzoek bewaard zullen worden en waarvoor ze gebruikt zullen worden. Ik stem in met deelname aan het onderzoek zoals beschreven in het informatiedocument.

Toestemming audio-/video opnamen

Ik geef toestemming om (s.v.p. aankruisen wat van toepassing is):

Ja	**Nee**	
☐	☐	*[video-/audio-]* opnamen van mij te maken voor dit onderzoek en deze opnames op te slaan volgens de geldende regels van de Radboud Universiteit
☐	☐	de geluidsopnamen uit te schrijven (transcriptie)
☐	☐	de anoniem gemaakte transcripten te gebruiken voor wetenschappelijk onderzoek
☐	☐	de *[video-/audio-]* opnamen te delen met prof. dr. Jan Jonker

overige opmerkingen: ……

Naam: …….. Geboortedatum:……..

Handtekening: ..... Datum:……..

Verklaring uitvoerend onderzoeker

Ik verklaar dat ik de hierboven genoemde persoon juist heb geïnformeerd over het onderzoek en dat ik mij houd aan de richtlijnen voor onderzoekers zoals verwoord in het protocol van de Ethische Toetsingscommissie Geesteswetenschappen.

Naam: ……..……..

Handtekening: ..... Datum:……..

Appendix 3: Interviewee overview

Interview number	**Company**	**Job title / Function (department)**
1	Demolition Firm	Owner & Director
2	Consultancy Firm & Knowledge Institute	Managing Director & Senior Advisor
3	• Concrete Agreement	• Chairwoman Former Minister of Housing, Spatial Planning, and the Environment Professor of Sustainable Innovation
4	• Concrete association • Manufacturer and supplier innovative concrete	• Chairwoman of the board • Managing Director
5	• Certification Office	• Creator Sustainable Concrete Advocate Promoter
6	Concrete Association	Initiator & Executor
7	Township	Policy Officer (Climate & Circular Economy)
8	Concrete Association	Secretary (Cement & Concrete) Technical Marketing Engineer
9	Manufacturer and supplier innovative concrete	Manager Technology & Sustainability
10	Construction group	Director (Development & Innovation)
11	Law Firm	Lawyer (Construction Law, Procurement Law)
12	Cement Factory	Deputy Director
13	• Concrete Agreement • National Institute for strategic policy analysis	• Progress committee • Senior scientific researcher Expert Circular Economy

• = to make a distinction in additional functions