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## A case study research into organizing the actor network and decision-making process

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**Publication date**
2020

**Document Version**
Final published version

**Published in**
Proceedings of the 36th Annual Conference 2020 (ARCOM 2020)

ARCOM

ASSOCIATION OF RESEARCHERS IN **CONSTRUCTION MANAGEMENT**

# THIRTY-SIXTH ANNUAL CONFERENCE

# 2020

September 7-8

# PROCEEDINGS

Association of Researchers in Construction Management (ARCOM)

# PROCEEDINGS OF THE 36TH ANNUAL CONFERENCE

**Edited by Lloyd Scott and Christopher J Neilson**

First published 2020

978-0-9955463-3-2

Published by

ARCOM, Association of Researchers in Construction Management

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# IMPLEMENTATION OF CIRCULARITY IN THE BUILDING PROCESS: A CASE STUDY RESEARCH INTO ORGANIZING THE ACTOR NETWORK AND DECISION-MAKING PROCESS

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Circularity aims to reduce waste by closing and narrowing resource loops and by extending the lifetime of materials and products. As a consequence of this fundamentally different approach to construction practices, implementation entails a different organization of the building process. The purpose of this research is to make recommendations with respect to the actor network and the decision-making process to facilitate implementation of circularity in construction practices. First, a theoretical framework is developed to structure and prioritize decision-making to implement circularity based on resource and value strategies. Second, this framework is applied to three circular building cases in the Netherlands, relying on stakeholder interviews and documentation. These cases include a renovation project, a newly built project, and a transformation project. Third, analysis of the case study data demonstrates the actor network and decision-making process including the following aspects: Actors, resources, relations, positions, influence, and decision rounds. It can be concluded that: i) some conventional actors have acquired knowledge on circularity; and ii) expert actors emerged who have specialized in circularity. Both types of actors are a prerequisite iii) to implement circular strategies for the beginning and end phase of the building's lifetime; and iv) should be involved early on (in the design-making processes) to influence decision-making on circularity, especially concerning the long-lived layers of a building.

Keywords: Actor network analysis, circular construction, life cycle, sustainability

## INTRODUCTION

The building sector and its linear building process is responsible for a large share of the total waste production and CO2 emissions globally. De Ridder (2018) illustrates that the building sector generates about 45% of the total waste in the Netherlands, whereas it only contributes for 10% to the GNP. This demonstrates the relevance to reduce waste and deal responsibly with materials and resources. Contrary to a linear building process, a circular building process helps to cut down production and consumption rates (Mulhall and Braungart 2010). By closing material cycles this approach aims to deal more consciously with resources by means of prevention,

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Gerding, D, Wamelink, H and Leclercq, E (2020) Implementation of Circularity in the Building Process: A Case Study Research into Organizing the Actor Network and Decision-Making Process *In:* Scott, L and Neilson, C J (Eds) *Proceedings of the 36th Annual ARCOM Conference,* 7-8 September 2020, UK, Association of Researchers in Construction Management, 556-565

reusing, recycling, and decomposition; and generally, utilises waste (that is generated after demolition) as a resource (Mcdonough and Braungart 2009).

Although circularity seems to be a promising concept, some difficulties appear to arise during its implementation. Adams *et al.,* (2017) indicate several barriers inherent to the conventional organization of the building process. These are amongst others: lack of awareness and knowledge of circular building processes that designers and clients have, a fragmented supply chain, and lack of considerations and incentives at the start and end phase of the building's lifetime (Adams *et al.,* 2017). Additionally, Gorgolewski and Ergun (2013) explain that probably other actors should be involved, such as demolition or salvage companies that could aid in sourcing reused materials.

This research aims to analyse current circular practices and make recommendations for the actor network and the decision-making process to facilitate implementation of circularity in the building process. It is assumed that impact for circularity is maximized when circular strategies are already considered in the beginning of the building process. In accordance, the following research question is posed: "Which actors should be involved in design-making processes to ensure circularity throughout all phases in the building process?". A theoretical framework based on a literature study guides analysis of the actor network and decision-making process of the cases.

# THEORETICAL FRAMEWORK

A circular building approach can be defined as "a life cycle approach that optimizes the buildings' useful lifetime, integrating the end-of-life phase in the design and uses new ownership models where materials are only temporarily stored in the building that acts as a material bank" (Leising, *et al.,* 2018:977). The conventional end-of-life phase (in this paper termed 'post-phase'), resulting in waste, should therefore be reconsidered and replaced by reduce, reuse or recycle. Preparations to guarantee dismantling and reuse or recycling at the end-of-life could already be made in the design-making processes (initiation, preparation and design phase). In this paper, these early on phases of the building process are termed 'pre-phase'.

Several authors have defined circular strategies (CSs) to guarantee reduction, reuse and recycling. In relation to materials and resources, some strategies are focused on dealing with waste at the end of life, others are focused on preventing waste upfront (Addis 2006). Although authors use different words and slightly different categorizations, there seems to be agreement that 'reduce' (including prevention and reduction) is the main aim for dealing with waste, followed by 'reuse' (including repair and maintenance, reuse and redistribution, and refurbishment and remanufacturing), and 'recycling' (including recycling, cascading and repurposing, and organic feedstock) (Lüdeke-Freund *et al.,* 2018; Kraaijenhagen *et al.,* 2018; Bocken *et al.,* 2014; and Ritala *et al.,* 2018). The following CSs are identified based on the framework established by Lüdeke-Freund *et al.,* (2018): (1) maximize material and energy efficiency and dematerialization, (2) functionality without ownership / product service system (PSS) and extending product value, and (3) extending resource value and industrial symbiosis, see Table 1.

The CSs (1) maximizing material and energy efficiency and de-materialization both focus on preventing waste upfront. Value is created by reducing components and material input and output. This results in using less materials and resources, thereby narrowing resource loops. In concrete terms this can be applied by means of evaluating the need for a (new) building, using less materials, using lightweight materials, and obtaining efficient construction and manufacturing processes (Lüdeke-Freund *et al.,* 2018).

The aim reuse slows the resource loop down, since the lifetime is extended (Ness and Xing 2017). The accompanying CS (2) extending product value can be implemented by means of maintenance and repair or redistribution (Kraaijenhagen *et al.,* 2018). The CS (2) functionality without ownership, also known as a product service system (PSS), is aimed at providing a service instead of a physical product or component (Kraaijenhagen *et al.,* 2018). This strategy is based on the assumption that a product-oriented business is likely to increase the number of products sold, and thereby the materials used, whereas a service-oriented business is motivated to extent the product's lifetime and minimize maintenance.

*Table 1: Framework of circular strategies (CSs) and aims, patterns, design strategies, resource strategies, and value strategies, these can be applied as pre- and post-phase scenarios of a building's lifetime, based on and expanded from Lüdeke-Freund et al., (2018); Kraaijenhagen et al., (2018); Addis (2006); Ritala et al., (2018); and Bocken et al., (2016).*

| circular strategy (CS): | (1) maximize material and energy efficiency, de-materialization | (2) functionality without ownership / product service system (PSS), extending product value | | | (3) extending resource value, industrial symbiosis | | |
|---|---|---|---|---|---|---|---|
| aim: | reduce | reuse | | | recycle | | |
| pattern: | prevention and reduction | repair and maintenance | reuse and redistribution | refurbishment and remanufacturing | recycling | cascading and repurposing | organic feedstock |
| design strategy: | resource efficiency | long-life, life extension | | | life extension, technical and biological cycles | technical and biological cycles | biological cycles |
| resource strategy: | narrowing | slowing down | | | closing | | |
| value strategy | reduce component and material input and output | retain component value | | | retain material value | | |

The aim recycling requires processing of components into materials and subsequently into new components (Iacovidou and Purnell 2016). Since recycling often requires energy this option could not be considered entirely circular, especially if value is lost when components degrade in function (downcycling) (Lüdeke-Freund *et al.,* 2018; Adams *et al.,* 2017). According to Mcdonough and Braungart (2009) for biological nutrients the resource loop can be closed by means of decomposition. Therefore, biological and technical nutrients should be separated (Mcdonough and Braungart 2009). The CSs (3) extending resource value and industrial symbiosis both focus on aligning waste output from one industry as a valuable resource for another (Kraaijenhagen *et al.,* 2018).

Applying these strategies to buildings indicates differences in applicability for long-lived layers (site, structure, skin) and short-lived layers (services, space plan, stuff) (Brand 1994). According to De Ridder (2018) long-lived layers, with a lifetime that generally transcends the building's lifetime, should be reused. And short-lived layers, with a lifetime shorter than the building's lifetime, should be recycled with a minimum amount of energy (De Ridder 2018). For short-lived layers "suppliers can take responsibility [...] via take back schemes" by means of leasing or buy back guarantee (Leising *et al.,* 2018:984). Components and materials with a long-lived life cycle can be reused which is facilitated via marketplaces (Leising *et al.,* 2018).

# METHOD

By means of case study research, data is gathered to evaluate actor involvement and influence on decision-making in the building process with respect to circularity. The case study research evaluates three circular building cases in the Netherlands (Table 2). These cases where selected based on criteria to provide sufficient ground for comparison: their ambition for circularity, their recent realization, and their fairly similar context and comparable building process. The case study analysis is based on two main sources of data: documents, policies, (architectural) plans, and meetings notes (secondary data); and stakeholder interviews (primary data). The stakeholder interviews consisted of semi-structured interviews. In total 9 stakeholders were interviewed of which 3 interviewees were associated with each case (Table 2). The analysis, involving manual coding, proceeded according to a standard iterative process typically employed for qualitative data.

*Table 2: Cases for case study research*

| case | type | year | location | standard | interviewees |
|---|---|---|---|---|---|
| Case I: Townhall Brummen | renovation | 2013 | Brummen | cradle-to-cradle certified | two contractors, designer |
| Case II: The Green House | newly built | 2018 | Utrecht | building circularity index | client, designer, project manager |
| Case III: EDGE Olympic | transformation | 2018 | Amsterdam | BREEAM Excellent | client, designer, dismantler |

The semi-structured interview questions were formulated in line with relevant criteria gathered from theory on actor network and decision-making processes. Methods for studying the actor network can be found in the field of actor network theory. An actor is defined as "a social entity, person or organization, able to act on or exert influence on a decision" (Enserink *et al.,* 2010:80). An actor is involved, because he or she could offer something to construct the building. This offer is depicted as a 'resource', which is defined as "the practical means that actors have to realize their objectives" (Enserink *et al.,* 2010:81). A relation displays an indication of exchange of information or coordination between actors (Van Ruijven 2016). The positions of the actors in the actor network relate to their centrality in the network. Centrality is defined as "the number of connections between a node and other nodes" (Van Ruijven 2016:127). The actor with the highest number of relations is positioned centrally in the network. This actor can be defined as transformation agent, who acquires support from others and mobilizes the actor network (Kraaijenhagen *et al.,* 2018). Influence on decision-making is depicted by the size of the node.

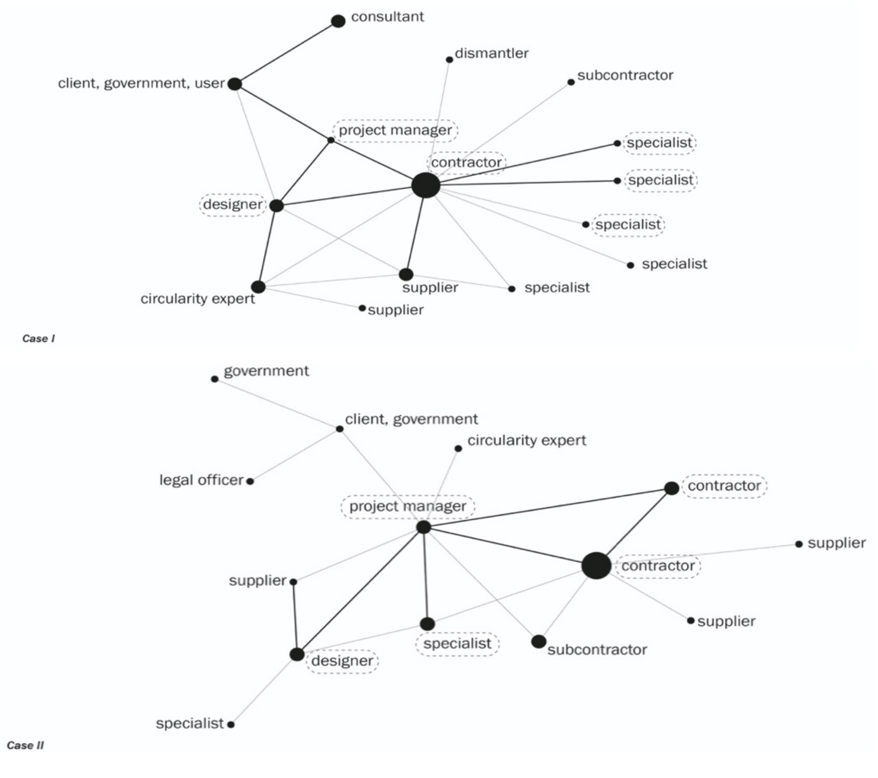
The work of Teisman (2000) discusses models for unravelling complex decision-making processes. Its relevance for this study can be found in its identification of the decision-making process, including the involvement and roles of multiple actors and their influence on decision-making (Teisman 2000). Contributions to this work by Klijn and Koppenjan (2016) is utilized to visualize the decision-making process and identify rounds. A round is a moment in time when the most crucial decision(s) regarding a topic is/are made. The content of the decision-making process regarding circularity is identified by relating the rounds to certain CSs. These rounds are positioned on the x-axis. This helps to identify when decisions were made and to evaluate the relation between decisions made early on (in the pre-phase) and their subsequent implementation.

# FINDINGS

## Composition of Actor Network for Circular Building Processes

These three cases show that different types of actors are part of the actor network. Figure 1 shows the actor networks as concluded from the case study research. The three cases all involved, to some extent, experts with knowledge on circularity. In Case I these expert actors are: A circularity expert, consultant, and dismantler. In Case II this is a circularity expert. And in Case III these actors are: A circularity expert, dismantlers, an investor, and reclamation experts. In addition, these cases involved conventional actors who have acquired knowledge on circularity. In Case I this was a specialist, and supplier. In Case II this was a subcontractor, and suppliers. And in Case III this was a subcontractor. These actors exert moderate or little influence on decision-making for these cases.

Within the actor network some actors work in close collaboration, formally called 'project team'. From the cases, it can be concluded that the actors part of the project team have higher influence on decision-making. The project team, for each case, consisted mainly of conventional actors: clients, contractors, designers, project managers, and specialists regarding building technology and services and structural engineering. Besides, some actors who are not part of the project team do have moderate influence: in Case I a circularity expert, client, consultant, and a supplier; in Case II a subcontractor; and in Case III a dismantler. Interestingly, these actors consist of expert actors and conventional actors who have acquired knowledge on circularity. Thereby, these actors all provide circularity-related resources.



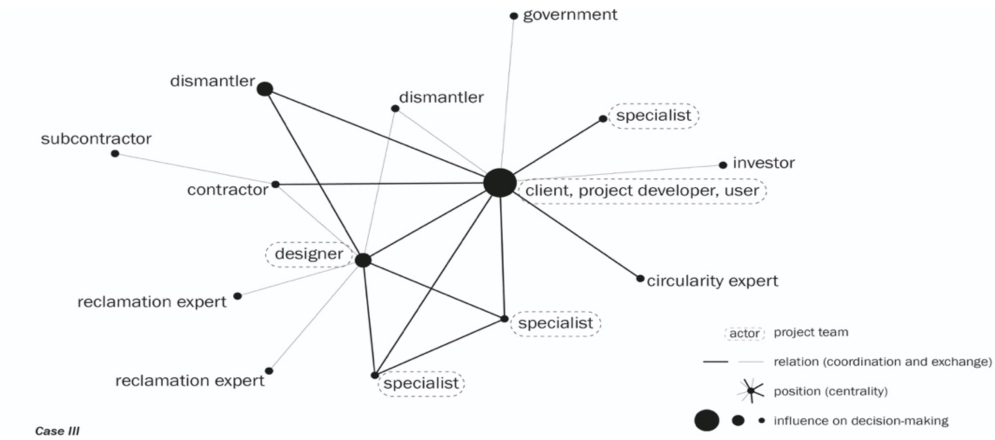



*Figure 1: Actor network including involved actors, their relations, positions, and influence on decision-making, for Case I (Townhall Brummen), Case II (The Green House), and Case III (EDGE Olympic)*

A high degree of coordination and exchange of information (thick lines) regarding circularity mainly occurs within the project team and to a lesser extent between the project team and surrounding actors. The following surrounding actors do coordinate frequently with project team actors (these do not all concern actors with resources to implement circularity): A circularity expert, client, consultant, and supplier (Case I); a supplier (Case II); a circularity expert, contractor, and dismantler (Case III). From these cases it remains uncertain whether already established relations are beneficial to implement circularity. Relations outside the actor network are established to facilitate in reuse of secondary components. This is facilitated, as occurs from these cases, by two aspects: 1) the proximity of secondary components in terms of distance, and 2) the external network of the involved actors. For all the three cases it appears that both contractors and designers facilitate in organizing reclamation of secondary components.

Actors positioned centrally, thus actors with the highest number of relations, are as follows: contractor (Case I), project manager (Case II), and client (Case III). For these cases, these actors act as transformation agents and fulfil a leading role. In Case I and III, the transformation agent also exerts the highest influence on decision-making. In Case II, the role of transformation agent and power to influence decision-making is separated and held by two actors; the project manager and contractor, respectively.

**Decision-Making and Implementation of Css in the Building Process**

Analysis of the decision-making process over time investigates the assumed benefit of early on decision-making with respect to circularity. Figure 2 shows the decision-making process over time as concluded from the cases. Several rounds have taken place to decide on beginning and end of life scenarios. Rounds are depicted by identifying decisions on CSs as determined by the theoretical framework. As can be seen in Figure 2, decisions to (1) maximize material and energy efficiency and dematerialization have been made for these cases relatively early on. These rounds are positioned in the pre-phase. However, different design strategies were applied in the three cases to reach this overarching goal of using less materials.

Decisions on the CSs (2) functionality without ownership and extending product value have been made for all three cases, although implementation differs.

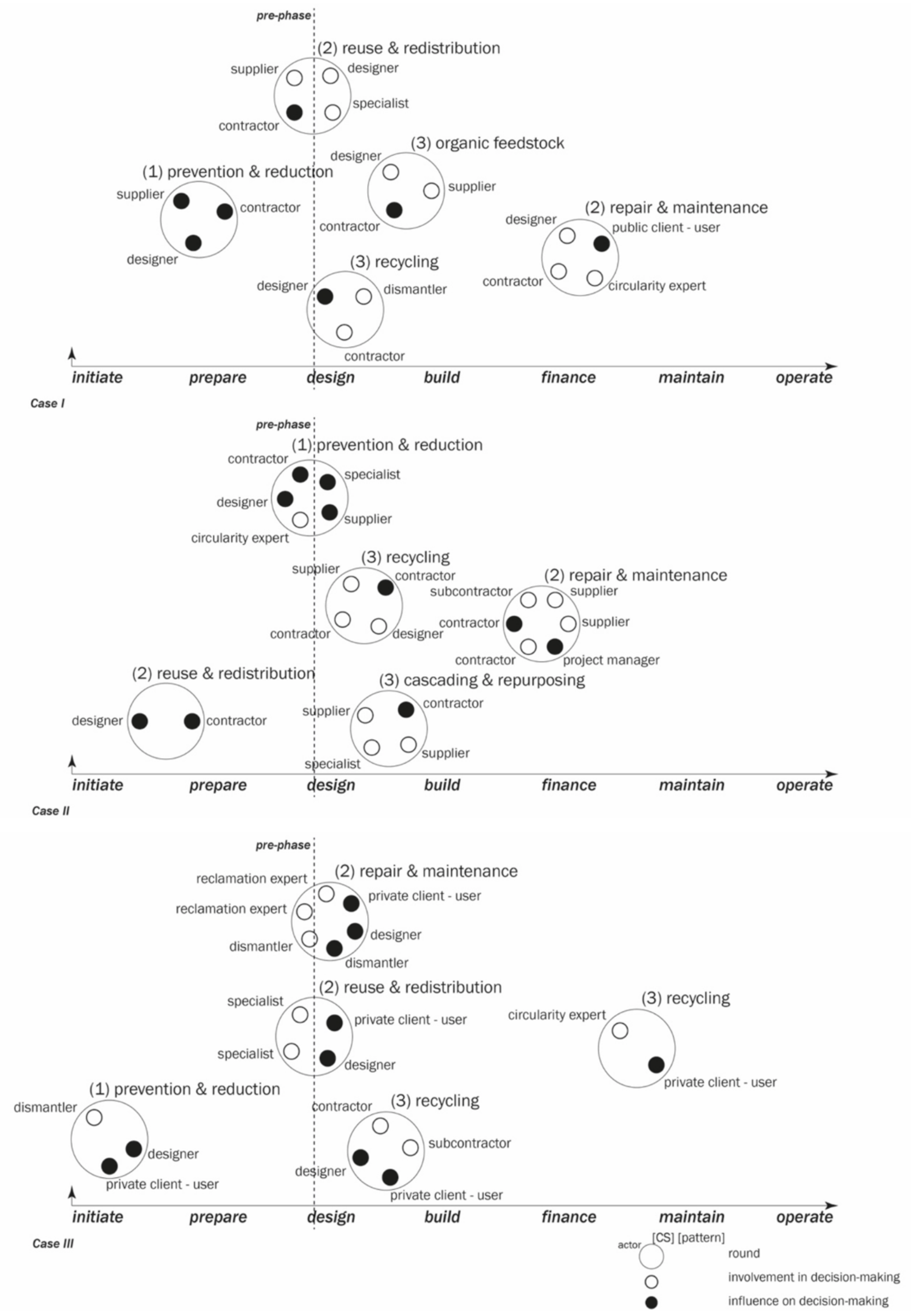



*Figure 2: Decision-making process including involved actors, topics (CSs and accompanying pattern), and rounds positioned over time, for Case I (Townhall Brummen), Case II (The Green House), and Case III (EDGE Olympic)*

Case I and Case II used the CS (2) to make agreements on delivery and take-back of components, determine end of life scenarios (i.e. securing demountability), and lay down ownership. Although, in the end this CS was not properly implemented in the case of Case I. Case III involved several expert actors to decide on CS (2) as a beginning of life scenario for the building, resulting in implementation of the design strategy long-life. The cases demonstrate that CS (2) was effectively implemented if the decision round took place early on. Later in the process, opportunities for implementation of this strategy appeared limited due to risks experienced by non-traditional ownership structures.

Proper application of CSs (3) extending resource value and industrial symbiosis in the three cases is questionable, since its implementation mainly resulted in downcycling. In particular, in Case III the functioning of secondary materials was degraded after recycling. Regarding Case I, some materials were applied based on their ability to degrade biologically at the end of life. This resulted in use of bio-based materials. In Case II, decisions were made to separate biological and technical nutrients to facilitate recycling.

These cases show that in the pre-phase designers and contractors are involved. Besides, in Case I a specialist and supplier are early on involved. In Case II this concerns a circularity expert, specialist, and supplier. And in case of Case III a dismantler, reclamation expert, and specialist were involved early on. For all three cases the client initiated the project by proposing a circular or sustainability related vision, such as tendering a sustainable building, demanding a demountable building, or demanding closed resource loops.

Table 3 provides an overview of CSs that have been decided upon and were in most cases also implemented in relation to the building's layers. Some CSs have primarily been applied to short-lived layers and others primarily to long-lived layers. As can be seen CSs (1) and (2) with the aim to facilitate reduce and reuse have been mainly applied to long-lived layers. Whereas CSs (2) and (3) to facilitate reuse and recycling were decided upon and implemented for short-lived layers, although complete implementation of CSs (2) for short-lived layers proved to be difficult.

*Table 3: Implementation of CSs for each case in relation to the building's layers*

| | site | structure | skin | services | space plan | stuff |
|---|---|---|---|---|---|---|
| case I | - | (1), (2) | (2) | (2) | (3) | (3) |
| case II | - | (1), (2) | (2), (3) | (2), (3) | (2), (3) | (2), (3) |
| case III | - | (1), (2) | (2) | (2) | (3) | - |

These findings demonstrate that for these cases the pre-phase is important to secure circularity in design-making processes and make provisions for the beginning and end of life scenarios of the building. For these cases, it can be concluded that all rounds that took place early on have been implemented. Rounds that took place later on have not all been implemented. Rounds that took place later on in the building process and were implemented, mainly relate to financial or documentation aspects (such as a decomposition manual) in relation to the CSs and mainly concerned short-lived layers. Rounds regarding materials aspects (take-back management, and waste handling and processing) that took place later on, were not implemented thoroughly.

## DISCUSSION

In addition to the current body of literature, the case study research identifies that some conventional actors acquired knowledge of circularity. These actors already developed to cope with renewed insights on how to deal with waste and facilitate implementation of circularity. This implies that when conventional actors will acquire in-depth knowledge to implement circularity themselves, instead of relying on expert actors, these experts become superfluous. Obviously, universities play a role in providing conventional actors (i.e. designers, contractor, specialists) with knowledge of circularity. Unfortunately, current state of practice is that conventional actors have not (all) acquired knowledge about circularity yet while playing a crucial role as part of the project team. As the three cases clearly demonstrate, actors' part of the project team have higher influence on decision-making. In case these conventional actors lack expertise on circularity, expert actors should be involved in order to be able to implement CSs. In order to increase their influence on decision-making these actors should become part of the project team, or at least be able to influence decision-making. Moreover, these cases particularly demonstrate that contribution of their resources regarding circularity is enlarged, if these experts are involved early on.

With respect to the wider construction industry, this study generates insight into how to accelerate the transition process to move from a linear to a circular building process. As the three cases clearly demonstrate, (expert) actors could influence decision-making on circularity via their position in the project team, via their relations, or via actors with influential resources (i.e. building policy and legislation). Furthermore, this transition concerns a shift of attention to the end of life phase of a building. The end of life phase should be integrated in the pre-phase of the building process. Since early on decision-making on implementation of CSs could mitigate risks as perceived from involvement of unconventional actors (i.e. dismantler), non-traditional ownership structures (PSS), and secondary materials.

# CONCLUSION

From the case analysis it can be concluded that the following actors should be involved and be influential in the design-making processes of circular building projects: i) conventional actors who have acquired knowledge on circularity; and ii) expert actors in the role of advisors, consultants, and assessors. Involvement of the following expert actors is, according to the cases, beneficial: circularity experts, dismantlers, investors, and reclamation experts. In addition, these cases demonstrate that implementation is facilitated when the following conventional actors are involved but only if they have knowledge of circularity: specialists, subcontractors, and suppliers. Furthermore, transformation agents could accelerate implementation of circularity by exploiting their central position to acquire support from others and mobilize the actor network.

Decisions-making regarding circularity is based on the following CSs: (1) maximize material and energy efficiency and dematerialization; (2) functionality without ownership / product service system (PSS) and extending product value; and (3) extending resource value and industrial symbiosis. Implementation of these CSs is benefited if decisions on CSs are made early on (preferably in the pre-phase). Subsequently, during the pre-phase these expert actors and other actors with expertise on circularity could help decide between the various beginning and end of life scenarios. This means that most decisions regarding reduce, reuse, and recycle with respect to short- and especially long-lived layers should be made early on in the process.

# REFERENCES

Adams, K T, Osmani, M, Thorpe, T and Thornback, J (2017) Circular economy in construction: current awareness, challenges and enablers, *Waste and Resource Management*, **170**(1), 15-24.

Addis, B (2006) *Making Reclamation, Reuse and Recycling Happen in Building with Reclaimed Components and Materials*, London: Earthscan, 55-86.

Bocken, N M P, de Pauw, I, Bakker, C and van der Grinten, B (2016) Product design and business model strategies for a circular economy, *Journal of Industrial and Production Engineering*, **33**(5), 308-320.

Bocken, N M P, Short, S W, Rana, P and Evans, S (2014) A literature and practice review to develop sustainable business model archetypes, *Journal of Cleaner Production*, **65**, 42-56.

Brand, S (1994) *How Buildings Learn - What Happens After They're Built*, London: Penguin Books.

De Ridder, H (2018) Naar een circulaire bouwsector, *In*: P Luscuere (Ed.) *Circulariteit: Op Weg Naar 2050?* Delft: TU Delft, 209-217

Enserink, B, Hermans, L, Kwakkel, J, Thissen, W, Koppenjan, J and Bots, P (2010) *Actor Analysis in Policy Analysis of Multi-Actor Systems*, The Hague: Lemma, 79-108.

Gorgolewski, M and Ergun, D (2013) Closed-loop materials systems, *In*: *Sustainable Building Conference,* Coventry: Coventry University, 235-243.

Iacovidou, E and Purnell, P (2016) Mining the physical infrastructure: Opportunities, barriers and interventions in promoting structural components reuse, *Science of the Total Environment*, **557-558**, 791-807.

Klijn, E H and Koppenjan, J (2016) *Governance Networks in the Public Sector*, New York: Routledge.

Kraaijenhagen, C, van Oppen, C and Bocken, N (2018) *Circular Business: Collaborate and Circulate 4th Edition*, Nieuwkoop, Netherlands: Ecodrukkers.

Leising, E, Quist, J and Bocken, N (2018) Circular Economy in the building sector: Three cases and a collaboration tool, *Journal of Cleaner Production*, **176**, 976-989.

Lüdeke-Freund, F, Gold, S and Bocken, N M P (2018) A review and typology of circular economy business model patterns, *Journal of Industrial Ecology*, **00**(0), 1-26.

Mcdonough, W and Braungart, M (2009) *Cradle to Cradle: Remaking the Way We Make Things*, London: Vintage Books.

Mulhall, D and Braungart, M (2010) *Cradle to Cradle Criteria for the Built Environment*, Nunspeet: Duurzaam Gebouwd.

Ness, D A and Xing, K (2017) Toward a resource-efficient built environment: A literature review and conceptual model, *Journal of Industrial Ecology*, **21**(3), 572-592.

Ritala, P, Huotari, P, Bocken, N, Albareda, L and Puumalainen, K (2018) Sustainable business model adoption among S&P 500 firms: A longitudinal content analysis study, *Journal of Cleaner Production*, **170**, 216-226.

Teisman, G R (2000) Models for research into decision-making processes: On phases, streams and decision-making rounds, *Public Administration*, **78**(4), 937-956.

Van Ruijven, T W J (2016) Multidisciplinary Emergency Management: A Comparative Study of Coordination and Performance of on-Scene Command Teams in Virtual Reality Exercises, Enschede, Netherlands: Gildeprint.