CIRCULAR ECONOMY OR CIRCULAR CONSTRUCTION? HOW CIRCULARITY IS UNDERSTOOD BY CONSTRUCTION PRACTITIONERS

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The increasing popularity of the Circular Economy (CE) concept in construction has come with a myriad of publications and solutions that aim to contribute to the transition. However, CE is still debated and the interpretations and framings in practice seem to be equivocal. In this study we developed two models: one to map the societal challenges that are addressed by CE and one to map the solutions. Here, we take the interpretations of practitioners as a basis to define CE in the Dutch construction context by means of 20 semi-structured interviews. Results revealed that there is a wide variety of societal challenges addressed by CE. Circular solutions in the current construction industry turn out to be highly asset and material specific. However, there seems to be a shared understanding of the solution strategies that contribute to becoming circular. Nevertheless, this collection of solution strategies does only partly address the main challenges mentioned. The results imply that a better alignment between problems and solutions is necessary to address CE. Therefore, we urge for context-specific considerations of CE and for distinguishing between CE and circular construction.

Keywords: circular economy; sustainability; transition; system change

INTRODUCTION

Circular Economy (CE) has in construction become one of the main themes to address the many societal challenges the sector is facing (Thomson *et al.,* 2021). In the transition towards a circular economy (CE), the construction industry is an important sector, due to its large share in emissions, resource consumption, and generation of waste (Benachio *et al.,* 2020). The body of literature on CE in construction has grown exponentially in the past half decade (Mhatre *et al.,* 2021), resulting in a myriad of conceptualisations and solutions for a circular construction industry (Hossain *et al.,* 2020). Also in practice, CE has received much attention. Both in theory and practice, it is generally linked to closing resource loops to minimize resource depletion, waste creation and wider environmental impact while sustaining a healthy economy.

To cover the various conceptualisations and interpretations (Goyal *et al.,* 2021), it has been presented as an umbrella concept (Blomsma and Brennan 2017). This means

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that its value lies in connecting the various ideas that come under it. Corvellec *et al.,* (2021) take it even a step further and state that CE as a concept lacks substance of its own. Despite these critiques, CE objectives have been implemented in national and supranational policies. In the European construction domain, CE has been strongly embedded in waste and sustainability policy, albeit fragmentedly (Giorgi *et al.,* 2022). To make these strategies operational, a comprehensive substantiation of the concept is needed, for which a clear and shared meaning amongst actors is important. However, such substantiations turn out to be context-specific in practice, varying between, e.g., geographical areas, actors and sectors (Salmenperä *et al.,* 2021).

Although various definitions and conceptualisations of CE have been discussed in literature - also regarding construction - still little is known about conceptualisations in practice (Klein *et al.,* 2021). How do practitioners perceive and frame circularity in specific contexts? Which problems do they relate to when talking about CE? And which solutions do they see as contributing to CE? In this paper, we will look at the interpretations of CE throughout the Dutch construction industry. Using a design science research (DSR) approach, we develop two models: one to map the problems that CE aims to address and one to map the solutions that aim to solve these.

We apply these models to study the CE conceptualisation in the specific Dutch construction context. The scientific contribution of this study is hence twofold. First, it provides a systemic approach to map the problems and solutions related to CE in construction. Second, by a case application, it shows the problem-solution space of CE as perceived by practitioners in the Dutch construction industry. This enables us to synthesize the many interpretations and to suggest directions for action in construction in order to 'build back wiser' in reaction to the many challenges that face construction. As such, this research supports practice by providing a synthesis of the variety of interpretations and it gives substance to the CE concept in the construction industry.

Principles of Circularity in Construction

Given the framing as an umbrella concept and the fact that such umbrella notions contribute to change, both from a science and from a governance perspective (Rip and Voß 2013), it is little useful to list comprehensive scholarly definitions of CE to understand its meaning for the Dutch construction context. After all, to eventually foster change in a specific societally desirable direction, the understandings of the challenges and solutions within a particular context need to converge (Elzen *et al.,* 2011). Nevertheless, there are several conceptual underpinnings of the concept that are useful to understand the fundaments of CE in construction.

Although most CE in construction literature departs from general CE definitions, Pomponi and Moncaster (2017) acknowledged the specific challenges of the construction context in terms of project-based structure, long asset lifespans and discrepancies with the manufacturing logic that add to the complexity of the sector. According to them, this implies that the major CE challenges draw upon the role of people and institutions rather than technology. In a similar vein, Giorgi *et al.,* (2022) see the lack of alignment of current legislation, policies and decision-making processes with CE principles as a central challenge for the sector to become circular. Here, a major reason is the equivocality of the CE concept. However, this does not prevent most studies in construction from leaving out an explication of CE (e.g., Charef and Lu 2021; Çimen 2021).

To parse the CE concept into its various aspects, the problem space can be separated from the solution space (Wanzenböck *et al.,* 2020). Here, the problem space contains the societal challenges that CE aims to address, whereas the solution space contains the changes and innovations that aim to tackle the problems. Given that the societal problems are wicked by nature (Head and Alford 2015), they cannot be inherently solved, yet can be positioned in a hierarchical order leading to a complex problem space. The solution space, on the contrary, can, next to the various levels of aggregation, be seen on various levels of abstraction. These include innovations, solutions strategies and structural conditions in order to facilitate these strategies. However, amplified by the fragmented nature of the construction industry (Dulaimi *et al.,* 2002), specific solutions depend on the specific asset types and lifecycle stages. Therefore, rather than focussing on specific circular changes or innovations, the solution space in construction should be described in terms of abstract solution strategies. The waste hierarchy (i.e., R-ladder) is one of the most dominant ways of positioning types of solution strategies (Joensuu *et al.,* 2020; Potting *et al.,* 2017).

METHOD

Because listing definitions will not provide the actual understanding of the problems and solutions of circularity in the construction context, we used the Design Science Research (DSR) approach to generate and synthesize perspectives from practice. By applying the models to practice, a synthesis of the problem space and solution space can be deduced from the various perspectives. Below, the DSR methodology is explained, followed by our approach towards data acquisition and analysis.

Design Science Research Method

Not only does design result in output, the design process itself also contributes to generating knowledge (Cross 2001). As such, DSR is considered suitable to develop and synthesize a plurality of ideas iteratively. We applied DSR methodology as presented by Coenen *et al.,* (2020, Figure 1), who used it to develop a conceptual framework in the construction context. It starts by defining the problem and defining the objectives of the model. Next, the solution principles with respect to CE are developed, of which the results are shown in the previous section. Following an iterative process that is guided by theoretical knowledge, practical insights and creativity, the models are designed. This is followed by an application to a practical context, which is in our case the Dutch construction industry. This application to practice was in our case primarily informed by interviews. Finally, the overall design is evaluated by peers, which offers input for design alterations. In this paper, only the final design results are presented. Where the solution principles are primarily led by scientific literature, are the design, development and application informed by Dutch construction practice. These empirical steps are explained below.

Design Steps and Application of the Models

Using the concepts of problem hierarchy and R-ladder explained in the 'Principles of circularity in construction' section, a conceptual way to map the problem-solution space in two models was formulated. To apply the models in order to study interpretations of CE in the Dutch construction practice, we investigated the framings by practitioners using in-depth interviews. We used a purposive sampling strategy to select interviewees such that both the various subsectors and the actor types were covered (Campbell *et al.,* 2020). To reach such variety, we covered the actor categories presented in Kuhlmann and Arnold (2001).

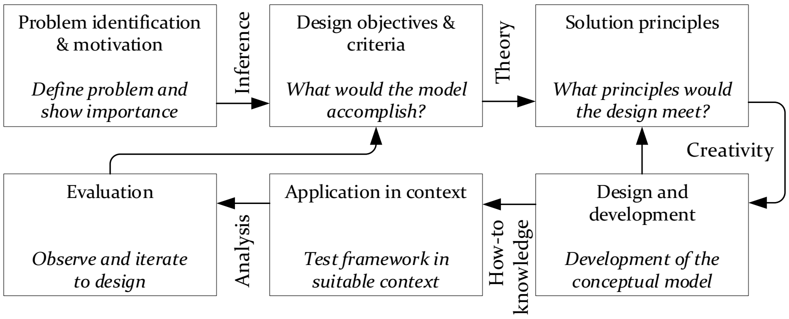

Figure 1: Design Science Research methodology (amended from Coenen et al., 2020)

After interviewing 20 individuals, saturation was reached on the various perspectives on the problems and solutions regarding CE in our context. This list included individuals with varying levels of experience with CE that offered a diverse representation of the sector. However, all individuals had in-practice experience with CE, such as cross-organisational working groups, pilot projects or sectoral networks. The list of interviewees consisted of four senior public construction clients, three public policymakers specialized in CE, four consultancies/engineering firms that were considered frontrunners in the sector, two contractor firms, two CE researchers, two network managers, a legal expert, a standardisation expert and an economic expert. All interviewees were asked for their informed consent before the start of the interviews and the data were treated in accordance with the Dutch General Data Protection Regulation.

In the interviews, we used the problem-solution space concept by Wanzenböck *et al.,* (2020) to distinguish the societal challenges CE aims to address (problems) from the changes and innovations that can be seen as circular (solutions) to substantiate the two models. The interviews led to a wide variety of answers and framings of those problems and solutions. The interview transcripts were coded using the problem-solution distinction and particularly aimed for revealing societal challenges and solution strategies in line with the 9 Rs (Potting *et al.,* 2017). The resulting coded quotations enabled us to link the problems and solutions to the models, to identify the number of interviewees that mentioned specific problems and solutions, and to see the applicability of the models. This enabled us to adjust them accordingly. This final step provided explanations for the problems and solutions found.

Design Application

The final versions of the two designs and their application to the Dutch construction context is presented and discussed in the next two subsections.

Problem space: challenges for CE to tackle in construction

The principles of the model aim to allow for collecting and listing all problems and challenges as well as to connect these in a hierarchical overview with respect to CE in a predefined context. The challenges addressed do not only aim at specific causes, but also address problems on various hierarchical levels in terms of causalities and aggregation. The wicked nature of such challenges makes it impossible to find final causes or solutions (Head and Alford 2015), so all challenges mentioned stem from something else and cause other challenges. Using the principle of causal hierarchy, we created a simplified scheme of the interrelations between the challenges that CE aims to address mentioned by the interviewees to illustrate the hierarchical positioning of and causal relations between the various challenges (Figure 1).

CE in the construction context was generally positioned by the interviewees within the environmental sustainability domain. Nevertheless, the underlying challenges mentioned appeared wider and more diverse. The most abstract categories that CE in the Dutch construction context seems to address are: (1) climate change; (2) depletion of the earth; (3) loss of biodiversity; and (4) welfare under pressure. All four trace back to wider concerns about a declining state of the living environment. Next to the problems that are plenty discussed in literature, such as resource depletion and carbon emissions, the application of the model revealed challenges that are barely addressed, such as loss of biodiversity, nitrogen pollution and increasing asset maintenance costs. Some causal relations were unexpected too, such as the relation between nitrogen emissions and increasing infrastructure costs. Drawing upon the interview transcripts, the most striking challenges and their relations are discussed below.

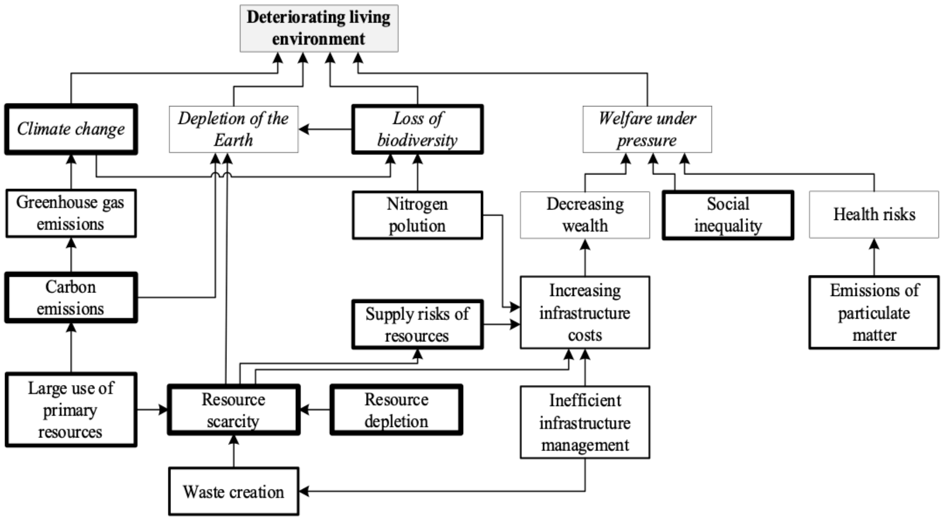

Figure 2: Problem-oriented model: hierarchy of challenges mentioned by interviewees for the Dutch construction context. Line width indicates the frequency mentioned.

A remarkably large number of interviewees mentioned social inequality and impact on labour division as challenges that are both affected by a transition towards circular construction and should be addressed by a future circular system. Furthermore, loss of biodiversity is often mentioned, particularly because of the impact of buildings and infrastructure on the public space. As such, interviewees argued, CE should contribute to preventing loss of biodiversity throughout the construction value chain and asset lifecycles, particularly when compared to the current linear way of working. Moreover, nitrogen pollution is mentioned by many interviewees to be tackled by circularity. This problem stands seemingly far from the scholarly CE definitions but becomes clear when considering the Dutch context. Here, the consequences of nitrogen emissions on construction continuity are, due to court ruling, large and can be reduced by decreasing the production of novel assets and the way of producing these. These nitrogen emissions (most notably ammonia and nitrogen oxides) affect the surrounding flora, which, in turn, affects the surrounding natural ecosystems.

Solution directions towards a circular construction sector

The second model aims at connecting the various solution strategies to become circular in the Dutch construction context. Following the section 'Principles of circularity in construction', these solution strategies are connected by asset lifecycle stage and the R-ladder. This resulted in a two-dimensional framework (Figure 3). After several iterations, we found that neither all strategies could be linked to single R strategies, nor to specific lifecycle stages. This led to the inclusion of the categories of 'full/multi asset lifecycle' and 'non/all/undefined R' in the model.

Interviews revealed ways in which the CE in the Dutch construction context was addressed in terms of change, innovations, processes and strategies. However, a respondent argued that throughout the sector there is consensus about the solution directions and strategies that can contribute to circular construction yet neither on their prioritisations nor their potential of becoming dominant in the transition. Therefore, the solution space is illustrated in terms of abstract solution strategies that contain many specific solutions. For example, the material recycling strategy contains, amongst others, concrete crushing, asphalt recycling and melting down steel. Figure 3 shows the case of circular construction in the Netherlands in terms of those strategies.

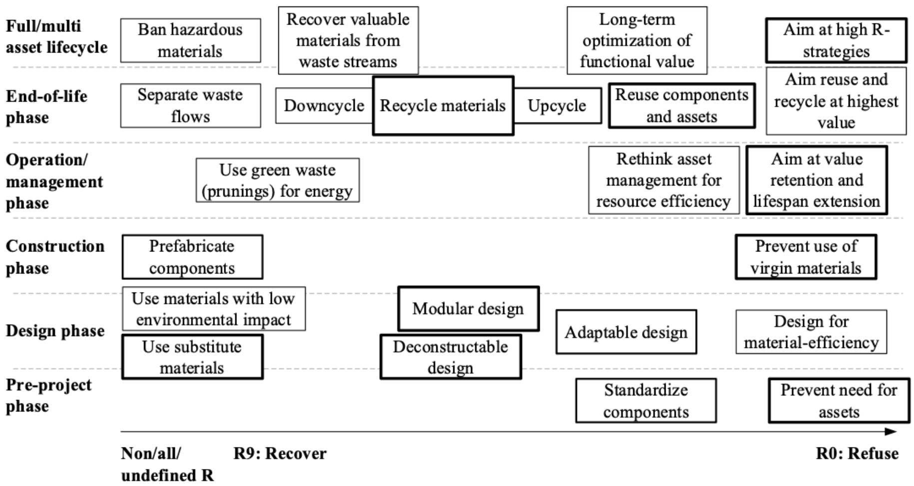

Figure 3: Solution-oriented model: strategies to make construction assets more circular. Line thickness indicates frequency of mentions

The most frequently mentioned strategies are 'recycling materials', 'reusing components', 'modular design', 'deconstructable designs' and 'substitute materials', such as bio-based materials. In terms of strategies, most aim at the highest Rs, being reducing, rethinking and refusing resource use. However, interviewees acknowledged that, although being most impactful, these strategies are the hardest to implement due to their large implications for practice. For example, preventing the need for assets requires ultimately a decrease of functional demand. This can only be achieved by fundamentally revising institutional and organisational processes. On the contrary, recycling strategies, for instance, can often be implemented without major changes in the institutions, supply chains, demolition processes and production processes.

There were several surprising strategies mentioned that are highly specific to the built environment. First, interviewees argued to revise the management of the vegetation, including mowing policy to stimulate biodiversity and using prunings for biomass energy. Second, industrialisation of the production process was mentioned, including the prefabrication of components to reduce waste and increase efficiency, and standardisation to ease maintenance and replacement of construction components. Third, there appeared to be a clear distinction by the interviewees between avoiding primary materials, including reuse, recycling and substitute materials on the one hand, and using any material at all on the other. Despite the seemingly small difference, its implications for strategies to use are enormous. Particularly the latter requires fundamental revisions on asset management and end-of-life practices.

In addition to these strategies, solutions were mentioned by interviewees that generate the conditions for those strategies rather than producing circular outcomes themselves. These are positioned particularly on institutional and organisational levels and include novel business models, shifts in attitude (or culture) towards reused components and revised maintenance practices. Also, policy interventions and changing legislation are mentioned on this level. However, since these merely stimulate or facilitate circular strategies and solutions, we did not include those in Figure 3 as circular solutions.

FINDINGS

Design Evaluation

The problem-oriented model has fulfilled its purpose of synthesizing the diverse set of challenges that are in construction practice thought to be addressed by circularity. Earlier versions of the model did not include an all-encompassing challenge that united all underlying challenges. However, by doing so in this final design, the model enables researchers and policymakers to link the CE concept to other concepts, such as sustainability or the energy transition. As such, it contributes to integrating the multiple societal challenges in a particular context. Moreover, it allows for comparison between understandings of concepts within contexts. Not only does this raise awareness for differences between those contexts, but it also enables researchers and policymakers to direct circular actions in line with a specific context.

The solution-oriented model allowed for generating insights into the various strategies and to link those to the more generic waste hierarchy and construction asset lifecycle stages. Its explanatory value lies in the ability to couple the strategies to various levels of circularity and to show which strategies are relevant when. Regarding the construction domain, this is particularly interesting because of the long lifespan of construction assets and differing lifespans of individual construction components (Joensuu *et al.,* 2020). Moreover, it indicates gaps in strategies. For example, in the case application, the emphasis by interviewees was on the design phase and end-of-life phase, while major circular improvements can be made during the asset life in terms of lifespan extension. As such, the model has the potential to compare and explain the solutions towards a CE between particular contexts and to direct policy.

The validity of the models can be increased in several ways. On the one hand, by extending it to other sectoral and geographic contexts and, on the other hand, by a quantitative approach to validate the results for the current context. Regarding the former, a similar sample can be used from another context, while, regarding the latter, a larger sample could help in increasing the validity of the case results. This can be done in the shape of large-scale surveys, but also using consensus methods such as the Delphi method or Q-methodology. In both ways, the categories of Kuhlmann and Arnold (2001) used in this study can be points of departure for selecting participants.

Understanding Circularity in Construction

By iteratively developing and applying two literature- and case-based conceptual models, the interpretations of the CE in the Dutch construction context were studied and synthesized. As such, this study on practitioners' interpretations of the circularity concept in the specific context has resulted in a comprehensive account of the challenges CE aims to address and the solutions that are aimed at becoming circular. Here, it seems that the challenges that are addressed by CE in Dutch construction practice go beyond both the challenges addressed in the formal policies (IenW and

EZK 2016) and what is in construction literature generally understood by CE (e.g., Çimen 2021; Joensuu *et al.,* 2020).

Considering the four top-level challenges found (climate change, depletion of the Earth, loss of biodiversity and welfare under pressure), particularly the link with biodiversity loss is barely mentioned in construction-related CE literature. Nevertheless, CE's implications for biodiversity should not be underestimated, considering both its potential impact and its limitations (Buchmann-Duck and Beazley 2020). Moreover, several challenges were mentioned that are rather construction specific. Examples are the nitrogen deposition that limits construction activities at specific locations and leads to delays and increasing costs and more general inefficiencies in the construction process and construction value chains.

The solutions indicate strategies that do largely match the solutions mentioned in literature (Benachio *et al.,* 2020; Gerding *et al.,* 2021). Several existing solution directions, such as recycling and reusing construction materials, components and assets are increasingly implemented in practice. However, the higher-R strategies (Reduce, Rethink, Refuse) are strongly advocated, but do not yet occur on a large scale in practice, particularly due to the large implications for construction practices. Solutions for circular construction appear to be, just as regarding the challenges, partly construction specific. Examples are the large focus on the long lifespan, which includes the optimisation of functional value of construction assets and their components as well was the asset management practices.

When considering the problem-solution space in which the various challenges and solution pathways need to converge and align for an effective transition (Wanzenböck *et al.,* 2020), there is a remarkable mismatch between problems and solutions. While the problem space covers this wide range of societal challenges, do solutions primarily address challenges regarding resource scarcity and waste creation. Despite the secondary effects that are beneficial for, e.g., reduction of greenhouse gas emissions, solution strategies that clearly contribute to, e.g., social inequality or nitrogen pollution are generally missing. Alignment is needed to effectively address challenges.

CONCLUSIONS

Our findings contribute to the large stream of CE research in the construction context by adding nuance to the often taken-for-granted definitions of circularity and by offering two models to study these in specific contexts. In addition, results indicate that the interpretations of CE were highly context-specific, aiming partly at construction-specific problems and proposing several construction-specific solution strategies. Therefore, we propose to take the contextual dimensions of CE more seriously when studying and implementing CE, considering both the spatial and sectoral dimensions. As such, it could be beneficial for conceptual integrity and policy directionality to explicitly distinguish circular construction from CE in order to reduce the equivocality. Moreover, the variety of problems and solutions do not have a direct fit, which calls for convergence to support the CE transition that is currently pushed by governments. The models developed in this paper could provide a starting point for mapping the problem-solution space and the context-specific elements.

The study has been conducted in a single context. Further research into the interpretations of CE in other sectoral or geographical contexts is needed to validate the models and to reveal the contextual differences of CE. Moreover, the study was based on 20 interviews. By extending the data sources, a more complete and further validated overview could be compiled on the problems and solutions that are linked to CE in the construction context. This would add nuance to the various problems and solutions covered under the CE umbrella throughout the sector and could reveal opportunities to align and converge the circular solutions. Nonetheless, we think that the current results show an appropriate overview of the most pressing problems and solution directions for the transition towards a circular Dutch construction context.

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