Circular Business Models

Building a Database of Case Studie

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CIRCULAR BUSINESS MODELS REPORT

Building a Database of Case Studies

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Circular Business Model Report

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0. Introduction

Knowledge and research related to circular economy (CE) have grown exponentially in the last years. Universities and specialised research institutes, such as the Ellen MacArthur Foundation, have been a fundamental boost to this production. In this regard, the Faculty of Architecture at TU Delft is not an exception. In the last years the topic of Circular Economy has been positioned as a leading roadmap for research and education involving students, researchers and lecturers. A clear example is the Circular Built Environment group, a platform for researchers at the Faculty of Architecture and the Built Environment of TU Delft and the Amsterdam Institute for Advanced Metropolitan Solutions (AMS Institute) with the aim to promote the development of knowledge towards a circular built environment that enables the design of future buildings, cities and infrastructures.

Nonetheless, as the research increases, it also becomes a challenge to have an overview and grasp the variety of approaches towards circular economy adopted by staff and students. Similarly, an increasing number of new projects and related business models have arisen in practice, however, it is not clear yet their level of development or even implementation within the circular economy goals.

The Circular Business Model Project (CBMP) is an initiative developed by the Campus Research Team for the Façade Leasing project. The former one, is part of the Public Real State chair in the department of Management in the Built Environment (MBE).From April until October 2019, the team worked in the construction and visualisation of two databases related to circular business models (CBM) in the built environment: (1) Thesis reports from students of the MSc track Management in the Built Environment, and (2) Case studies of circular business models extracted from literature review.

The decision of focusing on the particular field of business models within the circularity is twofold. Firstly, the development of new business models has been identified by scholars as one of the key elements that would enable the transition towards the circular economy (Bocken, de Pauw, Bakker, & van der Grinten, 2016; Geissdoerfer, Vladimirova, & Evans, 2018). Whilst an important part of the literature has focused on the conceptualisation and definition of circular business models, little is known about the level of development or implementation of these models in practice. The experience in the project Façade as-a-product (Azcarate-Aguerre, 2017; Azcarate-Aguerre et al., 2018) has shown the need for more applied research in the topic. Secondly, the development, implementation and/or evaluation of business models is part of the core knowledge and expertise of the MBE department, therefore, it is relevant to gain a better understanding of the state of the art of this topic for research and educational purposes.

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This project is guided by two main goals. The first goal responds to the academic-oriented gap and focuses on the organisation of the knowledge production at the MBE Department, and subsequently the Faculty of Architecture and the Built Environment regarding circular economy and new business models. Within this production, we gave special attention to the visualising of the work produced by graduate students. The second goal responds to the scientific-oriented gap related to the level of information about the implementation of circular business models in the built environment. The goals are the following:

1. To identify, organise and visualise the information related to circular business models produced by graduate students primarily by the MBE department, then the Faculty, and the University, respectively.

2. To select and categorise circular business models in the built environment in order to identify their level of development and/or implementation, and their respective circular strategies.

The report is structured in three main parts. The first section, Circular Business Models: knowledge production at TU Delft answers the following question: What is the state of the art of the intersection of CE and BMs in the research developed by TU Delft graduate students?. The section describes the selection and categorisation of master thesis reports, followed by the presentation of main quantitative and qualitative findings. The second section, Circular Business model implementation and development, answers the question: Which new business models in the context of Circular Economy in the built environment have been developed, used and/or evaluated?. The section presents a database of case studies selected from literature review. This is followed by a discussion regarding the characteristics of the selected business models, identifying their level of development and contribution to the transition to circular economy in the built environment. The third part, Lessons and learnings for future research, is a synthesis of the previous findings, followed by a discussion about learnings for both, education and scientific production.

Photo by Juan Azcárate-Aguerre

1.1 Introduction and methods |

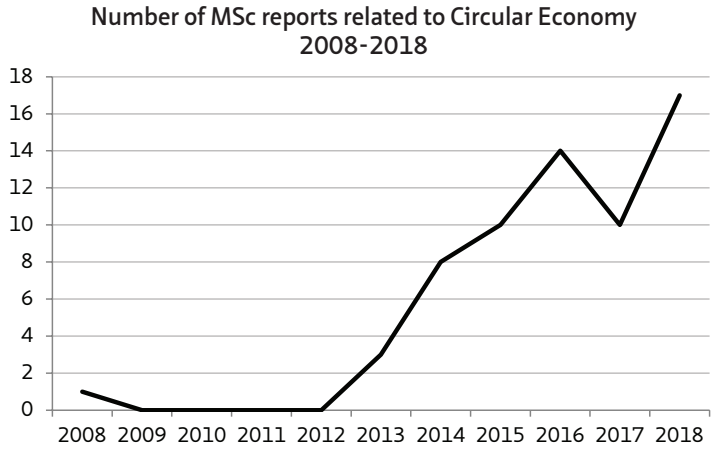
Section	Description	Parameters
INFORMATION	General information about MSc report and programme	Title, supervisors, graduation year, MSc programme, track and Faculty; participation in companies and/or research projects
FOCUS	Main topics addressed by the reports from the perspective of circular economy and new business models	Circular Built Environment levels and approaches. The categories considers : - Built environment levels: materials, components, buildings, cities. -Tools and methods: technology, design, economy, management, flows & resources, society & stakeholders. Components of the business model that are analysed or considered for the graduation project: customer segments, value propositions, channels, customer relationships, revenue streams, key resources, key activities, key partnerships, cost structure.
APPROACH	Methods and final results used to answer the research question	Methodology. Literature review, case study, design/proposal Product. Conceptual framework, operational model, assessment model, policy/practice recommendations, design/prototype.
RESEARCH SUMMARY	Relevant information about the research project	Problem statement, objective and research question, main findings, and brief description of the project.
THEORETICAL FRAMEWORK	Selection of main guiding concepts	Concepts. Authors and conceptual schemes
LEVEL OF DEVELOPMENT	Indication of the level of development in the case of products (supply-driven research) or a business model (demand-driven).	Technological readiness level – Concept, pilot/prototype, implementation in progress, implemented, evaluated Development – Business model. Theory, developed, used, evaluated
CASE STUDIES	If applicable, identification of case studies used in the research	Name, location, type of industry (construction, services, consumer products, food), type of construction sector (if applicable), and relevance of the case for the research topic.
RESULTS	Relevant findings	Images and/or schemes

Information collected per Master student report.

Source: authors' elaboration.

This section focuses on the question: What is the state of the art of the intersection of Circular Economy and Business Models in the research developed by TU Delft graduate students?. In order to answer the question, we created a database from two main sources: (1) Existent databases from the MBE Department and the Circular Built Environment group; (2) Search in TU Delft repository by topic (keywords: circular economy, business models, management) and by mentors who have worked or are working on this topic.

After the first selection, a database of 69 reports that address the topic of Circular Economy in the Built Environment was built. This database also includes reports from other faculties that seemed relevant for the topic. These reports were identified during the search, and they address the topic of Circular Business Models from the fields of industrial design, industrial ecology and technology and policies. From this database, 21 reports which are closely related to circular business models, were selected for an in-depth content revision. In order to organise the information, we used the programme File Maker Pro, a database manager that also provides a visual organisation of files sheets (see appendix). A shorter version of this file sheet is used to summarise the information and make it available in the format of a downloaded file in the university/ faculty websites. Table 1 shows the information collected from every report.



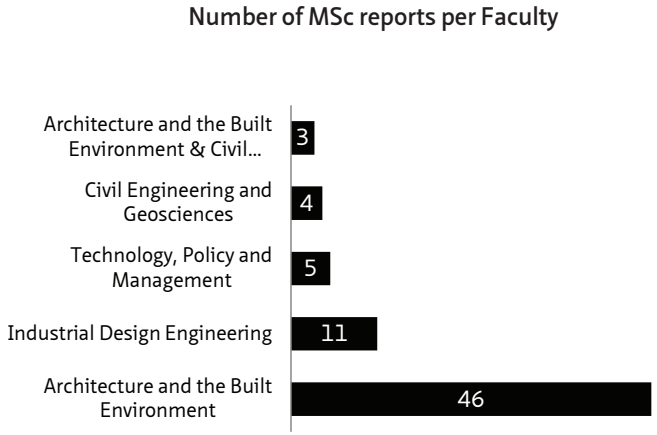


Figure 1. Total number of MSc reports related to CE organised by year (left) and by Faculty (right) .

Source: authors' elaboration.

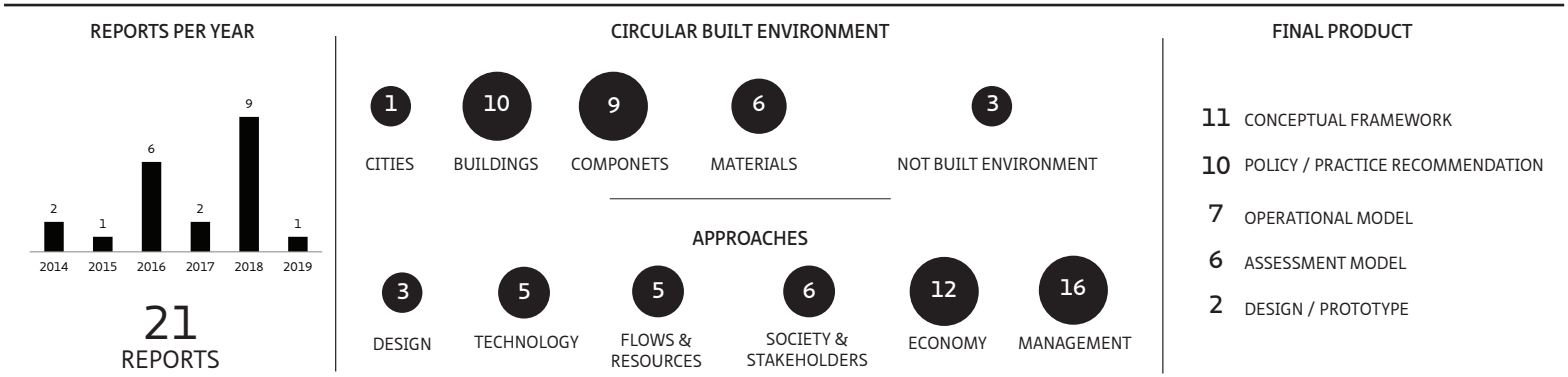


Figure 2. General information about selected MSc thesis organised per year, circular built environment classifications, and final products.

Source: authors' elaboration.

The first database of 69 reports shows an important increase of number of students working on the topic of circular economy, since 2013 (see Figure 1). The research was carried out in the MSc tracks at the Faculty of Architecture (46), Industrial Design (11), Technology, Policy and Management (5), Civil Engineering and Geosciences (4), and a group of theses developed jointly between Architecture and Civil Engineering programmes (3). From the database, we selected 21 thesis that refer to the topic of Circular Business Models for our analysis. General information of these reports is summarised in Figure 2.

The classification using the Circular Built Environment framework shows that the main scales of interest are buildings (10) and components(9), followed by materials (6), and cities (1). Additionally, some thesis refer to circular business models in general(3), and therefore, are not considered within the built environment categories. In terms of approaches, given the scope of the search, a higher number of reports focus on management and economy, as expected. Nonetheless, it is important to point out that only three reports address the problem from the design perspective which is also reflected on only few research products that considers design solutions or the construction of prototypes. On the contrary, final products from the reports are mostly conceptual frameworks and poly/practice recommendations.

Some of the graduation projects developed their research with external companies such as OVG Real Estate, Governmental Building Agency (Rijksvastgoedbedrijf), Dura Vermeer, Klöckner Metales ODS Nederland (ODS NL) and KPMG Sustainability. Besides the supervision, the companies also provided access to information, facilities and staff otherwise unreachable. These partnerships allowed students to deepen into the nature of the barriers and enablers facing by the companies during the implementation of circular ambitions in the business models on in the product development.

In terms of potential scientific output, it is important to mention the value of the reports as a source of case studies. From the 21 reports 40 case studies were identified, from which 21 are in the construction sector. The access to real-life case studies is valuable to understand the level of implementation, especially in the construction sector where barriers and difficulties of implementation have been clearly stated by scholars and practitioners. Furthermore, the reports developed qualitative approaches using interviews and focus groups, which provide valuable information of on-going processes and implementation challenges.

1.2 Findings: thematic clusters

In relation to the content, students' questions and goals focused on how to implement the transition towards circular economy. There is consensus about the need for practical translation of the concept of circular economy in order to enable its implementation. In this regard, the main challenges are related to the need for better understanding and knowledge by the entities in charge of this transition, and the need for new business tools and models to make this transition financially and organisationally possible.

The approach to the topic of circular business models can be summarised in three thematic clusters: (1) from the perspective of business model innovation identifying types, patterns and added value, (2) from the perspective of management identifying key processes and organisational systems to achieve circular business models, and (3) from a supply-driven perspective, providing solutions through the development of products and prototypes.

Within the first cluster, building model innovation (see Figure 5), the research problem was centred around the need for changes in the core of business processes to adopt circular economy, and along with it, the need for new business models, frameworks, tools and the respective entities to enable its implementation. In this regard, students' work focused on different phases of this transition: from the analysis of the capacity of existent frameworks to the proposal of new tools. Whilst one student focused on understanding the extent to which existent frameworks (e.g., Business Model Innovation) are useful to cope with the challenge of designing and implementing CBMs (Mentink, 2014), others focused on the development of tools to help companies to understand, improve and communicate their circular business models and sustainable ambitions better (Ackermans, 2016). Similarly, from the analysis of existent circular business models implemented by private firms, students focused on raising awareness among companies through the understanding of the barriers and enablers regarding the implementation of circular business models (Cha, 2017), or the identification of circular business patterns to facilitate decision-making processes (Huitema, 2018). Among the main findings, a better knowledge of circular business models can contribute to: identifying the opportunities and understanding the logics of this new market (Huitema, 2018), improve the quality of CBMs

Figure 3. Word cloud with key concepts addressed by MSc students reports.

Source: authors' elaboration.

Figure 4. Organisation of students' reports in thematic clusters following three main approaches: business model innovation, management and supply-driven.

Source: authors' elaboration.

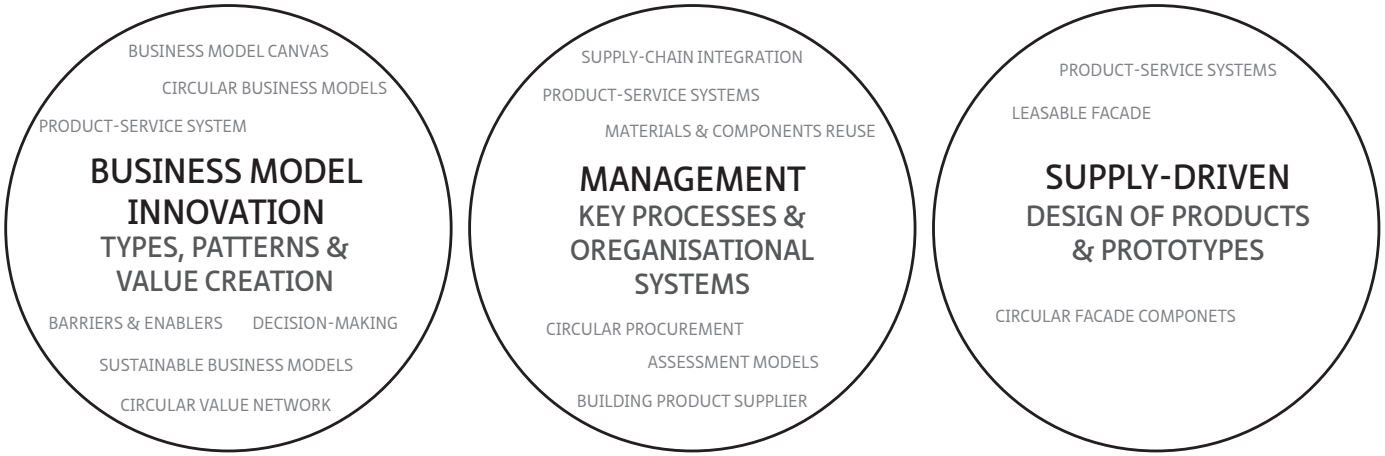


Figure 5. Perspectives and research problem focus developed by the students in the first thematic cluster: business model innovation.

Source: authors' elaboration.

#1
BUSINESS MODEL INNOVATION
TYPES, PATTERNS & VALUE CREATION

Perspectives	Research problem focus	Students
General business model innovation in circular economy	- The need for changes in the core of business processes to adopt circular economy	Mentik, 2014
	- The need for new business models, frameworks, tools and entities to enable its implementation	Ackermans, 2016; Cha, 2017; Huitema, 2017
Circular Business models in the construction sector	- Assess the risk associated to the transition from product to service models	Djoegan & Van den Reek, 2016; E. Michael, 2018
	- Propose business models prototypes with special attention to the role of the service provider	Van den Brink, 2016; Stigter, 2016; De Grauw, 2015

concepts (Mentink, 2014), or reveal the importance of circular value network in the implementation of CBMs (Cha, 2017) among other findings. However, conclusions also emphasised in the early condition of this transition, the lack of radical business models, and the need for more support and information at decision-making level.

In the reports that refer to circular business models in the construction sector, business models are analysed within the Product-Service System framework (Stahel, 2010; Tukker, 2004). Reports focused either on assessing the risk associated to the transition from product to service models, or proposing business models prototypes with special attention to the role of the service provider. In the first group, students focused on testing the financial feasibility of participating in the development of a circular building offering buildings products based on sale and buy back, and leasing (Djoegan & Van den Reek, 2016), and in the analysis of the risks in circular leases associated with the duration and cost of the lease, and the ownership of the product (E. Michael, 2018). In the design-oriented group, students proposed business models prototypes that organise the role of the service provider at the building level and analyse their organisational effects (van den Brink, 2016), developed a performance-service system applicable to the educational sector considering operational, organisational and financial levels (De Grauw), or designed a financial section of a business models in which building product providers operate within the set boundary conditions of the circular economy (Stigter, 2016).

Main findings showed that the implementation of product-to-service business models in the building industry requires a different mind-set in both, client and supplier throughout the entire supply chain (Djoegan & Van den Reek, 2016). It also showed that financial uncertainties on lease solutions depend, among other factors, on the resource prices and on the usability of the materials at the end-of-loop situation (Stigter, 2016), furthermore, the main bearer of the risk is the owner of the product (E. Michael, 2018). In general terms, there is consensus that the implementation of CE in the building sector under current conditions is likely to be, in the short-term, restrained to basic to intermediate services business models (van den Brink, 2016), rather than radical business strategies.

In terms of conceptual frameworks, the Business Model Canvas (Osterwalder, Pigneur, & Tucci, 2005) was primarily used by the students to frame and define in general terms the components of a business model. In order to understand the new challenges of circular economy, students referred to the concepts, and respective classification frameworks of Sustainable Business Models and Circular Business Models (e.g., Bocken, Rana, and Short (2015), Bocken, Short, Rana, and Evans (2014), Lüdeke-Freund, Gold, and Bocken

Figure 6. Perspectives and research problem focus developed by the students in the second thematic cluster: management and organisational systems.

Source: authors' elaboration.

#2

MANAGEMENT

KEY PROCESSES & ORGANISATIONAL SYSTEMS

Perspectives	Research problem focus	Students
The need for information for better decision-making in the public and private sector	- Identification of re-development potential of materials and components to allow closed-loops in the building sector	P. Michael, 2018; van Hemmen, 2016; Disseldorp, 2018; Gremmen, 2018
	- Decision-making gaps in Dutch public procurement	van Haagen, 2018; van Veenen, 2018
The need for coordination between actors for better supply-chain integration	- Improve the role of circular-related actors and networks such as the contractor or the building product supplier	van der Wijk, 2018; de Blok, 2018; E. Leising, 2016

(2019)). In terms of specific business model strategies, the conceptual framework of Product-Service Systems (e.g., Baines and Lightfoot (2013), Tukker (2004)), was the most utilised by the students to refer to the implementation of circular economy in the building sector.

In the second cluster, management and organisational systems (see Figure 6), an important body of the reports focuses on filling knowledge gaps of circular models implementation. This is mainly addressed from two perspectives: the need for information for better decision-making in the public and private sector, and the need for coordination between actors for better supply-chain integration. In relation to the first one, the lack of information for decision-making in the private sector is addressed from the identification of the re-development potential of materials and components to allow closed-loops in the building sector. Students' reports aimed at the development of a flowchart to enhance the reuse potential of components and materials for circular demolition processes (P. Michael, 2018), the design of a model to assess the quality of flows of materials in the built environment (van Hemmen, 2016), the construction of an indicator to assess circular redevelopment potential for Dutch heritage buildings (Disseldorp, 2018), and the identification of barriers, drivers and opportunities for circular demolition and integration of components for reuse (Gremmen, 2018). In the public sphere, decision-making gaps were addressed in the topic of public procurement, with research projects about the level of room for circular economy within Dutch procurement laws (van Haagen, 2018), and the development of guidelines for a more effective public procurement of circular infrastructure (van Veenen, 2018).

Main findings pointed out the relevance of the indicators and assessment models to improve decision-making processes in the construction sector by increasing the awareness of materials' values (van Hemmen, 2016), by getting objective data of the applied materials' characteristics and corresponding conditions of the building elements (Disseldorp, 2018), and by identifying

the potential of retrieving and reusing them (P. Michael, 2018). Even though the potential of circular demolition and component reuse have been pointed out, barriers persist in relation to behavioural and societal dimensions. A shift in the mind-set of governments and companies is required in order to stimulate component reuse (Gremmen, 2018). In the case of circular procurement, relevant elements to improve public procurement conditions are the intensive cooperation and collaboration, and transparency between contracting entities and tenders, the strategic vision of circularity by (semi) public institutions (van Haagen, 2018), and the identification of expert contracts to carry out the circular ambitions (van Veenen, 2018).

The second group of reports focuses on improving the role of circular-related actors and networks, such as the contractor or the building product supplier. The role of the contractor is analysed from the identification of the main factors that can stimulate the adoption of circular building methods within its inter-firm network (van der Wijk, 2018). The role of the real estate developers as service providers is explored through the development of operational models that support real estate developers to perform this role in the context of Product-Service systems (de Blok, 2018). From the supply-chain management perspective, students also examined in what way supply chain collaboration in the built environment can contribute to the transition to circular economy in the Netherlands (E. Leising, 2016).

Among main findings, reports emphasised the need for long-term supply-chain collaboration and long-term value creation for customers, implying a mind-set change in real estate developers to ensure incentives towards long-term service delivery (de Blok, 2018), and in the extension of responsibilities along larger parts of the supply chain in new ownership models around materials to actually close supply chains (E. Leising, 2016). In this long-term partnerships, the role of the general contractor may take the role of an integral manager to manage social network, supply chain and building processes (van der Wijk, 2018).

Leading sources used by students come from supply-chain management with emphasis on how to manage technological innovation and the knowledge flow among stakeholders. Business model innovation relies on having adequate and up-to-date management systems. In this regard, the literature used by the students focuses on the relationship between internal and external actors and the need for further system integration in order to achieve the best value in delivering services. Supply and demand chain integration(e.g., Ruben Vrijhoef and Koskela (2000), R. Vrijhoef and De Ridder (2005), Segerstedt and Olofsson (2010)) appears as a relevant way to deal with complex processes in the context of new circular models, which

Figure 7. Perspectives and research problem focus developed by the students in the third thematic cluster: supply-driven and product development.

Source: authors' elaboration.

#3
SUPPLY-DRIVEN
DESIGN OF PRODUCTS & PROTOTYPES

Perspectives	Research problem focus	Students
Proposal and design of circular facades components and their respective business models	- Analysis of the potential of the facade as a Product-Service system by evaluating a leasing facade project in educationa buildings	Azcarate-Aguerre, 2014
	-Improvement of an existing curtain wall system in order to make the principles of circular economy applicable	R. Leising, 2017

need comprehensive and long-term approaches that go beyond the traditional one-off approach of projects in the fragmented construction sector. Another approach is the use of the conceptual steering model and its adaptation to circular building projects (e.g., De Leeuw (2002), Heurkens (2012)) to draw the relationships between internal and external actors under specific context conditions. A second group of sources comes from the concepts of sustainable building adaptation (e.g., Wilkinson, Remøy, and Langston (2014)), and circular demolition processes (e.g., Kühlen, Volk, and Schultmann (2016)).

Finally, the third cluster: supply-driven and product development (see Figure 7), presented the least amount of reports, and focused on the proposal and design of circular façades components and their respective business models. Two approaches were developed: the analysis of the potential of the façade as a Product-Service system by evaluating economic, functional, energetic and strategic advantages of a leasable façade in educational buildings (Azcárate-Aguerre, 2014), and the improvement of an existent curtain wall system of ODS NL company in order to make the principles of CE applicable (R. Leising, 2017).

Although the potential of leasing of products and services has been proven by other industries, findings showed that main limitations in the construction industry are related to the financial and industrial capacity of the service provider, the specific regulations within his jurisdiction, the interest and type of client he can expect to deal with, among others (Azcárate-Aguerre, 2014). Furthermore, as shown in the case of ODS Netherlands, the development of circular products requires substantial changes in the companies' business strategies from a 'sell faster model' to a more 'service-based approach' whereby the end of life is integrated (R. Leising, 2017).

1.3. Conclusions

This section presented the way how MSc students addressed in their final reports the topic of circular business models in the built environment from the faculty of Architecture and the Built Environment, Industrial Design, Technology and Policy Management and Civil Engineering and Geoscience. Based on 21 reports, we discussed approaches to the topic organised in three thematic clusters: (1) from the perspective of business model innovation identifying types, patterns and added value, (2) from the perspective of management identifying key processes and organisational systems to achieve circular business models, and (3) from a supply-driven perspective, providing solutions through the development of products and prototypes. The results showed a wide variety of points of view to address the development of new business models according to circular ambitions. In order to achieve this transition, students pointed out the relevance of having indicators and assessment models to improve decision-making processes in the construction sector, the need for better knowledge of circular business models to understand the logic behind this new market, the need for long-term supply chain collaboration and long-term value creation, and the need for a mind-set change in both client and suppliers throughout the entire supply chain.

Photo by Ossip van Duivenbode

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2. Circular Business models: implementation and development |

2.1 Introduction and methods |

This section focuses on the research question: Which new business models in the context of Circular Economy in the built environment have been developed, used and/or evaluated?. In order to answer this question, a literature review was carried out in publication databases such as Scopus and Web of Science (key words: Circular business model, built environment, business model innovation). The search was complemented with relevant literature identified in the MSc reports, consolidating a database of 125 items which considers 81 scientific papers, 15 books, 4 technical reports, and 21 MSc thesis.

From this literature body, case studies of circular business models were selected and identified. The first search considered the selection of 97 case studies. The cases were categorised using the definition of Circular Business Model strategies developed by Bocken et al. (2016). The use of this categorisation draws a line between cases that only represented an example of sustainable business models, and those that refer to circular business models. After this, a database of circular business models was consolidated to 74 cases. It is important to note that students reports contributed with almost the same amount of cases as the papers; 35 cases were identified in students reports, 34 in papers, and 5 in both sources.

In the following sections the main findings related to the description, characteristics and type of the case studies are presented.

| 2.2 Circular Business Models: frameworks and definitions

The need for new business models has been identified as necessary and relevant to materialise the transition towards circular economy, which represents a radical change, and therefore, a complete different way of doing business (Bocken et al., 2016; Geissdoerfer, Vladimirova, et al., 2018). In the literature review, this is reflected in numerous definitions around the concept of circular business models. This conceptual differentiation comes from the need of supporting companies through their business model innovation processes by mapping the necessary activities, challenges and tools (Geissdoerfer, Vladimirova, et al., 2018). Nevertheless, since the process of implementation is rather complex, the definitions are multiple and scholars do not agree on one comprehensive framework (Nussholz, 2017). This is reflected in overlapping frameworks (see for example Bocken et al. (2016); Geissdoerfer, Vladimirova, et al. (2018); Lüdeke-Freund et al. (2019)), which make an attempt to distinguish between the grayscale definitions in the ladder of business model innovation, sustainable business model and circular business models. Geissdoerfer, Vladimirova, et al. (2018) define this relationship as an imperfect overlapping between concepts and its categories as Figure 8 shows.

Existent frameworks refer to circular business model archetypes (Bocken et al., 2014; Tukker, 2004), circular business tools (Bocken, Strupeit, Whalen, & Nussholz, 2019), strategies (Bocken et al., 2016; Reim, Parida, & Örtqvist, 2015), and patterns (Lüdeke-Freund et al., 2019) , as an attempt to understand and operationalize business model innovations to achieve circularity. With regards the construction sector, it is important to note the framework proposed by Geissdoerfer, Morioka, de Carvalho, and Evans (2018) . The framework focuses on the integration of circular business models and supply chain management discussing their interrelation and the contribution to the dimensions of sustainability (Geissdoerfer, Morioka, et al., 2018). However the majority of circular business models categorisations and definitions are proposed from the field of industrial design and industrial ecology focusing on product design. This also shows the need for more precise and adjusted frameworks to the building sector.

The definitions of circular business models are mostly developed from the differentiation of the actions and strategies involved in a linear and a circular economy. In this regard, the framework of slowing, closing and narrowing resources developed by Bocken et al. (2016) presents a clear and comprehensive categorization of business models strategies placing the focus on how the resources flow through a system. This framework, that builds on the work by Stahel (1982, 2010) and by McDonough and Braungart (2010), is developed in the field of industrial design, and specifies the actions

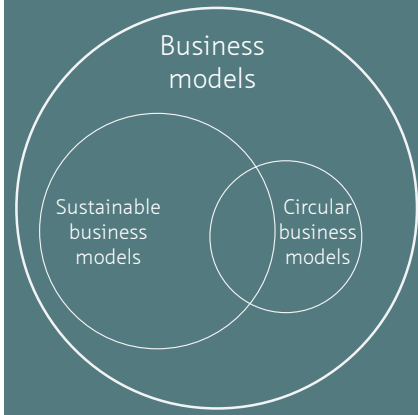

Figure 8. Business models, sustainable business models and circular business models as overlapping concepts and categories based on Geissdoerfer, Vladimirova, et al. (2018).

Source: authors' elaboration.

needed to achieve circularity for circular product design by defining circular approaches (slowing, closing and narrowing) and respective business model and design strategies that fit in these approaches.

According to Bocken et al. (2016) while slowing loops is about prolonged use and reused of goods over time through the design of long-life goods and product life extension, closing loops is about reuse of materials through recycling. Narrowing loops is about resource efficiency aiming at reducing resource use in the product and its process. The authors pointed out that an important difference between slowing and narrowing loops is the time dimension. The later accepts the speed of resource flows and therefore 'resource efficiency can easily lead to further speeding up of linear resource flows (selling more of a more efficient product), resulting in very little overall savings' (Bocken et al., 2016, p. 310). Narrowing loop is therefore, not considered as a circular approach by the authors.

Within the approaches, six circular business model strategies were identified. The business model strategies for slowing resources loops encourage product life and reuse of products through business model innovation considering four strategies: (1) Access and Performance Model, (2) Extended product Value, (3) Classic Long Life, (4) Encourage Sufficiency. Business model strategies for closing loops are related to the capacity of capturing value from a linear business model by-products or waste, considering two strategies: (5) Extending Resource Value, and (6) Industrial Symbiosis. The strategies are defined in Table 2.

We used this framework to categorise the case studies selected in the literature review. Although the framework does not come from the construction sector, it provides sufficient clarity in the CBMs definitions and a level of hierarchy that allows us to differentiate and position our examples in the six categories of circular business model strategies. Additionally, since the cases selected are not exclusively limited to the construction sector, a more comprehensive framework is indeed more appropriate for this purpose.

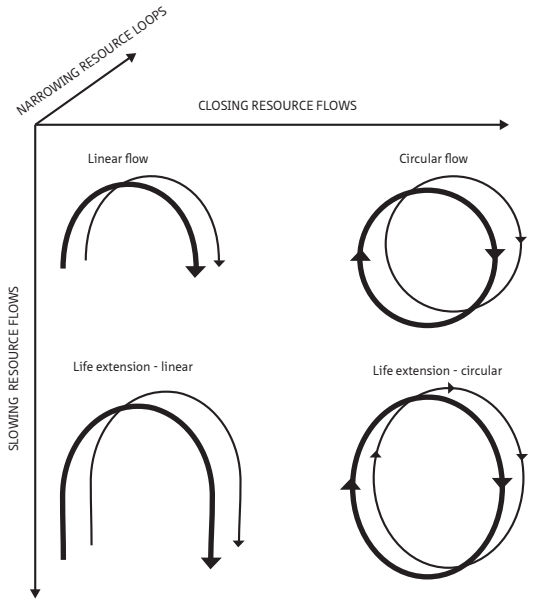

Figure 9. Categorisation of linear and circular approaches for reducing resource use developed by Bocken et al., 2016.

Source: authors' elaboration.

	Approach	Strategy	Description (Bocken et al., 2016)
Sustainable BMs	Narrowing loops	Resource Efficiency	Reducing resource use associated with the product and the production process, it does not address the time dimension.
Circular BMs	Slowing loops	Access and performance model	Providing the capability or services to satisfy user needs without needing to own physical products
		Extending product value	Exploiting residual value of products- from manufacture, to consumers, and then back to manufacturing - or collection of products between distinct business entities
		Classic long-life model	Business models focused on delivering long-product life, supported by design for durability and repair for instance
		Encourage sufficiency	Solutions that actively seek to reduce end-user consumption through principled such as durability, upgradability, service, warrantees and reparability and non-consumerist approach to marketing and sales
	Closing loops	Extending resource value	Exploiting the residual value of resources: collection and sourcing of otherwise wasted materials or resources to turn these into new forms of value
		Industrial Symbiosis	A process-orientated solution, concerned with using residual outputs from one process as feedstock for another process, which benefits from geographical proximity of business

Table 2. Approaches and strategies defined by Bocken et al. (2016).

Source: authors' elaboration.

2.3 Building a case study database | An overview across cases

The database consolidated 74 cases of circular business models with different levels of circular ambitions, different circular strategies and diverse levels of implementation. In this regard, it is important to point out that the cases and their classification is an exploratory exercise that attempts to understand the state of the art of a small sample of case studies while using a pre-defined framework. We based the classification of the cases on the information provided by the literature review.

The 74 cases were organised in four main types of industry: consumer products (31), construction (29), services (9) and food (5). Figure 10 shows a summary of the case studies by strategies and industry type, and Table 3 displays the case information. It is important to note that the numbers indicated in the strategies refer to the times that a specific strategy was applied by the cases, in which one case can develop more than one strategy.

Looking into slowing loops approaches, the strategy of Access and Performance Model was the most applied especially in the consumer product and construction industry. In the cases related to the consumer products, servitization models were developed in a diverse range of products such as clothing, air systems, lighting, bicycles, equipment, or furniture, among others. For instance, the case of Philips Lighting developed the 'Pay per lux' model in conjunction with the long life LED lighting, converting revenue from point of sale to a service model. The collaboration included RAU Architects and installation partners Cas Sombroek who integrated sensors and control systems to maximise the use of natural light (Ackermans, 2016; Bocken, Schuit, & Kraaijenhagen, 2018; Huitema, 2018). Similarly, the case of M-Use® Elevators- Mitsubishi Electric Europe represents a leasing model in which MEE retains ownership of the product to increase reusability of components while offering longer product life and quality (E. Michael, 2018; Ploeger, Prins, Straub, & van den Brink, 2017) . Similarly, Another example is the pilot lease and remanufacturing system for baby strollers by the Bugaboo company. In the 'Bugaboo flex plan' strollers would be leased for two consecutive use cycles and refurbished after each lease cycle (Bocken et al., 2018; Sumter, Bakker, & Balkenende, 2018). Despite the differences, the projects aim at transferring maintenance responsibilities and control of the product to the manufacturer, in which the customer pays for a specific and customised service, and not for the product itself.

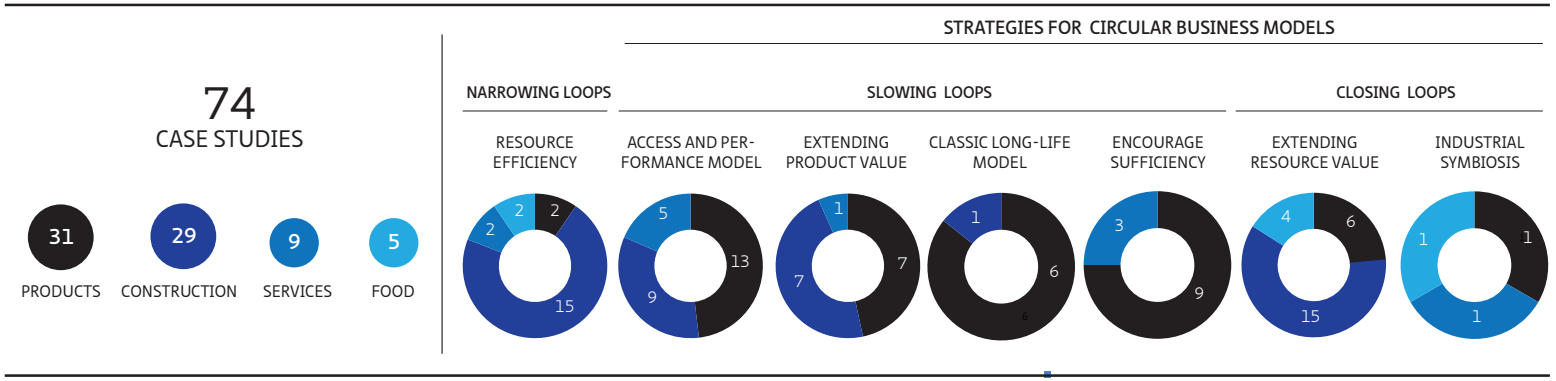

Figure 10. Summary of business models identified organised by type of industry (left) and by circular business model strategies for narrowing, slowing and closing loops (right).

Source: authors' elaboration.

The second most applied strategy for slowing loops is Extending Product Value, which is often combined with Access and Performance Models. The use of take-back guaranties to ensure the return of the product to the manufacturer to exploit their residual value is a common example. For instance, in the case of Cisco - IT systems, 100% of old systems are picked up by Cisco for free to be refurbished or recycled (Ackermans, 2016; Huitema, 2018). In the case of the headquarters of Tennet, a take-back guarantee is incorporated within the procurement process for all its furniture and infill (Prins, Mohammadi, & Slob, 2015). The case of The Green House in Utrecht is another example in the construction sector. The pavilion was designed to be dismantled and their elements reused after 15 years (Disseldorp, 2018; Gerding, 2019). An example that combines access and performance strategy with take-back guarantees is the case of MUD jeans focused on minimizing the environmental and societal cost of fast fashion. Customers pay upfront memberships fees which includes free repairs and three end of lease term solutions. The company recycles the jeans when worn down reusing the fibres (Bocken et al., 2018; Brown, Bocken, & Balkenende, 2018).

The Classic long-life model focuses on delivering long-lasting products with high levels of services for repairs and maintenance (Bocken et al., 2016). This strategy was the least applied among the cases and it usually appeared in our database combined with other strategies for slowing resources either Access and Performance Model, Extending Product Value or Encourage Sufficiency. For instance, in the case of M-Use® Elevators, the possibilities of repairs and maintenance, under the framework of the leasing, aim at having longer product life and quality. In the case of Fairphone, the social enterprise designs smartphones in order to maximise

product lifetimes by incorporating modularity and ease of repair (Brown et al., 2018; Huitema, 2018). The cases of Martela Oyj Fi Furniture and Orangebox Office furniture, focus on providing durability and reliability by designing customised long-life products (Jensen, Prendeville, Bocken, & Peck, 2019; Whalen, 2017).

Encourage Sufficiency strategies have a similar approach as Classic-Long Life model regarding long-lasting products, however, the main difference resides on the emphasis in a non-consumerist approach to marketing and sales in which companies focuses on actively reduce end-user consumption (Bocken et al., 2016). Examples in the clothing industry are companies such as Patagonia, or Brunello Cucinelli. Patagonia pledges to 'build useful things that last, to repair what breaks and recycle what comes to the end of its useful life'. Along with this, customers are asked to only buy what is needed and will last, make repairs and reuse and recycle anything else and consider second hand products (Bocken & Short, 2016). Another example is the office copier business of Kyocera. The company focuses on managing the demand for printing and copying by offering a holistic product-service solution including paper management consultation, system redesign, and real time monitoring (Bocken & Short, 2016). The company is aware that this might reduce their demand for printers, but they compensate it by increasing the service provision. It is important to point out that no cases in the construction sector were identified within this strategy.

In closing loops strategies, Extending Resource Value was the most applied within the cases, and the second most applied regarding all the strategies (for narrowing, slowing or closing). The strategy focuses on exploiting the residual value of resources incorporating new collaborations or take-back systems to collect or source materials to turn them into new forms of value (Bocken et al., 2016). Examples in the construction sector show building designs that consider materials with resource passports to facilitate materials to be recycled and reused at the end of its life-cycle , bio-degradable construction, demolition process that considers the reuse of materials, and cradle to cradle products. For instance, in the renovation process of the educational building Gilde opleidingen, every supply chain partners took back the demolished materials, parts and products for reuse and recycling. Additionally a take- and/or buy-back guarantee, captured in a resource passport using BIM, is incorporated for all the new products that supply chain partners have provided (Prins et al., 2015). Another example is Desso, a Dutch manufacturer of flooring and carpets that has incorporated cradle to cradle principles to its production, material recover techniques and take back of already existing carpet tiles in their business model for recycling them into new ones (Brown et al., 2018; Huitema, 2018; Prins et al., 2015). The case of Unilever and the project RECOUP/REFLEX, considers

packaging recycling and waste banks in which the value proposition consists on selling waste according to its value (Ackermans, 2016).

Industrial Symbiosis is a process-oriented strategy for closing loops focusing on turning waste outputs from one process into feedstock for another process (Bocken et al., 2016). Our database only has three examples applying this strategy. One of them is the Eco-industrial Park Kalundborg which is a network of industries that gain advantage of materials exchange and resource reuse (Bocken et al., 2016). The case of AB Sugar is also mentioned by the same authors. The company has focused on trying to turn waste and emissions from their core manufacturing processes into feed stock for new product lines such as animal feed, use of latent heat and C02 to heat greenhouses near the industry facilities and a new bioethanol production facility. Another example is the case of SAB miller, in which the waste from the brewing process is eliminated by selling spent grain to farmers to be re-used (Ackermans, 2016).

Strategies for narrowing loops are considered sustainable strategies but not necessarily leading to circular ambitions. However, this classification was incorporated in the table given its relevance for the construction sector. As Figure 10 shows, 15 cases in the construction sector apply resource efficiency strategies, meaning actions to use less resources, either in circular or linear economy. Some examples are the design of modular architecture that facilitates its reuse and eventually more than one circular loop, material reduction by design, conscious use of materials or energy neutral buildings.

It is important to note that while most of the literature emphasised on circular ambitions, value capture, creation and delivery of the business models, less is mentioned about the implementation level, as well as the success of failure in achieving these ambitions. The next section will elaborate more about the relation between strategies and level of implementation in the construction sector.

Strategies and level of implementation in the construction sector

During the literature review, 29 cases related to the construction sector were identified. As Figure 11 shows, the cases were organised according to the type of building, and the applied strategies according to the level of implementation. The cases belong to corporate (9), residential (7), educational (4), public (3) and commercial (1) buildings. Additionally, five cases were identified as services for the construction sector such as demolition or provision of equipment (e.g., elevators). It is important to mention the relevance of the students reports to identify cases in the construction sector, 19 out 29 cases appeared only in MSc students thesis, in contrast with 8 cases identified only scientific papers, and 2 cases identified by both, students reports and papers. The student's work is therefore especially relevant to unveil the state of the art regarding Dutch circular business models in the construction sector by identifying and collecting unpublished information. The classification considers the level of implementation (concept, test/pilot, implementation in progress, implemented and evaluation). The classification was based on the information provided by the reports and papers. Only when the information was not sufficient to classify, additional sources were consulted to check. In any case, the level of implementation is defined by the implementation stated by the company or by the second source, and it does not refer to the success of this implementation.

Cases such as the renovation of the office buildings of Alliander in Duiven and Arnhem, the master plan of Park 20/20, the renovation of the headquarters of Tennet, or the new offices of Triodos Bank, are examples of corporate companies implementing circular approaches in their own buildings. Either driven by circular ambitions, by the goal of having a more efficient use of their own resources, or by both, the new buildings allow to test and to implement strategies for narrowing, slowing or closing loops. The implementation of circular ambitions is often detailed and mentioned in their websites as part of their marketing strategy. In the public sector, municipal or public institutions such as the municipality of Brummen or the RVB (Government Real Estate Agency) in the Netherlands, use their own facilities to build a temporary building for disassembly, or to reuse materials from demolition, respectively. Linked to public real estate, educational buildings and University campus also use their facilities to implement or test circular strategies. Cases like the demolition and construction of new facilities at the Medical Centre in Erasmus University, the use of campus facilities to test a leasing façade prototype in TU Delft, the renovation process of Gilde opleidingen are some examples of participation of educational institutions implementing circular strategies. In this regard, It is important to mention the participation of researchers as initiators and developers of circular projects, as well as advisors in circular initiatives developed by the construction

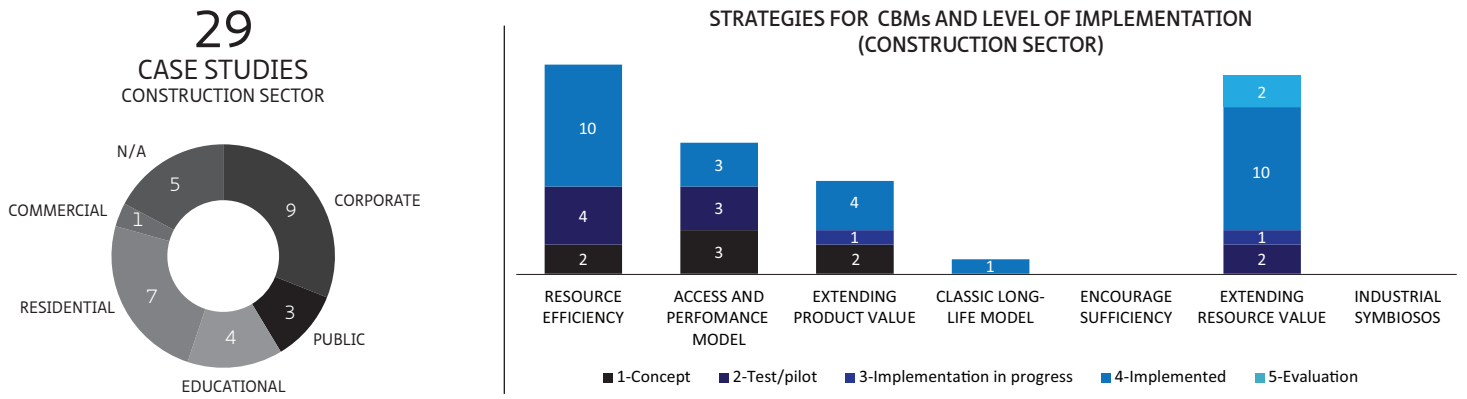

Figure 11. Cases in the construction sector organised by the type of building (left) and by the strategies for circular business models according to the level of implementation (right). The numbers indicated the amounts.

Source: authors' elaboration.

industry. For instance, the research projects REHAB and Circular Kitchen, both still in early development levels, were initiated in the university to promote circularity in Dutch social housing (van Stijn, 2019). Similarly, the case of the Circular retrofit lab - BAMB focuses on the reuse and refurbishment of the VUB Campus' prefabricated student housing in Brussels. In the residential sector, besides the aforementioned concepts and prototypes developed with the university, other projects like the Growing Green module, Heijmans module or the Lewan apartment complex focus on narrowing loops by having a conscious material choice, and by designing modular dwellings and components contributing to a cheaper and more efficient building process (van den Brink, 2016).

Regarding the strategies and their level of implementation, Figure 11 shows how Resource Efficiency and Extending Resource Value are the most common strategies in the construction sector, having also a similar number of implemented projects. In most cases, these two strategies are paired, in the sense that projects that consider extending resource value would probably be already developing resource efficiency measures as well. For instance in the renovation of the offices complex of Alliander in Duiven the extending resource value strategy is the re-used of materials during the renovation, at the time that the renovation considers turning the buildings into a sustainable complex, C02 neutral and self-sufficient in its energy (E. Leising, 2016; van den Brink, 2016; van Haagen, 2018). The use of C2C products, biodegradable materials, the re-use of demolition materials into new buildings, or the integration of material resource passports are actions within the Extending Resource Value strategy that can be understood as implemented and eventually can also be assessed. However, in other strategies such as Extending Product Value, Access and Performance

Model or Classic Long-life Model, the implementation of the actions cannot be fully assessed until the end of the life-cycle of the building or the components.

In the case of Access and Performance Model strategies, there are three cases that were categorised as implemented: one is the service model proposed by M-Use® Elevators, and two cases of the lease of modular facilities in a healthcare centre and an hospital campus in Finland. While the first case is a component that can be easily isolated in the building design and its installation is already servitized as an external component, the cases in Finland represent a leasing model in which the circular ambitions are not clearly stated and there is not sufficient information of their implementation. On the other hand, there are also cases still in conceptual and prototype phases that propose more complex leasing models of building components such as the façade or the casco which are not usually understood as legally separated components of the building. Some examples are the prototype of leasing façade implemented in TU Delft university campus in which the client, rather than purchase the façade panel a product, hires the energy performance and user comfort services delivered to his building by this new façade system (Azcarate-Aguerre, 2017; Azcarate-Aguerre et al., 2018), and the Boutique Office project in which the casco and the interior of the building are assigned to separate ownership (de Blok, 2018). In both projects already cultural, legal, managerial and financial implementation barriers have been identified in pilot implementations (Azcarate-Aguerre et al., 2018; de Blok, 2018).

Regarding Extending Resource Value, examples are related to the provision of maintenance services such as the case of the Triodos Bank which implementation is still in progress. A contract between the bank and the façade supplier is arranged for maintenance, operation and take-back of the façade (de Blok, 2018). Implemented examples are projects conceived as temporary buildings and designed for disassembly such as the Town Hall Brummen, the Circular Pavilion the Green House in Utrecht. However, as previously indicated, the projects have not ended their current cycle, so there is no information about the success of the building components being re-used in new cycles. In a conceptual stage, projects such as the Circular Kitchen and REHAB focuses on the development of modular design and circular components. While the REHAB project focuses on designing and testing circular housing retrofit system and building components (the roof, the façade, the boiler, and the kitchen), the circular kitchen develops a modular design that facilitates circular loops by separating parts based on their lifespan (van Stijn, 2019).

	SUSTAINABLE BMS	CIRCULAR BMS								
	NARROWING LOOPS	SLOWING LOOPS				CLOSING LOOPS				
CASE	RESOURCE EFFICIENCY	ACCESS AND PERFORMANCE MODEL	EXTENDING PRODUCT VALUE	CLASSIC LONG-LIFE MODEL	ENCOURAGE SUFFICIENCY	EXTENDING RESOURCE VALUE	INDUSTRIAL SYMBIOSIS	SECTOR	LOCATION	SOURCE TYPE
A. Van Liempd - demolition company						■		Construction	The Netherlands	Student report
AB Sugar refiners							■	Food	United Kingdom	Publication
Alliander - renovation of Bellevue building	■					■		Construction	The Netherlands	Student report
Alliander - renovation of offices complex in Duiven	■					■		Construction	The Netherlands	Student report
Alston transport - Train Life Services)		■						Services	N/A	Publication
Basisweg building project		■						Construction	Amsterdam, Nethe	Student report
Black Bear Carbon. Carbon Black						■		Consumer Product	The Netherlands	Student report
Bouwcarrousel - demolition company						■		Construction	The Netherlands	Student report
Brunello Cucinelli - clothing					■			Consumer Product	Italy	Publication
Bugaboo. Consumer durables Strollers		■			■			Consumer Product	The Netherlands	Publication
Carlsberg - beverages	■					■		Food	N/A	Student report
Caterpillar and dealers (Equipment Management Services)		■						Consumer Product	N/A	Publication
Circular Kitchen - Applied research project	■	■	■					Construction	The Netherlands	Publication
The Green House - circular pavilion	■		■			■		Construction	The Netherlands	Student report
Circular retrofit lab - BAMB (Buildings as materials banks)	■	■						Construction	Belgium	Publication
Cisco - IT systems			■					Services	N/A	Student report
Coca Cola Enterprise	■					■		Food	N/A	Student report
Dell						■		Consumer Product	N/A	Student report
Desso. Carpet and flooring materials		■				■		Consumer Product	The Netherlands	Student report and Publication
DSM NIAGA. Carpet machine and adhesive	■							Consumer Product	The Netherlands	Student report
Ecovative - packaging	■							Consumer Product	United States	Student report
EDGE Olympic- building renovation	■					■		Construction	The Netherlands	Student report
Erasmus MC campus - buiksings demolition and renovation						■		Construction	The Netherlands	Student report
Façade Leasing - Prototype	■	■						Construction	The Netherlands	Publication
Fairphone- smartphone			■	■	■			Consumer Product	The Netherlands	Student report and Publication
Fijn Wonen (contractor Van Wijnen)	■					■		Construction	The Netherlands	Student report
Fresh-r - decentral ventilation system with heat recovery		■						Consumer Product	N/A	Publication
Gilde opleidingen - building renovation			■			■		Construction	The Netherlands	Publication
Gispen- furniture		■	■					Consumer Product	N/A	Publication
Growing Green module	■							Construction	The Netherlands	Student report
G-star Raw - clothing						■		Consumer Product	N/A	Publication
H&M - clothing			■					Consumer Product	N/A	Student report
Headquarters of Tennet- renovation			■					Construction	The Netherlands	Publication
Healthcare center - modular facilities		■						Construction	Finland	Publication
Heerema Head Office- building demolition and renovation	■					■		Construction	The Netherlands	Student report
Heijmans One module	■							Construction	The Netherlands	Student report
Hospital campus- modular facilities		■						Construction	Finland	Publication
Interface								Consumer Product	N/A	Publication
Kalundborg- Eco-industrial Park							■	Services	Denmark	Publication
Kyocera – document management system manufacturer		■			■			Services	N/A	Publication
Lewan apartment complex	■							Construction	The Netherlands	Student report
Maersk Line - container shipping								Services	Denmark	Student report

Table 3. Case study database of circular business models.

Source: authors' elaboration.

	SUSTAINABLE BMS	CIRCULAR BMS								
	NARROWING LOOPS	SLOWING LOOPS				CLOSING LOOPS				
CASE	RESOURCE EFFICIENCY	ACCESS AND PERFORMANCE MODEL	EXTENDING PRODUCT VALUE	CLASSIC LONG-LIFE MODEL	ENCOURAGE SUFFICIENCY	EXTENDING RESOURCE VALUE	INDUSTRIAL SYMBIOSIS	SECTOR	LOCATION	SOURCE TYPE
MAN - fleet Management		■						Services	N/A	Publication
Martela Oyj Fi- furniture				■	■			Consumer Product	N/A	Publication
Michelin - automotive		■		■	■			Consumer Product	N/A	Student report
Miele- washing machines				■	■			Consumer Product	N/A	Publication
Mud Jeans -clothing		■	■					Consumer Product	N/A	Publication
M-Use® Elevators- Mitsubishi Electric Europe		■		■				Construction	Europe	Student report and publication
Nespresso						■		Food	N/A	Student report
Orangebox- office furniture	■			■				Consumer Product	United Kingdom	Publication
Park 20/20- building construction	■					■		Construction	The Netherlands	Student report
Patagonia – outdoor sports gear manufacturer					■			Consumer Product	N/A	Publication
Philips Healthcare Refurbished Systems (Philips RS)		■	■					Consumer Product	The Netherlands	Publication
Philips Lighting		■	■	■				Consumer Product	The Netherlands	Student report and Publication
Reduse – equipment ('unprinter') manufacturer	■				■			Services	United Kingdom	Publication
REHAB - applied research project	■	■	■					Construction	The Netherlands	Publication
Renault - automotive			■					Consumer Product	N/A	Student report
Ricoh - office supplies		■						Consumer Product	N/A	Student report
Riversimple – automotive manufacturer and car lease service	■	■			■			Services	United Kingdom	Publication
Rolls-Royce Civil Aerospace (TotalCare)		■						Services	N/A	Publication
Rotor DC						■		Construction	Belgium	Student report
Royal Auping- beds, mattresses and accessories		■		■		■		Consumer Product	N/A	Publication
RVB (Government Real Estate Agency) circular demolition of Tax Office						■		Construction	The Netherlands	Student report
SAB miller - beverages							■	Consumer Product	United Kingdom	Student report
Siemens Wind Power (SWP)					■			Consumer Product	N/A	Publication
SUPERLOCAL - project, demolition company HEEMwonen						■		Construction	The Netherlands	Student report
The boutique office - building renovation		■						Construction	The Netherlands	Student report
Town-Hall of Brummen- building renovation	■		■			■		Construction	The Netherlands	Student report and publication
Triodos Bank- new building construction			■					Construction	The Netherlands	Student report
Unicykel- bicycle manufacturer		■			■			Consumer Product	Sweden	Publication
Unilever						■		Food	N/A	Student report
Van Houtum- toilet paper						■		Consumer Product	The Netherlands	Student report
Vitsoe – furniture manufacturer					■			Consumer Product	United Kingdom	Publication
Xerox- managed print services		■						Consumer Product	N/A	Publication

CASE	DESCRIPTION	LEVEL OF DEVELOPMENT	SOURCE
A. Van Liempd - demolition company	Demolition company with circular business components: to use the income generated by reclaimed components to be cheaper than other demolition companies and compete with them on price while also being circular	4-Implemented	Gremmen, L. (2018)
Alliander - renovation of Bellevue building	Renovation of existing building using circular and sustainanle principles in Arnhem. Reuse of materials for the renovation, use of new materials from reponsible sources.	4-Implemented	van der Wijk, L. (2018);
Alliander - renovation of offices complex in Duiven	Renovation of an existing offices complex where five buildings were transformed into one sustainable complex. Co-creation with employees. The complex is CO2 neutral and self-sufficient in its energy by using only renewable energy sources. The materials used during the renovation were re-used as much as possible.	4-Implemented	Leising, E. (2016); van Haagen, F. (2018); van den Brink, R.J. (2016)
Basisweg building project	Redevelopment of a building from 1974. HVAC installation as a service from an energy company.	1-Concept	de Blok, I. (2018)
Bouwcarrousel - demolition company	Facilitating reuse of building components by means of deconstruction (bankruptcy in 2010).	5-Evaluation	Gremmen, L. (2018)
Circular Kitchen - Applied research project	Modular design which facilitates various circular loops by separating parts based on lifespan	1-Concept	Van Stijn, A. (2018)
The Green House - circular pavilion	Pavilion that hpuses commercial functions (restaurant, meeting rooms, greenhouse). The pavilion will be dismanteled and elements reused after 15 years. Conscious choice of materials, energy neutral building.	4-Implemented	Disseldorp, W. (2018); Gerding, D. (2019)
Circular retrofit lab - BAMB (Buildings as materials banks)	The pilot project tested and implemented different scenarios for the reuse and refurbishment of the VUB Campus' prefabricated student housing, without generating a large amount of waste.	2-Test/pilot	Van Stijn, A. (2018)
EDGE Olympic- building renovation	Renovation of a office building implementing digital infrastructure to manage the building. Smart building	4-Implemented	Gerding, D. (2019)
Erasmus MC campus - builsings demolition and renovation	Demolition and new construction by trying to minimise waste and trying to find new uses for many of the components extracted from the buildings that will be demolish.	3-Implementation in progress	Gremmen, L. (2018)
Façade Leasing - Prototype	Rather than purchase the façade panels as a product, the client hires the energy performance and user comfort services delivered to his building by this new façade system.	2-Test/pilot	Azcárate-Aguerre, J. (2014)
Fijn Wonen (contractor Van Wijnen)	Develop standardized houses which will contribute to a cheaper and more efficient building process.	2-Test/pilot	van der Wijk, Lieke (2018)
Gilde opleidingen - building renovation	Renovation process in which every supply chain partners took back the demolished materials/parts and products for reuse and recycling. A take- and/or buy-back guarantee, captured in a resource passport, is incorporated for all the new products that supply chain partners have provided.	4-Implemented	Prins, M., Mohammadi, S., & Slob, N. (2015)
Growing Green module	Housing renovation. A new façade structure that is placed instead of the old structure, and new installations that provide heating and/or cooling in the dwelling (Potential to add a service like maintenance).	4-Implemented	van den Brink, R. J. (2016)
Headquarters of Tennet-renovation	Take-back guarantee is incorporated, within the procurement process, for all its furniture and infill. This relates to one single loop after its first use-cycle.	4-Implemented	Prins, M., Mohammadi, S., & Slob, N. (2015)
Healthcare center - modular facilities	Lease period of 5 years. Offices and consulting rooms	4-Implemented	Kyro, R., Jylha, T., & Peltokorpi, A. (2019).
Heerema Head Office- building demolition and renovation	First BREEAM certificate for sustainable demolition and disassembly of previous offices. Waste streams from the demolition were colected and reused or recicled. New building includes energy savings measures.	4-Implemented	Leising, E. (2016)
Heijmans One module	Modular, movable one-person-household home. (It can be re-used, but it was not created under circular ambitions).	2-Test/pilot	van den Brink, R. J. (2016)
Hospital campus- modular facilities	Lease period of 5 years. Modular buildings delivered to the campus in 2012 and comprise imaging facilities and offices.	4-Implemented	Kyro, R., Jylha, T., & Peltokorpi, A. (2019).
Lewan apartment complex	Ecological building complex. The project uses hay as main construction material. Conscious choice of materials that meet econolgical standards (it was not created with a circular ambition).	4-Implemented	van den Brink, R. J. (2016)
M-Use® Elevators- Mitsubishi Electric Europe	Leasing model. MEE retains ownership of the product to increase reusabiliy of components, and offer longer product life and quality.	4-Implemented	Michael, E. (2018); Ploeger, H., Prins, M., Straub, A., & van den Brink, R. (2017)

Table 4. Case study database of circular business models. Cases in the construction sector. S

Source: authors' elaboration.

CASE	DESCRIPTION	LEVEL OF DEVELOPMENT	SOURCE
Park 20/20- building construction	Newly built Cradle to Cradle inspired business park. The masterplan provides an offices area with closed cycles of water, waste and energy and sustainable buildings based on flexible working. All materials in the buildings have their resources passports.	4-Implemented	Leising, E. (2016); Huitema, L. (2018)
REHAB - applied research project	Design and test of circular housing retrofit system in co-creation with housing associations and building industry partners. The retrofit system consists out of several building retrofit components which will be developed towards a prototype: the roof, the facade, the boiler including heating system and the kitchen.	1-Concept	Van Stijn, A. (2018)
Rotor DC	It is an autonomous side-project of Rotor, a non-profit firm engaged in promoting and facilitating the reuse of building components as a strategy on the path towards a more resource-efficient materials economy.	4-Implemented	Gremmen, L. (2018)
RVB (Government Real Estate Agency) circular demolition of Tax Office	Circular demolition and by extension components reuse for the old tax office in Winterswijk.	5-Evaluation	Gremmen, L. (2018)
SUPERLOCAL - project, demolition company HEEMwonen	The goal of the project is to develop a number of new properties by using only materials and components taken from the old buildings. Urban Innovative Action subsidy.	2-Test/pilot	Michael, P. (2018)
The boutique office - building renovation	Extension of an exisitng building in wich the real estate developer act as service provider. The ownership of the casco is transferred towards the investor while the fit-out of the building remains with the real estate developer.	2-Test/pilot	de Blok, I. (2018)
Town-Hall of Brummen- building renovation	Sustainable building with a temporal life. Project designed for disassembly,bio-degradable construction and several C2C products. The strict budget and limited time span resulted in certain choices that did not always benefit their vision and circularity.	4-Implemented	Gerding, D. (2019); Prins, M., Mohammadi, S., & Slob, N. (2015); van Haagen, Floris
Triodos Bank- new building construction	Contract between Triodos Bank and the façade supplier, arranging the maintenance, operation and take-back of the façade. Lease was not legally possible.	3-Implementation in progress	de Blok, I. (2018)

elft Darmstadt München
es Education Circular Business Models Report

Photo by Juan Azcárate-Aguerre

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This section presented a selection of 74 case studies of different circular business models in the construction, consumer products, food and service industry. The cases were selected from secondary sources namely papers, books, technical reports and MSc thesis, and provided an overview of ongoing practices. The cases were categorised using the framework of Circular Business Strategies developed by Bocken et al. (2016) in order to understand how business models are being developed and/or implemented. The main findings showed that strategies for both approaches, slowing and closing loops, are being put in practice. Whilst Access and Performance Model and Extending Resource Value are the most used, Classic Long-life Model and Industrial Symbiosis are the least implemented. Within the product consumer industry Access and Performance Model is the most frequent strategy, while in the construction sector this is Extending Resource Value.

A closer look into the construction sector showed that not all the strategies seem equally suitable nor implemented. This can be related to the specific characteristics of the construction sector where strategies like encourage sufficiency, classic long-life model or industrial symbiosis seem difficult or even unfeasible to implement. In this regard, it is important to identify more specific strategies and customised classificatory frameworks for the construction sector in order to better understand how and why current business models are being created and implemented.

Circular strategies aim at a long-term process that comprises the whole life-cycle of the product or the building component. In this regard, the long-time life cycle in the construction sector has an important influence on the extent that we can actually evaluate circularity in the construction sector nowadays. So far, we can mostly identify stated circular ambitions, goals, and activities implemented by the construction sector. However, the cases analysed showed that there is not yet sufficient evidence to confirm that the declared ambitions and actions are actually being implemented correctly along the entire process in order to achieve this circularity.

Photo by Juan Azcárate-Aguerre

As a synthesis, this section summarises three main learnings for the educational and scientific production in the topic of circular economy and new business models.

Firstly, the value of the students' production as up-to-date source of knowledge of emerging topics. Students reports were a relevant source of case studies, contributing with 50% of the examples. This allows us to identify and register cases that are not yet being investigated in research projects or which information has not been published yet. Students' reports, although more general in their content, are more dynamic in making data and qualitative information available from which researchers and academic can benefit. Moreover, information in students' reports can be used as starting point to formulate future research projects. The MSc projects developed with the industry contributed to fill knowledge gaps between theory and practice by using conceptual frameworks to explore and support companies in the development of circular ambitions. The categorisation and systematic review of MSc thesis and then, their synthesis, can contribute to increased visibility to this work which is now only accessible through the university repository.

Secondly, the relevance of the Universities as living labs, promoting circularity in the built environment. The database showed the role of the universities developing applied research in partnership with private and public stakeholders, but also using their own campus facilities to test pilot projects. The combination of both, applied research and pilot projects on-campus, has the potential of positioning universities as living labs where circular business models and strategies can be tested and evaluated. This process not only contribute to a better understanding of the barriers and enablers of their implementation, but also to a closer dialogue between the academy and different stakeholders. This is therefore, a valuable contribution to the transition towards a circular economy: it provides empirical evidence for the construction sector while representing a pedagogic and up-to-date tool for educational purposes.

Thirdly, the level of implementation of circular strategies in the construction sector is still difficult to identify and to assess. On the one hand, the sector is still in the process of putting new circular ambitions into practice making difficult to evaluate strategies and actions in which the final result can only be assessed at the end of the building or components cycle. On the other hand, available information focuses on circular ambitions and value propositions, but it is not sufficient and often not clear regarding the success or failure of the strategies. In this regard, more applied research and, closer and long-term cooperation between the construction sector and the universities is needed to grasp the complexities of the processes, to develop evaluation mechanisms and to develop a systematic documentation in order to promote and support informed decision-making process in circular business models.

Photo by Anders Jildén

TU Delft Delft University of Technology

References |

Ackermans, S. F. (2016). Circular Business Models: A company perspective. (Master Master), Delft University of Technology, Delft. Retrieved from https://repository.tudelft.nl/islandora/object/uuid%3Ad9eed313-4fbb-4114-b498-342328208f12?collection=education

Azcárate-Aguerre, J. (2014). Façades as a Product-Service System: The potential of new business-to-client relations in the facade industry. (Msc). Retrieved from https://repository.tudelft.nl/islandora/object/uuid%3A0aca38e7-81ae-4ca7-9b1f-ffcf0f2e33fc?collection=education

Azcarate-Aguerre, J. F. (2017). Integrated facades as a product-service system: Business process innovation to accelerate integral product implementation. Journal of Facade Design and Engineering, 6(1), 41.

Azcarate-Aguerre, J. F., Klein, T., Den Heijer, A., Vrijhoef, R., Ploeger, H. D., & Prins, M. (2018). Façade Leasing: Drivers and barriers to the delivery of integrated Facades-as-a-Service. Real Estate Research Quarterly, 17(3).

Baines, T., & Lightfoot, H. (2013). Made to Serve: How Manufacturers can Compete Through Servitization and Product Service Systems. Chichester, West Sussex, United Kingdom: Wiley.

Bocken, N., de Pauw, I., Bakker, C., & 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. doi: 10.1080/21681015.2016.1172124

Bocken, N., Rana, P., & Short, S. (2015). Value mapping for sustainable business thinking. Journal of Industrial and Production Engineering, 32(1), 67-81.

Bocken, N., Schuit, C., & Kraaijenhagen, C. (2018). Experimenting with a circular business model: Lessons from eight cases. Environmental Innovation and Societal Transitions, 28, 79-95. doi: https://doi.org/10.1016/j.eist.2018.02.001

Bocken, N., & Short, S. (2016). Towards a sufficiency-driven business model: Experiences and opportunities. Environmental Innovation and Societal Transitions, 18, 41-61. doi: https://doi.org/10.1016/j.eist.2015.07.010

Bocken, N., Short, S., Rana, P., & Evans, S. (2014). A literature and practice review to develop sustainable business model archetypes. Journal of Cleaner Production, 65, 42-56. doi: https://doi.org/10.1016/j.jclepro.2013.11.039

Bocken, N., Strupeit, L., Whalen, K., & Nussholz, J. (2019). A Review and Evaluation of Circular Business Model Innovation Tools. Sustainability, 11(8). doi: 10.3390/su11082210

Brown, P., Bocken, N., & Balkenende, R. (2018). Towards Understanding Collaboration Within Circular Business Models. In L. Moratis, F. Melissen & S. O. Idowu (Eds.), Sustainable Business Models: Principles, Promise, and Practice (pp. 169-201).

Cha, Y. (2017). Implementation of Circular Business Models in Firms: Prospects and Barriers. (Master Master), Delft University of Technology, Delft. Retrieved from https://repository.tudelft.nl/islandora/object/uuid%3Ab08ae462-53f2-4a52-b8aa-1ab7166852bb?collection=education

de Blok, I. (2018). Real estate developers as circular service providers. (Master), Delft University of Technology, Delft. Retrieved from https://repository.tudelft.nl/islandora/object/uuid%3Abd029b7c-45ce-4743-8697-7ea70b1b887e?collection=education

De Grauw, D. N. Closing the loop in real estate; implementing the circular economy at constructions. Retrieved from https://repository.tudelft.nl/islandora/object/uuid%3Af84baef7-f2cb-46d4-9742-05f1b1796288

De Leeuw, A. C. J. (2002). Bedrijfskundig management : primair proces, strategie en organisatie.

Disseldorp, W. (2018). (RE)DEVELOP THE FUTURE: An instrument to develop and implement the concept of circularity for the redevelopment initiation phase. (Master Master), Delft University of Technology, Delft. Retrieved from https://repository.tudelft.nl/islandora/object/uuid%3Af4862a9a-78ac-4cae-ba52-4fe69044dc89?collection=education

Djoegan, C. E. S., & Van den Reek, D. L. (2016). Supply yourself: A circular reorganisation on the supply side in the construction industry from a financial perspective. (Master Master), Delft University of Technology, Delft. Retrieved from https://repository.tudelft.nl/islandora/object/uuid%3A053b14e4-1216-44c7-aa4f-e0c79494d833?collection=education

Geissdoerfer, M., Morioka, S. N., de Carvalho, M. M., & Evans, S. (2018). Business models and supply chains for the circular economy. Journal of Cleaner Production, 190, 712-721. doi: https://doi.org/10.1016/j.jclepro.2018.04.159

Geissdoerfer, M., Vladimirova, D., & Evans, S. (2018). Sustainable business model innovation: A review. Journal of Cleaner Production, 198, 401-416. doi: 10.1016/j.jclepro.2018.06.240

Gerding, D. (2019). Talking circularity - the influence of actors on the building process: A study into actor networks and influence on decision-making regarding the implementation of circularity into the building process. (Master Master), Delft University of Technology, Delft. Retrieved from https://repository.tudelft.nl/islandora/object/uuid:e8123875-ceee-4f63-9bcc-09e7542c31d8?collection=education

Gremmen, L. (2018). Circular Demolition and Component Reuse in Construction: The Current Building Stock as a Source of Components for New Buildings. (master master), Delft University of Technology, Delft. Retrieved from https://repository.tudelft.nl/islandora/object/uuid%3Abda514d5-8c7d-48eb-b777-abb43e20b5e7?collection=education

Heurkens, E. (2012). Private sector-led urban development projects: management, partnerships and effects in theNetherlands and the UK. (Doctoral). Retrieved from https://repository.tudelft.nl/islandora/object/uuid%3Aa40cdc44-fa7f-4f57-99d3-9053fb07aa85

Huitema, L. (2018). Circular Business Model Patterns and their Relevance towards a more Circular Economy: A case survey of 34 circular companies. (Master Master), Delft University of Technology, Delft. Retrieved from https://repository.tudelft.nl/islandora/object/uuid%3A00e4ca0f-f52e-474c-958e-4511e8de8fe9?collection=education

Jensen, J. P., Prendeville, S. M., Bocken, N. M. P., & Peck, D. (2019). Creating sustainable value through remanufacturing: Three industry cases. Journal of Cleaner Production, 218, 304-314. doi: https://doi.org/10.1016/j.jclepro.2019.01.301

Kühlen, A., Volk, R., & Schultmann, F. (2016). State of the Art of Demolition and Reuse and Recycling of Construction Materials. Paper presented at the Proceedings of the CIB World Building Congress.

Leising, E. (2016). Circular Supply Chain Collaboration In the Built Environment. (Master), TU Delft and Leiden. Retrieved from https://repository.tudelft.nl/islandora/object/uuid:6e1a6346-eb45-4107-bb1f-f286902ccde2?collection=education

Leising, R. (2017). Steel curtain walls for reuse. (Master), Delft University of Technology, Delft. Retrieved from https://repository.tudelft.nl/islandora/object/uuid%3Ac0d3e7cb-6b2d-4c1c-bc37-c16d9b4fe97c?collection=education

Lüdeke-Freund, F., Gold, S., & Bocken, N. M. P. (2019). A Review and Typology of Circular Economy Business Model Patterns. Journal of Industrial Ecology, 23(1), 36-61. doi: 10.1111/jiec.12763

McDonough, W., & Braungart, M. (2010). Cradle to cradle: Remaking the way we make things: North point press.

Mentink, B. (2014). Circular Business Model Innovation: A process framework and a tool for business model innovation in a circular economy. (Master Master), Delft University of Technology, Delft. Retrieved from https://repository.tudelft.nl/islandora/object/uuid%3Ac2554c91-8aaf-4fdd-91b7-4ca08e8ea621?collection=education

Michael, E. (2018). Product to Service in Circular Economy: A critical assessment. (Master), Delft University of Technology, Delft. Retrieved from https://repository.tudelft.nl/islandora/object/uuid%3A56299326-e067-4495-9903-34b5215119f4?collection=education

Michael, P. (2018). Circular demolition process: Enhancing the reuse potential of components and materials in the building industry. (Master Master), Delft University of Technology, Delft. Retrieved from https://repository.tudelft.nl/islandora/object/uuid%3A6eda829e-a31e-483b-9a39-e9dc1b979ee0?collection=education

Nussholz, J. L. K. (2017). Circular Business Models: Defining a Concept and Framing an Emerging Research Field. Sustainability, 9(10). doi: 10.3390/su9101810

Osterwalder, A., Pigneur, Y., & Tucci, C. L. (2005). Clarifying business models: Origins, present, and future of the concept. Communications of the association for Information Systems, 16(1), 1.

Ploeger, H., Prins, M., Straub, A., & van den Brink, R. (2017). Circular economy and real estate: alternatives for operational lease. Paper presented at the International Research Conference 2017 "Shaping Tomorrow's Built Environment", Salford, United Kingdom. 11 Sep 2017- 12 Sep 2017.

Prins, M., Mohammadi, S., & Slob, N. (2015). Radical Circular Economy. Paper presented at the Proceedings of the CIB joint international symposium - Going north for sustainability: Leveraging knowledge and innovation for sustainable construction and development, London, UK, 23-25 November 2015; Authors version. http://resolver.tudelft.nl/uuid:b80ad8fd-3ffc-48cf-a1b6-82554a3a9a3c

Reim, W., Parida, V., & Örtqvist, D. (2015). Product-Service Systems (PSS) business models and tactics - A systematic literature review (Vol. 97).

Segerstedt, A., & Olofsson, T. (2010). Supply chains in the construction industry. Supply Chain Management: An International Journal, 15(5), 347-353. doi: doi:10.1108/13598541011068260

Stahel, W. (1982). The Product Life Factor. An Inquiry into the Nature of Sustainable Societies: The Role of the Private Sector (Series: 1982 Mitchell Prize Papers), NARC.

Stahel, W. (2010). The Performance Economy (Vol. 572). Hampshire, UK: Palgrave Macmillan.

Stigter, R. (2016). Suppliers going circular. An examination of the transition from product-based business models to a performance-based business model in the construction industry. (Master Master), Delft University of Technology, Delft. Retrieved from https://repository.tudelft.nl/islandora/object/uuid%3A767baf60-8bf3-4c69-bec9-fb96a3437aa4?collection=education

Sumter, D., Bakker, C., & Balkenende, R. (2018). The Role of Product Design in Creating Circular Business Models: A Case Study on the Lease and Refurbishment of Baby Strollers. Sustainability, 10(7). doi: 10.3390/su10072415

Tukker, A. (2004). Eight types of product–service system: eight ways to sustainability? Experiences from SusProNet. Business Strategy and the Environment, 13(4), 246-260. doi: 10.1002/bse.414

van den Brink, R. J. (2016). At your service! Circular business model prototypes for a service provider in the construction industry. (Master Master), Delft University of Technology, Delft. Retrieved from https://repository.tudelft.nl/islandora/object/uuid%3A229e1340-846c-4f82-981a-1f36bc481cf0?collection=education

van der Wijk, L. (2018). Stimulating Circular Building Methods:

A cross-case analysis to identify the role of the general contractor. (Master), Delft University of Technology, Delft. Retrieved from https://repository.tudelft.nl/islandora/object/uuid%3A37a2afd8-c944-438d-902b-889959745442?collection=education

van Haagen, F. (2018). Circulair aanbesteden: DNA-match: het geheim achter een spraakmakende circulaire aanbesteding. (Master), Delft University of Technology, Delft. Retrieved from https://repository.tudelft.nl/islandora/object/uuid%3A5c297398-efc5-45f9-a1fe-c29c8f2d2184?collection=education

van Hemmen, B. (2016). Economic circularity in the built environment: An assessment and decision-making supporting model for the real estate sector & construction industry. (Master Master), Delft University of Technology, Delft. Retrieved from https://repository.tudelft.nl/islandora/object/uuid%3Adda510cd-1766-4dde-b0e6-b89dedd2b197?collection=education

van Stijn, A. (2019). REHAB. Developing a circular retrofit system for post-war habitats. TU Delft.

van Veenen, A. (2018). A Best Value approach to public procurement. (Master), Delft University of Technology, Delft.

Vrijhoef, R., & De Ridder, H. (2005). Supply chain integration for achieving best value for construction clients: clients-driven versus supplier-driven integration. Paper presented at the Proceedinngs QUT Research Qeek.

Vrijhoef, R., & Koskela, L. (2000). The four roles of supply chain management in construction. European journal of purchasing & supply management, 6(3-4), 169-178.

Whalen, K. (2017). Classifying circular business models: a practice-based review.

Wilkinson, S. J., Remøy, H., & Langston, C. (2014). Sustainable building adaptation: innovations in decision-making: John Wiley & Sons.

Appendix |

MSc reports selected for an in-depth content revision. In order to organise the information, we used the programme File Maker Pro, a database manager that also provides a visual organisation of files sheets.

Circular Business Models

A company perspective

Author Stephan Ackermans **Year** 2016 **MSc programme, Faculty** Strategic Product Design Programme

Advisors Geissdörfer, M.; Bocken, N. **Company** N/A **Project** N/A **Link** https: //repository.

FOCUS

BE: Materials; Component; Buildings; Cities; ✓ N/A

TOOLS & METHODS: Technology; Design; ✓ Economy; Management; Flows and resources; ✓ Society and stakeholders

NEW BUSINESS MODELS

✓ Supply-driven; ✓ Demand-driven

BM COMPONENTS: ✓ Customer segments; ✓ Value propositions (VP); Channels; Customer relationships; Revenue Streams (R$); ✓ Key Resources; Key activities (KA); Key partnerships (KP); Cost structure (C$)

APPROACH

METHODOLOGY: ✓ Literature review; ✓ Case study; Design/proposal

PRODUCT: ✓ Conceptual framework; Operational model; Assessment model; ✓ Policy/practice Design/Prototype

KEY WORDS

design research; sustainability; sustainability ambitions; circular economy; circular business models; company review

SUMMARY

There is not much insight yet in the exact relation between sustainability and already implemented circular economy solutions, especially from a company point of view. This research focuses on how companies interpret sustainability and circular business models and how they see the relationship between these two concepts. This will help to gain more insight in the relation between circular economy and sustainability and gain a more complete overview of how companies can successfully implement circular economy in their business models. Combining literature from circular business models and sustainable business models, a framework is proposed to analyse thirteen companies. The framework focuses on sustainability ambitions, business model, implementations strategies & Circular Business Model orientation, Sustainable Business Models and Circular Business Model elements. Based on the results and interviews with three companies, the tool was reviewed, and eight different possible circular business models were defined. The tool can help companies to understand, improve and communicate their circular business models and sustainability ambitions. Main findings show that most companies implement circular initiatives around their existing products, rather than applying more radical business model innovation as promoted in literature.

The tool can be used to analyse: (1) How the sustainability ambitions do against the deployed business models, (2) How circular business models fulfil the set sustainability ambitions, (3) If both the sustainability and circularity are communicated the way a company wants.

New directions for Circular Business Model classifications were found, for instance a narrowing the loop business model classification or new directions in the dematerialisation orientation. The virtualisation or digitalisation of their products is viewed as a great opportunity.

PROBLEM STATEMENT

Much research is done on the benefits of circular economy and the practical implementation of circular economy in existing systems. However, there is not much insight yet in the exact relation between sustainability and already implemented circular economy solutions, especially from a company point of view. How companies interpret this relation is an area that is currently unexplored.

GOAL

this research will look at the circular business models within companies to investigate the relation between the circular economy and companies.The goal is to analyse how circular business models help companies to fulfil the sustainability ambitions the company has set for itself. How do business models for the circular economy help companies to realize their sustainability ambitions?

CONCLUSIONS & SCIENTIFIC RECOMMENDATIONS

Most companies implement circular initiatives around their existing products, rather than applying more radical business model innovation as promoted in literature.

KEY CONCEPTS / AUTHORS

Business model

Shafer et al. (2005) Osterwalder et al.

Sustainable business models

Stubbs & Cocklin Bocken et al. (2014)

Circular business models

Ellen MacArthur Bakker et al. (2014) Accenture (2014)

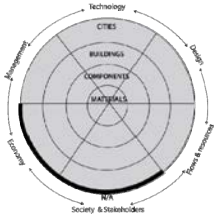
Bocken et al. (2016) Tukker & Tischner Short et al. (2013)

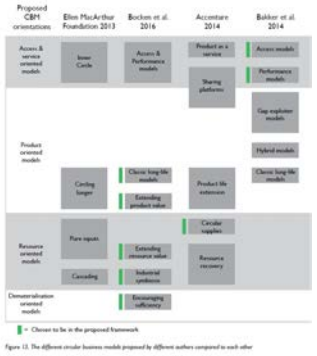
PRODUCT/BUSINESS MODEL DEVELOPMENT

	TECHNOLOGICAL READINESS	BUSINESS MODEL
1.	N/A N/A	1. Sustainable Business model: ✓ Theory; Developed; Used; Evaluated — Bocken et al. (2014), Bocken et al. (2016)
2.	N/A N/A	2. Circular Business model orientations: ✓ Theory; Developed; Used; Evaluated — Tukker & Tischner (2006)

CASE STUDIES

CASE STUDY	LOCATION	SECTOR	BUILDING TYPE	RELEVANCE
Dell		Consumer	Corporate	To measure sustainability ambitions from interviews and
Ricoh		Consumer	Corporate	To measure sustainability ambitions from interviews and
Philips		Consumer	Corporate	To measure sustainability ambitions from interviews and
Coca Cola Enterprise		Food	Corporate	To measure sustainability ambitions from reports
, Renault, Michelin, SAB miller, Nespresso, Cisco,Vodafone,		Consumer	Corporate	To measure sustainability ambitions from reports



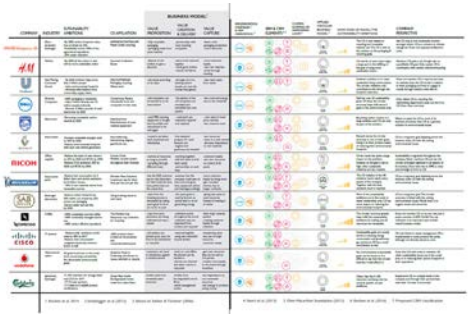


Circular business model framework

Comparable circular business model classifications of the different authors are positioned in line with each other to find the similarities and differences in the literature. Based on the Ellen MacArthur foundation (2013), Bocken et al. (2016), Accenture (2014) and Bakker et al. (2014). The similarities and differences between the classifications of these authors can be recognised and gaps can be identified.

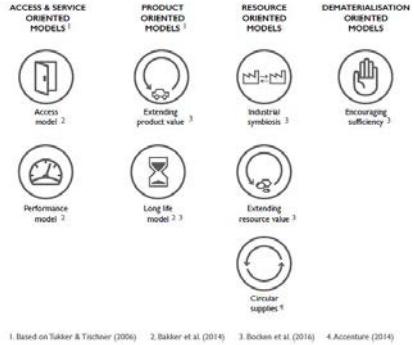
Criteria to analyse the case studies

The criteria represents sustainable and circular strategies, orientations and elements. The set of criteria is based on Schaltegger et al (2012), Tukker & Tischner (2006), Short et al. (2013), Ellen Macarthur foundation (2012), Bocken et al. (2016)



Summary of the companies reviewed

The table was built based on the following indicators: Industry, sustainable ambitions, CE affiliation, Business model (based on Bocken et al, 2014), Implementations strategies & CBM orientation (based on Schaltegger, 2012 and Tukker & Tischner, 2006, respectevely), SBM & CBM elements, comparable CBMs from literature, How CE helps fulfil sustainability ambitions, company perspective.



Type of Circular Business Models

Visualisation of eight types of circular business models used by the companies based on Tukker & Tischnner (2006), Bakker et al. (2014), Bocken et al. (2016), Accenture, (2014). Based on the analysis results, a new proposed categorization was created because none of the existing classifications could fit all the reviewed business models.

Façades as a Product-Service System

The potential of new business-to-client relations in the facade industry

Author Juan Azcarate-Aguerre **Year** 2014 **MSc programme, Faculty** Architecture, Urbanism & Building Sciences Programme

Advisors Klein, T.; Den Heijer, A.C. **Company** **Project** **Link** https: //repository.

FOCUS

BE
- [x] Materials
- [x] Component
- [x] Buildings
- [ ] Cities
- [ ] N/A

TOOLS & METHODS
- [x] Technology
- [x] Design
- [x] Economy
- [x] Management
- [ ] Flows and resources
- [ ] Society and stakeholders

CIRCULAR ECONOMY

NEW BUSINESS MODELS

BM COMPONENTS
- [x] Supply-driven
- [ ] Demand-driven
- [x] Customer segments
- [x] Value propositions (VP)
- [x] Channels
- [ ] Customer relationships
- [x] Revenue Streams (R$)
- [x] Key Resources
- [x] Key activities (KA)
- [x] Key partnerships (KP)
- [x] Cost structure (C$)

APPROACH

METHODOLOGY
- [x] Literature review
- [ ] Case study
- [x] Design/proposal

PRODUCT
- [x] Conceptual framework
- [ ] Operational model
- [ ] Assessment model
- [x] Policy/practice
- [x] Design/Prototype

KEY WORDS

facades; leasing; PSS; disassemblable; resource efficient; sustainable renovation; business-model; economics; finance; building technologies; curtain wall; integrated services; smart facades; marketing;

SUMMARY

This thesis studies the potential of a Product-Service System applied to facades. It analyses the stakeholders involved in the decision-making process for new building constructions, and then evaluates the economic, functional, energetic and strategic advantages of a "leasable facade" for each of these parties. After identifying recent trends in commercial architecture in the Netherlands, the report analyses commercial and financial scenarios which have been in practise (successfully) in other industries, and finally proposes architectural and technological strategies for adapting the facade industry, as well as the way in which we envision and produce facades, to emerging trends in marketing and asset management practices. This work also explores a variety of possible design and technical schematic models for a disassemblable facade, and their potential as resource-efficient, market-focused facade solutions. Product-Service Systems applied to facades could improve not only the way in which we design, produce, operate and dispose of essential building elements, it could also improve the difficult communication process that occurs in most business to client relations during construction projects.

PROBLEM STATEMENT

Whether we are talking of architecture as an artistic and aesthetic tendency, or as an integrated collaboration of a series of highly technical disciplines, the only way to achieve a truly sustainable culture is by matching the needs and interests of these three main groups. Finding the way to integrate technology, nature and real estate needs into horizontally integrated design solutions.

GOAL

This research explores the value of facades and their impact on the overall user-, energy- and financial-performance of an architectural project.

CONCLUSIONS & SCIENTIFIC RECOMMENDATIONS

The research has established the basic design parameters that would have to be taken into account, and come up with a series of schematic design strategies that might fit within the broader requirements of the system, and which would provide different benefits and potentials to the diverse parties involved.

Main limitations are: the financial and industrial capacity of the service provider (in case he is also the manufacturer), the specific regulations within his jurisdiction, the interest and type of client he can expect to deal with. There are external factors that might affect the decision-making process, and which can hardly be predicted by any of the stakeholders.

By bringing all parties into the table, at the right moment, and ensuring that these same players will be forced to collaborate during the entire life of the project, we can increase the chances of successful initiatives, reduce the margin of error and unnecessary risks, and shift our methods of production so that they are more inclusive and transparent.

KEY CONCEPTS / AUTHORS

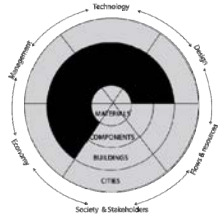
Product-Service Systems

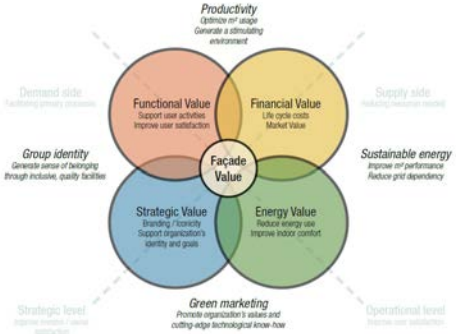
PRODUCT /BUSINESS MODEL DEVELOPMENT

TECHNOLOGICAL READINESS		BUSINESS MODEL	
1. Facade Leasing	1. Concept	1. Product Service Systems	[x] Used
		2.	[ ] Theory [ ] Developed [ ] Used [ ] Evaluated

CASE STUDIES

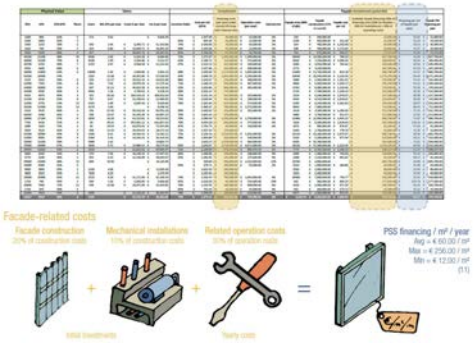
CASE STUDY	LOCATION	SECTOR	BUILDING TYPE	RELEVANCE
TU Delft 3mE Building	Delft, The Netherlands	Construction	Public	Apply the concept of facade leasing





Evaluation methodology

Assessing "facade value", linked to performance criteria (Den Heijer 2011, edited) The structure of this image has been remodelled from the original reference, and new caption in the overlapping regions (in italics) have been added to reflect that in most cases performance values are not pure and specific, but a combination of decisions being taken on one field for the improvement of another.

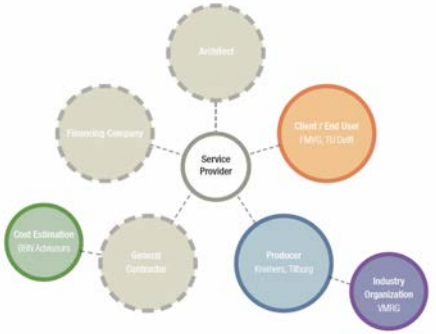


Breakdown of yearly expenses related to building envelope and mechanical support

Yearly financing of initial investment plus percentage of yearly operation costs result in the yearly cost per square meter of facade paid every year by the building owner. These values will be the reference when calculating and appropriate market price for a leasable system.

Six strategic models proposed

Summary of the 6 strategic model, showing (some) potential clients, and an approximate performance in terms of each one of the 4 value criteria. The schematic design paths are divided according to their expected service-life time frame, as well as their circular economy strategy.



The Service provider role

An ideal system will offer incentives throughout the supply and demand spectrum., even if these incentives will not always come in the same form, or at the same time. By contacting some of these interested parties early-on in the process, it is possible to slightly modify the course of the research to offer more attractive possibilities to all the decision-makers involved.

Implementation of Circular Business Models in Firms

Prospects and Barriers

Author Yewon Cha **Year** 2017 **MSc programme, Faculty** Management of Technology Programme

Advisors Verburg, R.; Quist, J.; Scholten, V. **Company** N/A **Project** N/A **Link** https: //repository.

FOCUS

CIRCULAR ECONOMY

BE
- ☐ Materials
- ☐ Cities
- ☐ Component
- ☑ N/A
- ☐ Buildings

TOOLS & METHODS
- ☐ Technology
- ☐ Design
- ☑ Economy
- ☑ Management
- ☐ Flows and resources
- ☐ Society and stakeholders

NEW BUSINESS MODELS

BM COMPONENTS
- ☑ Supply-driven
- ☑ Demand-driven
- ☑ Customer segments
- ☑ Value propositions (VP)
- ☐ Channels
- ☑ Customer relationships
- ☑ Revenue Streams (R$)
- ☑ Key Resources
- ☑ Key activities (KA)
- ☑ Key partnerships (KP)
- ☐ Cost structure (C$)

APPROACH

METHODOLOGY
- ☑ Literature review
- ☑ Case study
- ☐ Design/proposal

PRODUCT
- ☑ Conceptual framework
- ☐ Operational model
- ☐ Assessment model
- ☑ Policy/practice
- ☐ Design/Prototype

KEY WORDS

Circular Economy, Circular Business Model, Waste to Material, Material Recovery, Value Network

SUMMARY

The understanding of circular business models is essential for companies to adopt a circular economy. The objective of this research is to facilitate the dissemination of circular business models in firms by understanding the prospect and barriers of the implementation of circular business models. To do so, this research carries out a literature review in order to identify the different dimensions, frameworks and tools of circular business models. The findings of the literature review are summarised in a conceptual framework, which is used to analyse three case studies that are using waste tire carpet, and paper. The analysis of each case and a the comparison of them focused on Circular Business Models, Circular Value Network and Business Models tool for Circular Business Models. The findings of this research are threefold: (1) the concept of upcycling is one of the elements that defines a Circular Business Models, (2) the most critical factor for the success of Circular Business Models is a circular value network, (3) the business modeling tools for Circular Business Models should emphasize the element of circular values. The research contributed to the development of business modeling tools for companies, and to the provision of guidelines for policy makers to reform the waste policy and legislation.

PROBLEM STATEMENT

To induce industries to move forward in the CE, having a clear, direct, and visible business model is critical because profitability is one of the primary goals of firm activities. In this regard, theoretical and practical research on CBMs is important. However, CBM it is a relatively recent concept, and there is a lack of knowledge and experience in both academia and industry.

GOAL

The objective of this research is to facilitate the dissemination of CBMs in firms by understanding the prospect and barriers of the implementation of CBMs. The main question is : How to facilitate the implementation of circular business model at a firm-level?

CONCLUSIONS & SCIENTIFIC RECOMMENDATIONS

The importance of circular value network in the implementation of Circular Business Models has been recognized for the first time. The research provides the analysis of actors, their role, and relationships in the network with a visualization of the material flow between the actors. This is contribution for the future research on the circular value network.

This research contributes to the development of business modelling tools for Circular Business Models. The analysis of Circular Business Models revealed that some elements that are critical to Circular Business Models, but not included in the existing BM tools. Suggestions were made to the development of business modelling tools that applies to CBMs.

For the policy makers, this research can be used as a guideline on the revision or reformation of the waste policy and legislation. The research gives an overview of the issues that the circular firms are facing and makes suggestions.

KEY CONCEPTS / AUTHORS

Circular Business Model

Lewandowski (2016) De Haes et al. (2016) Achterberg et al.

The four value dimensions of business models

Al-Debei and

BM tools :Triple Layered Business Model Canvas and Value Mapping

Osterwalder (2010) Joyce and Paquin Bocken et al. (2013)

Conceptual Sustainable Business Model Framework

Bocken et al. (2015)

Sustainable Circular Business Model Innovation

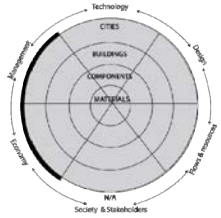
Antikainen and

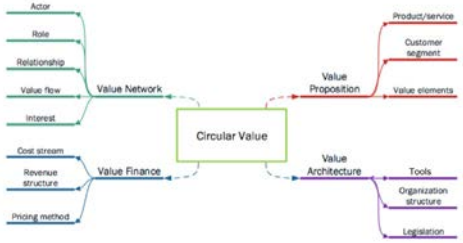
PRODUCT/BUSINESS MODEL DEVELOPMENT

TECHNOLOGICAL READINESS	BUSINESS MODEL
1. N/A	1. The four value dimensions of business models — ☐ Theory ☐ Developed ☑ Used ☐ Evaluated Al-Debei and Fitzgerald (2010)
2. N/A	2. Conceptual Sustainable Business Model Framework — ☐ Theory ☐ Developed ☑ Used ☐ Evaluated Bocken et al. (2015)

CASE STUDIES

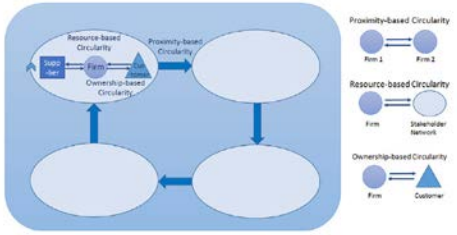
CASE STUDY	LOCATION	SECTOR	BUILDING TYPE	RELEVANCE
Black Bear Carbon. Carbon Black	The Netherlands	Consumer	N/A	Dutch start-up that upcycles carbon black from end-of-life tires
DSM NIAGA. Carpet machine and adhesive		Consumer	N/A	Redesigns daily-used products to be fully recyclable.
Van Houtum. Toilet paper		Consumer	N/A	Produces toilet hygiene supplies such as toilet paper, soap, air





Framework of circular value case study

To gain a deep understanding of CBMs, this study uses a framework that was adapted from two business model frameworks: the four value dimensions of business models by Al-Debei and Fitzgerald (2010) and the conceptual sustainable business model framework by Bocken et al. (2015). The proposed framework for this case study provides a holistic view of CBMs by



The circularity map based on three scopes of circularity to classify CB Models

(1)Proximity-based is the circularity in the industrial ecosystem where resources circulate among nearby firms,(2)Resource-based is the circularity in a firm's stakeholder network, which includes suppliers, logistic companies, customers, and sometimes competitors, (3)ownership-based is the circularity between the firm and its customers caused by the shift of the ownership of products.

Flow diagram of DSM NIAGA Network

The value flow of DSM NIAGA does not have the shape of a circle because the product of the company is equipment and knowledge, not the material that is circulated. Six actors are identified as important in the value network: the knowledge provider, machine manufacturers, carpet manufacturers, polyester upcyclers, carpet collectors, and carpet users.

	Knowledge provider	Machine manufacturer	Carpet manufacturer	Polyester upcycler	Carpet collector	Carpet users
Actor	DSM NIAGA	LACOM	Mohawk	CONAPOL	Waste collector	End-users
Function	Developing ways to changing waste to material	Developing customized automated machine	Producing carpet	Upcycling waste to material	Collecting waste and send it to recyclers	Use carpet
Role	Providing technology and adhesive for recyclable carpet	Providing recyclable-carpet manufacturing machine	Producing recyclable-carpet	Providing recycled carpet fiber	Collect used carpet and send it to polyester recycler	Purchase carpet and use it
Action	Develop technology and adhesive	Develop carpet manufacturing machines	Purchase NIAGA machine and make reusable carpet	Make used carpet into carpet fiber	Collect used carpet and sell it to polyester recycler	Select and purchase carpet
Interest	More carpet manufacturers using their adhesive	More carpet manufacturers using their machines	Low production & purchasing cost, making better carpet	Stable supply of waste carpets. Stable demand of recycled fiber	Higher waste value	Non-toxic, easy to clean carpet
Relationship with DSM NIAGA		R&D partner	Customer	No direct relationship	No direct relationship	No direct relationship

Actor analysis of DSM NIAGA

DSM NIAGA adapted the business model canvas by adding the residual value of used carpet and showing the change of the value added by each step in the flow of material. The company finds success factors in forming a balanced network from which every actor can benefit. Changing the traditional way of producing carpet with many different materials is a challenge for the penetration of recycling.

Real Estate developers as circular service providers

Author Imardo de Blok **Year** 2018 **MSc programme, Faculty** Architecture, Urbanism & Building Sciences Programme

Advisors Heurkers, E.; Vrijhoef, R. **Company** OVG Real Estate **Project** N/A **Link** https: //repository.

FOCUS

BE: Materials; Cities; Component; N/A; Buildings

TOOLS & METHODS: Technology; Design; Economy; Management; Flows and resources; Society and stakeholders

CIRCULAR ECONOMY

NEW BUSINESS MODELS

BM COMPONENTS: Supply-driven; Demand-driven; Customer segments; Value propositions (VP); Channels; Customer relationships; Revenue Streams (R$); Key Resources; Key activities (KA); Key partnerships (KP); Cost structure (C$)

APPROACH

METHODOLOGY: Literature review; Case study; Design/proposal

PRODUCT: Conceptual framework; Operational model; Assessment model; Policy/practice Design/Prototype

KEY WORDS

Product-service-System; Service provider; real estate developer Circular Economy; Servitization

SUMMARY

There is an important knowledge gap about the functioning of circular Product-Service-Systems in the real estate sector. This thesis focuses on management strategies and uses the conceptual steering model as a framework to develop an operational model. This model aims at supporting real estate developers to perform the role of the service provider within the project organization of circular real estate development projects. The model is based on the synthesis of two outputs: the findings from the literature review; and lessons derived from the analysis of three case studies (Triodos Bank, Basisweh, The boutique office). The main conclusion is that the leading role of the service provider is to find the right partnerships and ensure that incentives will be directed towards long-term service delivery. The form and content of these partnerships is essential in order to implement Product-Service-Systems successfully.

PROBLEM STATEMENT

Real estate developers do not know how to interact with service suppliers and customers to implement Product-Service-Systems in order to realise circular real estate development projects, since there is not enough knowledge available in science and practice about (1) the functioning of Product-Service-Systems on an operational level; and about (2) the position and the role of the service provider within the project organization of circular real estate development projects.

GOAL

Conceptualize the functioning of circular Product-Service-Systems on an operational level and develop conceptual working models that could be applied by real estate developers to perform the role of the service provider within the project organization of circular real estate development projects.

CONCLUSIONS & SCIENTIFIC RECOMMENDATIONS

As Product-Service-Systems aim at meeting end-users needs, service value is created over time. This implies that a mindset change within the real estate sector is needed in order to servitise real estate development projects. Organizations in the real estate sector should hereby aim at long-term value creation for customers and collaborate with partners.

Actors within the supply chain should opt for equal partnership and form networks of organizations around a specific goal.

The role of the service provider is hereby to find the right partnerships and ensure incentives will be directed towards this long-term service delivery. The form and content of these partnerships is essential in order to implement Product-Service-Systems successfully. The service provider could establish this by using the developed 'Interaction Model'.

KEY CONCEPTS / AUTHORS

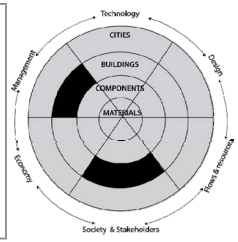
Inter-organizational systems		
Heurkens (2012)	Segerstedt & Olofsson	Vrijhoef & De Ridder
Process system		
Heurkens (2012)		
Internal / external management measures		
Reim, W., Parida, V., &	De Leeuw (2002)	
Product-Service-Systems business tactics		
Tukker (2004)	Stahel (2006)	Reim, W., Parida, V., &
Conceptual steering model		
De Leeuw (2002)		

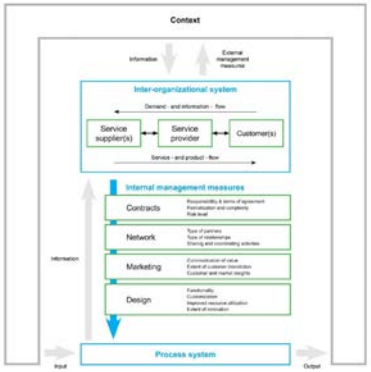
PRODUCT/BUSINESS MODEL DEVELOPMENT

	TECHNOLOGICAL READINESS	BUSINESS MODEL
1.	N/A N/A	1. Product-Service-Systems ✓Theory; Developed; ✓Used; Evaluated
2.	N/A N/A	2. N/A Theory; Developed; Used; Evaluated

CASE STUDIES

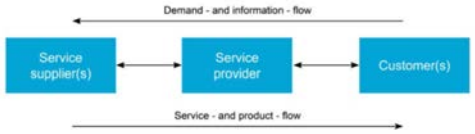
CASE STUDY	LOCATION	SECTOR	BUILDING TYPE	RELEVANCE
Triodos Bank	Zeist, Netherlands	Construction	Corporate	Façade as a service
Basisweh	Amsterdam, Netherlands	Construction	Corporate	Comfort & energy as service
The boutique office	Amsterdam, Netherlands	Construction	Corporate	Real estate developer as service provider





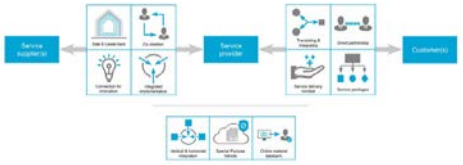
Conceptual Framework

Conceptual framework based on the steering model developed by De Leeuw (2002) and Heurkens (2012). The concepts in the model are linked to real estate development processes and explain the mechanisms occurring in a project. The framework focuses on three main concepts: 'inter-organizational system', 'process system' and 'internal management measures'



Inter-organizational system

Inter-organizational system (Segerstedt & Olofsson, 2010; Vrijhoef & De Ridder, 2005)



Interaction model

A conceptual model is proposed after the cross-case analysis and the literature review findings. The model, based on four business tactics defined by Reim et al (2015), is created for real state developers to interact with customers and service suppliers.

Results

Summary of research findings

Closing the loop in real estate

Implementing the circular economy at constructions

Author David De Grauw **Year** 2015 **MSc programme, Faculty** Architecture, Urbanism & Building Sciences Programme

Advisors Prins, M.; Den Heijer, A.C. **Company** N/A **Project** N/A **Link** https://repository.

FOCUS

BE
- CIRCULAR ECONOMY
- ☐ Materials ☐ Cities
- ☐ Component ☐ N/A
- ✓ Buildings

TOOLS & METHODS
- ☐ Technology
- ☐ Design
- ✓ Economy
- ✓ Management
- ☐ Flows and resources
- ☐ Society and stakeholders

BM COMPONENTS
- NEW BUSINESS MODELS
- ☐ Supply-driven
- ☐ Demand-driven
- ☐ Customer segments
- ✓ Value propositions (VP)
- ☐ Channels
- ☐ Customer relationships
- ✓ Revenue Streams (R$)
- ☐ Key Resources
- ☐ Key activities (KA)
- ☐ Key partnerships (KP)
- ✓ Cost structure (C$)

APPROACH

METHODOLOGY
- ✓ Literature review
- ✓ Case study
- ✓ Design/proposal

PRODUCT
- ✓ Conceptual framework
- ✓ Operational model
- Assessment model
- Policy/practice
- Design/Prototype

KEY WORDS

circular economy, Product-Service System, Performance-Service , System, decision

SUMMARY

In the current construction sector there is an urgency to implement principles of the Circular Economy. Unfortunately, there is no step-by-step plan on how to make a transition towards a Circular Economical system, existing a lack, but also, a need for information and knowledge. The thesis elaborates on the concept of Circular Economy by developing a Performance-Service System applicable for the construction sector considering operational, organisational and financial levels. The development of the Performance-Service System model is combined with the development of financial models. The model was tested by doing interviews and test cases in the educational sector (Delft University of Technology). Main results showed that according to the principles of the Circular Economy the best strategy would be to use an Operational Gross Lease. However, Its implementation depends on the clients' wishes and requirements if this strategy fits the needs best. Although the model will not support decisions on its current state, the content of the model stimulated discussions about Circular Economy, and it gave insights into the implementation of Circular Economy in the Dutch Educational Sector.

PROBLEM STATEMENT

In the current construction sector there is an urgency to implement principles of the Circular Economy. Unfortunately, there is no step-by-step plan on how to make a transition towards a Circular Economical system. There is a lack of, but also a need for, data, information, and knowledge regarding the Circular Economy within the construction sector.

GOAL

The main goal is to develop a Performance-Service System to implement the principles of Circular Economy in the current construction sector. How to develop and implement a Performance-Service System in constructions of the educational sector regarding operations, organisation and financial schemes?.

CONCLUSIONS & SCIENTIFIC RECOMMENDATIONS

The Performance-Service System is a tool to support strategic decision making for clients with respect to constructions. This model includes information about the organisation, operations and the finance. The model should provide the client with different sets of information so they can make founded decisions. The implementation of the Performance- Service System depends on a few variables, such as principles of the CE, the context of the client, the operations, organisation and financial schemes.

The content of the model is good, but in order to operationalize this model a few modifications need to be made. It can be said, due to the model the discussion about the Circular Economy is stimulated. It gives, by using relatively simple figures, a good illustration of what the Circular Economy is all about. Although it does not support decisions in its current state, the model gives a lot of different insights of the Circular Economy in the Dutch educational sector.

First of all a lot of different opportunities have been shown. Tools and thoughts on how to make a transition in our economic system have been explored. Furthermore obstacles are exposed and therefore new students can explore for solutions of these obstacles.

KEY CONCEPTS / AUTHORS

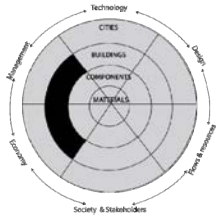
Product-Service Systems		
Mont (2002)	Deckmyn et al. (2014)	Bastein et al. (2013)
Performance-Service Systems		
Webster (2013)	Stahel (2013)	Deckmyn et al. (2014).

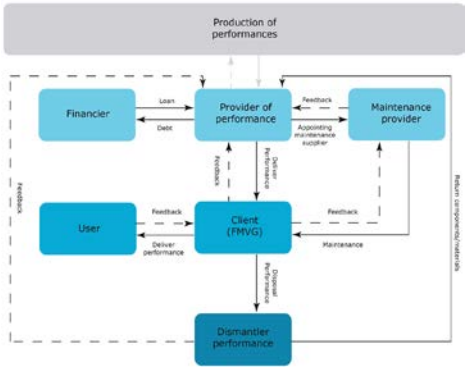
PRODUCT/BUSINESS MODEL DEVELOPMENT

	TECHNOLOGICAL READINESS	BUSINESS MODEL
1.	N/A N/A	1. Performance-Service Systems — ☐ Theory ☐ Developed ✓ Used ☐ Evaluated
2.	N/a N/A	2. ☐ Theory ☐ Developed ☐ Used ☐ Evaluated

CASE STUDIES

CASE STUDY	LOCATION	SECTOR	BUILDING TYPE	RELEVANCE
Delft University of Technology FMVG (Facilitair Management &	Delft, The Netherlands	Construction	Public	test case. University is the client



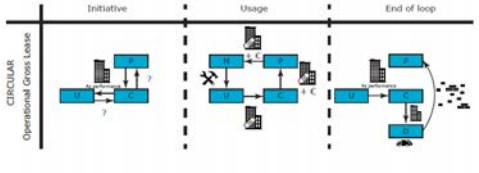


Performance- Service System Model

Model used to used during interviews with employees of FMVG TU Delft. The model includes the following stakeholders who are expected to have a relationship with the client: User, Provider, Maintenance Provider, Dismanteler, Financier.

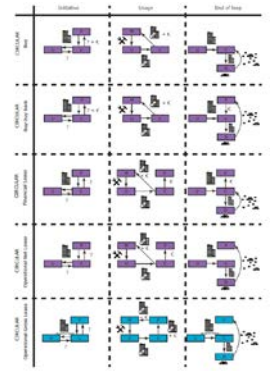
Differences between Product-Service System and Performance-Service System

The service cannot be produced or consumed in itself and is subordinate to the performance. At last, the system is a mix of performances, the subordinate products and services, and the communication required between client and provider.



The Performance-Service System - Operational gross lease

At this moment, only the Operational Gross Lease fulfils the requirements of the Circular Economy. This is the only strategy in which clients can procure in performances. In all other cases the client is in some degree responsible for the components and/or materials that are needed (In the figure P:provider, C: client, U: user, M: maintenance provider, D: dismantler, B: broker).



Diifferent strategies regarding the procurement of new facilities

All strategies are explained in terms of organisation, operations and financial schemes. The organisation and the operations will be explained below. The financial scheme will not be elaborated because this would be different for every strategy.

(RE)DEVELOP THE FUTURE

An instrument to develop and implement the concept of circularity for the redevelopment initiation phase

Author Wouter Disseldorp **Year** 2018 **MSc programme, Faculty** Architecture, Urbanism & Building Sciences Programme

Advisors Remoy, H.; Koppels, P. **Company** Rijksvastgoedbedrijf **Project** N/A **Link** https: //repository.

FOCUS

BE
- ✓ Materials
- ✓ Component
- ✓ Buildings
- Cities
- N/A

TOOLS & METHODS
- ✓ Technology
- Design
- Economy
- ✓ Management
- ✓ Flows and resources
- Society and stakeholders

NEW BUSINESS MODELS

Supply-driven
✓ Demand-driven

BM COMPONENTS
- ✓ Customer segments
- ✓ Value propositions (VP)
- Channels
- Customer relationships
- Revenue Streams (R$)
- Key Resources
- Key activities (KA)
- Key partnerships (KP)
- Cost structure (C$)

APPROACH

METHODOLOGY
- ✓ Literature review
- ✓ Case study
- ✓ Design/proposal

PRODUCT
- Conceptual framework
- Operational model
- ✓ Assessment model
- Policy/practice
- Design/Prototype

KEY WORDS

Adaptive reuse; Circular Economy; building circularity indicator; condition assessment; reutilization potential; circular redevelopment; assessment model; Circular Redevelopment potential

SUMMARY

Circular Economy could contribute and accelerate adaptive reuse of societal heritage, nevertheless, current Dutch heritage is rarely participating in new investment alternatives for redeveloping real estate. This research focuses on identifying and assessing circular redevelopment potential in order to initiate circularity during the redevelopment process. To do so, an indicator is proposed to assess the Circular Redevelopment Potential (CRP) of different components of the built environment. The indicator comprises six consecutive strategies: Reuse, Repair, Refurbish, Remanufacture, Repurpose and Recycle. The model is theoretically developed and subsequently tested with one case study (Circular Pavilion The Green House). The research concludes that the CRP indicator is useful to get objective data about the applied material characteristics and corresponding condition status of building elements; to identify preconditions for circularity, and to provide information to enable contractors to differentiate from their competitors. Although the model is not intended as a certificate or label, it can be used as supportive instrument to substantiate any classification on this matter.

PROBLEM STATEMENT

Currently the Dutch heritage is reluctant to participate in new investment alternatives for redeveloping real estate. Solutions to prevent vacancy and dilapidation like renovation and conversion regularly fail due to numerous reasons. The phenomenon 'circular economy' could contribute and accelerate adaptive reuse of societal heritage.

GOAL

To assess circular redevelopment potential in order to initiate circularity during the redevelopment process. Within this perspective the comprehensive aim is to develop a tool which can be used as an instrument for principals (i.e. the client, searching for a highest and best use for the upcoming exploitation phase of the property) and identify a performance indicator within the built environment.

CONCLUSIONS & SCIENTIFIC RECOMMENDATIONS

The Circular Redevelopment Potential (CPR) Indicator is a useful tool for the assessment of properties to implement circularity during the redevelopment process.

Building inspectors can provide property managers/ owners with objective data about the applied material characteristics and corresponding condition status of building elements. It supports principals to identify preconditions, in order to specify their ambition on circularity and provide the sufficient information to actually enable contractors to differentiate from their competitors during tenders.

The assessment model is not intended as a certificate or label, however could be used as supportive instrument to substantiate any classification on this matter.

KEY CONCEPTS / AUTHORS

Adaptive Reuse
Wilkinson et al., Walker (2003) Wilkinson and Remøy

Circular value creation
Ellen Macarthur

Reutilization strategies
Verberne (2016)

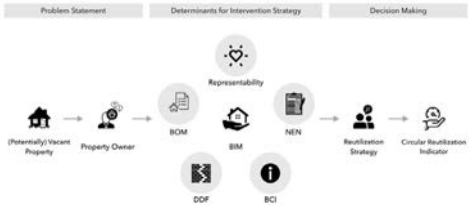
Building Circularity Indicator

PRODUCT/BUSINESS MODEL DEVELOPMENT

	TECHNOLOGICAL READINESS		BUSINESS MODEL	
1.	N/A	N/A	1. N/A	Theory Developed Used Evaluated
2.	N/A	N/A	2. N/A	Theory Developed Used Evaluated

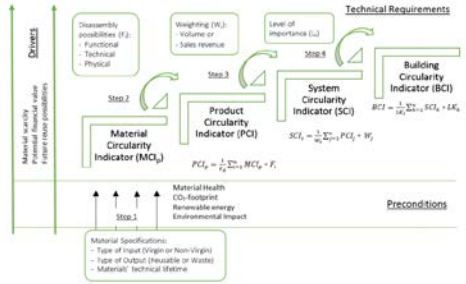
CASE STUDIES

CASE STUDY	LOCATION	SECTOR	BUILDING TYPE	RELEVANCE
Circular Pavilion 'The Green House	Utrecht, Netherlands	Construction	Public	Case used to apply and validate the indicator



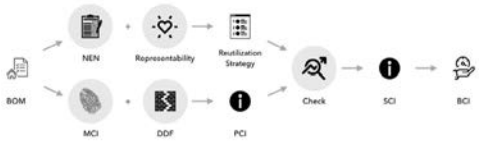
Visual representation of the Circular Redevelopment Potential

The Indicator has the objective to help actors in the built environment to determine at what level a building component or material is most suitable to reutilize in order to initiate adaptive reuse. The CRP Indicator is mainly focused on circularity. Therefore, economic,societal and sustainability are excluded from this method.



Assessment model

Conceptual structure for the circularity assessment model of materials within the technical cycle (Verberne, 2016)



Information flow of the Circular Redevelopment Potential Indicator

The CRP Indicator is designed following a five step approach: (1) information gathered into a BOM, (2) classify any defects observed on site, (3) check on representability, (4) result on six strategies, (5) reutilization performance indicator (BCI).

Supply yourself

A circular reorganisation on the supply side in the construction industry from a financial perspective

Author Cherryl Djoegan & Dirk van **Year** 2016 **MSc programme, Faculty** Architecture, Urbanism & Building Sciences Programme

Advisors De Jong, P.; Prins, M. **Company** N/A **Project** N/A **Link** https: //repository.

FOCUS

BE: Materials; Cities; ✓ Component; ✓ N/A; Buildings

TOOLS & METHODS: Technology; Design; ✓ Economy; ✓ Management; Flows and resources; Society and stakeholders

CIRCULAR ECONOMY

NEW BUSINESS MODELS

Supply-driven; ✓ Demand-driven

BM COMPONENTS: ✓ Customer segments; ✓ Value propositions (VP); Channels; Customer relationships; ✓ Revenue Streams (R$); ✓ Key Resources; ✓ Key activities (KA); Key partnerships (KP); ✓ Cost structure (C$)

APPROACH

METHODOLOGY: ✓ Literature review; ✓ Case study; ✓ Design/proposal

PRODUCT: ✓ Conceptual framework; ✓ Operational model; Assessment model; Policy/practice; Design/Prototype

KEY WORDS

circular economy, construction industry, suppliers, building products, circular building, financial business model

SUMMARY

The translation of circular economy models in the construction industry seems to be absent. Therefore, the research focuses in this translation by discussing the possibilities for building product supplier to transact their product by using Product-Service Systems. The research aims at testing whether it is financially feasible to participate in the development of a circular building by offering building products based on sale and buyback, and leasing. The feasibility is calculated using a discounted cash flow analysis, and is expressed as a financial yield known as the Net Present Value. The analysis was conducted with four different case studies of building product groups. The findings, in comparison with the yields of a regular sale transactions, do not appear to be financially feasible due to extra costs, expenses and risks the supplier would need to take during the use of the product. The findings were also used to determine the possibility of a building being developed with the use of PSS only. Despite the negative findings, it is possible to assume that a circular economy is only to be implemented successfully in case resource prices increase, possibly in combination with decreasing labour costs for the supplier.

PROBLEM STATEMENT

There are two main problems in the construction industry: Firstly, processes in which products are reused or recycled are currently not financially feasible, explaining why building product suppliers do not have their businesses perform in such a way. Secondly, suppliers have not enough knowledge to comprehend the required changes, what these changes entail, what kind of influence these would have on their way of doing business, and how they could benefit and thrive under these changed circumstances and possible benefits to its business.

GOAL

The research aims at testing whether it is financially feasible for building product supplier in the construction industry to participate in the development of a circular building by offering building products based on sale and buyback, and leasing.

CONCLUSIONS & SCIENTIFIC RECOMMENDATIONS

The financial feasibility of PSS is to be achieved by: (1) Increasing resource prices making reuse more attractive (2) Taking the disassembly and dismantle possibilities into consideration in the design of products, (3) A changing financial sector, (4) Changing governmental regulations in order to stimulate reuse (5) A different mindset of both clients and suppliers.

In the case of Sale and buyback, the increase in prices due to resource depletion and the following financial feasibility, assumes that the feasibility depends on a certain ratio between resources and material costs on the one hand, and labour and transaction costs on the other.

In the case of lease, a long lease term includes higher risks for both the client and the supplier. The costs for storing the product and qualitative depreciation rise when the supplier cannot find a client. The costs for retrieving and renewing the product strongly depend on the product design, regarding the possibility to disassemble and dismantle the product.

KEY CONCEPTS / AUTHORS

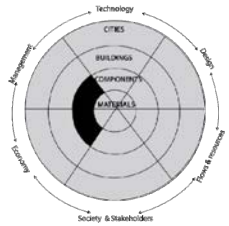
Product Service Systems		
Tukker & Tischner	Stahel (2010)	Mont (2004)
Deckmyn, S., Leyssens,	Tukker (2004)	Lay et al. (2009)
Building models		
Habraken (1961)	Duffy (1990)	Brand (1995)
Prins (1992)	Durmisevic and	

PRODUCT/BUSINESS MODEL DEVELOPMENT

	TECHNOLOGICAL READINESS	BUSINESS MODEL	
1.	N/A	N/A	1. Product-oriented PSS: Sale and buy back — ☐ Theory ☐ Developed ✓ Used ☐ Evaluated
	N/A	N/A	2. Use-oriented PSS: Lease — ☐ Theory ☐ Developed ✓ Used ☐ Evaluated

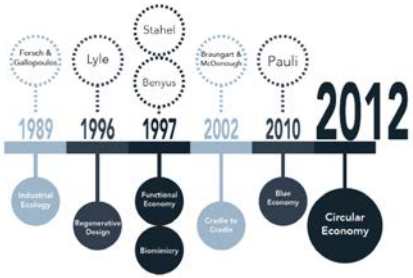
CASE STUDIES

	CASE STUDY	LOCATION	SECTOR	BUILDING TYPE	RELEVANCE
–	Group 1: Concrete slab floor	bouwkosten (supplier)	Construction	N/A	Building component
–	Group 2: Airconditioning system	STB (supplier)	Construction	N/A	Building component
–	Group 3: Sandwich panel and a pantry & closet	Logge Maatwerk (supplier), Unisol	Construction	N/A	Building component
–	Group 4: Small storage cabinet	Logge Circulair (supplier)	Construction	N/A	Building component
–					

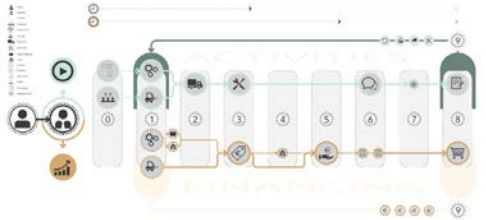


Circular Building Model

The model combines aggregation levels (based on disassembly and dismantle possibilities), and scale levels. The model comprises the following elements: (1) Building system scale, (2) The general system: shell, installations, infill, (3) disassembly system:Non-Demountable Mechanical connections, Demountable Mechannical connections. No mechanical connections. and (4) Product system.

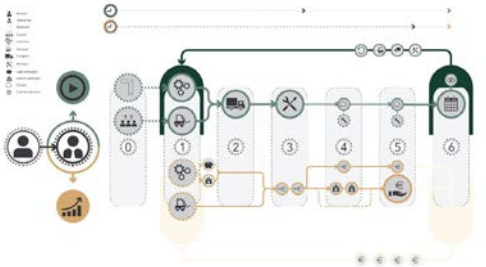


Schools of thoughts regarding circular economy



Sale and buyback transaction model to analyse the case studies

The model focus on the revenues and costs for the building product supplier of the building product in question. The goal of the model is to examine the financial feasibility from the perspective of the supplier. The feasibility is calculated using a discounted cash flow analysis, and is expressed as a financial yield known as the Net Present Value.



Lease transaction model to analyse the case studies. The model focus on the revenues and costs for the building product supplier of the building product in question. The goal of the model is to examine the financial feasibility from the perspective of the supplier. The feasibility is calculated using a discounted cash flow analysis, and is expressed as a financial yield known as the Net Present Value.

Talking circularity - the influence of actors on the building process

A study into actor networks and influence on decision-making regarding the implementation of circularity into the building process

Author Ditte Gerding **Year** 2019 **MSc programme, Faculty** Construction, Management and Engineering Programme

Advisors Leclercq, E. **Company** N/A **Project** N/A **Link** https: //repository.

FOCUS

BE
- ✓ Materials
- Component
- ✓ Buildings
- Cities
- N/A

TOOLS & METHODS
- Technology
- Design
- Economy
- ✓ Management
- ✓ Flows and resources
- ✓ Society and stakeholders

CIRCULAR ECONOMY

NEW BUSINESS MODELS

BM COMPONENTS
- Supply-driven
- ✓ Demand-driven
- ✓ Customer segments
- Value propositions (VP)
- Channels
- Customer relationships
- Revenue Streams (R$)
- ✓ Key Resources
- Key activities (KA)
- ✓ Key partnerships (KP)
- Cost structure (C$)

APPROACH

METHODOLOGY
- ✓ Literature review
- ✓ Case study
- Design/proposal

PRODUCT
- ✓ Conceptual framework
- Operational model
- Assessment model
- ✓ Policy/practice
- Design/Prototype

KEY WORDS

circularity; sustainability; building process; built environment; actor network; decision-making; circular building; circular economy;

SUMMARY

Difficulties in relation to the process, cost and time, and collaboration hamper the implementation of circularity in practice. Therefore, this research focuses on the actor network and the decision-making process. The main goal is to gather information from current practices and make recommendations to facilitate implementation of circularity in the building process. By using the concepts of circular patterns and strategies, actor network and contextual factors, the research develops an analytical framework. This framework is used to analyse three case studies built with circular ambitions : Towanhall Brummen, the Green House and EDGE Olympic. The main results showed that initiation and preparation phases offer important moments to decide upon beginning and end of life scenarios and thereby implement circularity. This thesis concludes that circular-related actors and traditional actors with circular related resources should be involved and be influential in decision-making. Furthermore, the study demonstrated the benefit of early on involvement of the following circular-related actors: transformation agent, circularity expert, reclamation expert, dismantler, and legal officer.

PROBLEM STATEMENT

Although circularity seems to be a promising concept, difficulties in relation to the process, cost and time, and collaboration hamper the implementation of circularity in practice. It can be considered that the 'start' and 'end' phase of the building's life time need to be reconsidered to obtain a circular process and close the cycle. To do so, different relations between actors should be established and other actors should be involved.

GOAL

To gather information from current practice(s) and make recommendations for improving the actor network and the decision-making process to facilitate implementation of circularity in the building process.

CONCLUSIONS & SCIENTIFIC RECOMMENDATIONS

The case study research concluded that particularly for the long-lived layers of the building early on decision-making is beneficial for implementing circularity in practice. In the initiation phase the client should demand to build a circular building by providing a vision which includes circular-related requirements in a general or specific manner.

Circular-related actors and traditional actors with circular-related resources should be involved and be influential in decision-making of circular building projects. This study demonstrates the benefit of early on involvement of the following circular-related actors: transformation agent, circularity expert, reclamation expert, dismantler, and legal officer.

In the preparation phase actors should decide on patterns for the beginning and end of life scenarios of the building, thereby aiming for certain ends, i.e. reduce, reuse, and recycle, in this order. Subsequently, circular strategies (CSs) and design strategies should be chosen to facilitate implementation of these ends.

KEY CONCEPTS / AUTHORS

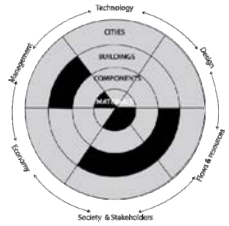
Circular patterns and strategies (or circular business models, circular		
Lüdeke-Freund, Gold	Kraaijenhagen et al.	Bocken, Short, Rana &
Addis (2006)	Stahel (2016)	Mcdonough &
Bocken et al. (2016)		
Actor network		
den Heijer & van der	Wamelink (2010)	Ness & Xing (2017)
Contextual factors		
Addis (2006)	Kibert (2013)	Pomponi & Moncaster

PRODUCT/BUSINESS MODEL DEVELOPMENT

TECHNOLOGICAL READINESS		BUSINESS MODEL	
1. N/A	N/A	1. Circular Patterns and Strategies	✓ Theory Developed Used Evaluated
		Lüdeke-Freund, Gold & Bocken (2018)	
2. N/A	N/A	2. N/A	Theory Developed Used Evaluated

CASE STUDIES

CASE STUDY	LOCATION	SECTOR	BUILDING TYPE	RELEVANCE
Townhall iby RAU	Brummen, Netherlands	Construction	Public	New project, circular ambition and information available
The Green House in Utrecht	Utrecht, Netherlands	Construction	Commercial	New project, circular ambition and information available
EDGE Olympic	Amsterdam, Netherlands	Construction	Corporate	Renovation project, circular ambition and information



Conceptual framework

Conceptual framework of circular patterns and their subsequent circular strategies (CSs), resource strategies, value strategies, and design strategies, 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), these can be applied as a beginning and as an end of life scenario for the building.

Table 3.7 Analytical framework as concluded from the literature study.

Topic	Aspects	Research question

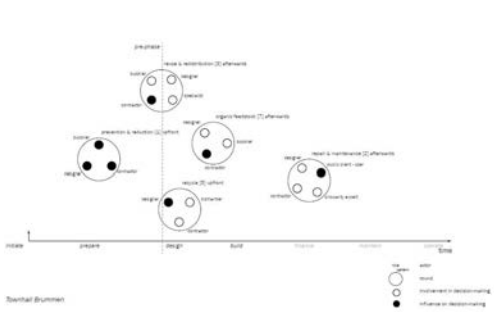
Actor network	• Actors (traditional and unconventional actors)
	  • Resources
	• Relations
	  • Formal, informal
	  • Previously established relations, long-term
	• Positions (roles)
	  • Centrality
	• Influence on decision-making
		"Which actors are involved in the building process of circular building projects?"
		"Which actors influence decision-making on circularity?"

Decision-making process	• Involved actors that influence decision-making
	• Rounds/decisions
	  • Patterns
	  • Circular strategies (CSs)
	  • Design strategies (type of materials, layers)
	  • Upfront and afterwards scenarios: beginning and end of building's life time
	• Time
	  • Phases of the building process
	  • When does it take place (early on)
		"Which actors influence decision-making on circularity?"
		"What decisions on circularity are made?"
		"When are decisions on circularity being made?"

Contextual factors	• Contract & form of collaboration • Evaluation tool • Goodwill & mindset	-

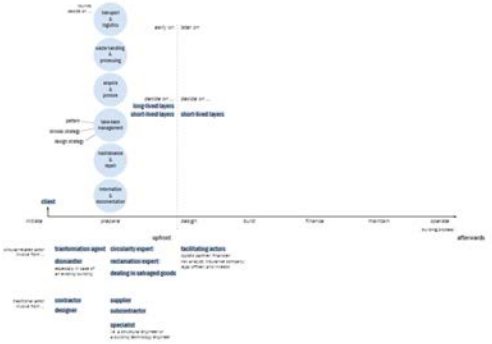
Analytical framework

The framework considers three main topics: actor network, decision-making process (circular patters and strategies), and contextual factor.



Case study analysis: Townhall Brummen

Townhall Brummen analysis regarding decision-making process including involved actors, topics and rounds positioned over time. Framework based onKlijn & Koppenjan (2016).



Recommended building process regarding actors and decision-making to facilitate

This shows recommended decision-making including circular aspects that should be discussed in the prepare phase, these can be dealt with by means of defining patterns, circular strategies, and design strategies to be applied as upfront or afterwards scenario. This Figure shows the most significant actors that benefit circularity by means of their (circular-related) resources. Depending on the nature of

Circular Demolition and Component Reuse in Construction

The Current Building Stock as a Source of Components for New Buildings

Author Luuk Gremmen **Year** 2018 **MSc programme, Faculty** Architecture, Urbanism & Building Sciences Programme

Advisors Heintz, J. van Bueren, E. **Company** N/A **Project** N/A **Link** https: //repository.

FOCUS

BE: ☑ Materials ☐ Cities ☑ Component ☐ N/A ☑ Buildings

TOOLS & METHODS: ☐ Technology ☐ Design ☐ Economy ☐ Management ☑ Flows and resources ☑ Society and stakeholders

CIRCULAR ECONOMY

NEW BUSINESS MODELS

BM COMPONENTS: ☐ Supply-driven ☐ Demand-driven

☐ Customer segments ☐ Value propositions (VP) ☐ Channels ☐ Customer relationships ☑ Revenue Streams (R$) ☑ Key Resources ☑ Key activities (KA) ☐ Key partnerships (KP) ☐ Cost structure (C$)

APPROACH

METHODOLOGY: ☑ Literature review ☑ Case study ☐ Design/proposal

PRODUCT: ☐ Conceptual framework ☐ Operational model ☑ Assessment model ☑ Policy/practice ☐ Design/Prototype

KEY WORDS

Circular economy, Urban mining, Circular demolition, Deconstruction, Component reuse, Exploratory, Case study

SUMMARY

In the transition towards a circular building industry the focus is usually put upon new buildings designed for deconstruction. However, little research has been done into component reuse for components reclaimed from current buildings. This research approaches the challenge of transitioning to a circular building industry from the side of the current building stock. The aim of this research is to explore the different drivers and barriers that have been experienced by professionals, trying to reclaim components or construct buildings using them. This research explores five cases that are trying to solve this issue in different ways. The case studies are used as a basis to identify drivers, barriers, and opportunities for circular demolition and component reuse. Results show that the main drivers are environmental, societal, and behavioural in nature. Whereas the main barriers are economic, behavioural, and governmental. Opportunities for entrepreneurs and governments have been identified to overcome these barriers.

PROBLEM STATEMENT

In the transition towards a circular building industry the focus is usually put upon new buildings designed for deconstruction. However, little research has been done into component reuse for components reclaimed from current buildings.

GOAL

The aim of this study is to look at the micro-level of single buildings and building components to find drivers and barriers that encourage or inhibit circular demolition and component reuse, as well as identifying opportunities for entrepreneurs and policy makers. What are the current drivers, barriers, and opportunities for circular demolition and the integration of component reuse into new buildings in the Benelux?

CONCLUSIONS & SCIENTIFIC RECOMMENDATIONS

The drivers and barriers for circular demolition are different from those of component reuse. Circular demolition benefits from broader acceptation in the industry, having drivers in the societal and behavioural dimensions as well as in environmental and governmental dimensions.

The principal barrier to circular demolition is the limited of demand for reclaimed components, however, a limited supply of identical high-quality components prevents adoption among businesses.

There are mayor barriers to component reuse in the behavioural and societal dimensions. The lack of economic and governmental drivers mean that these barriers are unlikely to be overcome without a shift in behaviour. This is creating opportunities for policy makers to develop legislation to stimulate not only waste minimisation but also component reuse.

KEY CONCEPTS / AUTHORS

Up-cycling and down-cycling
Iacovidou & Purnell McDonough &

Urban Mining
Wallsten, Carlsson, Johansson, Krook, Brunner (2011)

Supply Chain management in the Construction Industry
Segerstedt & Olofsson Vrijhoef & Koskela Alonso, Gregory, Field,

Circular Demolition for Component Reuse
Addis (2012) Chini & Bruening Lacovidou & Purnell

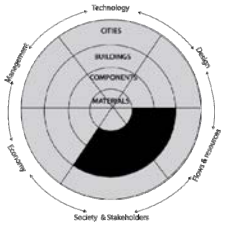
Circular Economy in Construction
Pomponi & Moncaster

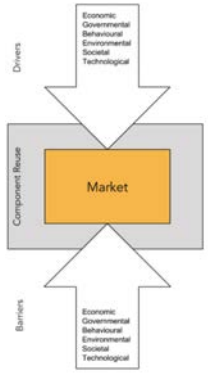
PRODUCT/BUSINESS MODEL DEVELOPMENT

	TECHNOLOGICAL READINESS	BUSINESS MODEL
1.	N/A	1. N/A ☐ Theory ☐ Developed ☐ Used ☐ Evaluated
2.	N/A	2. N/A ☐ Theory ☐ Developed ☐ Used ☐ Evaluated

CASE STUDIES

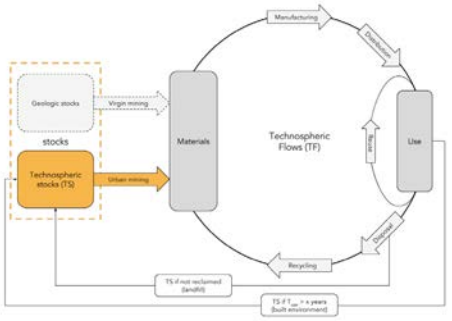
CASE STUDY	LOCATION	SECTOR	BUILDING TYPE	RELEVANCE
Rotor DC	Belgium	Construction	N/A	It is an autonomous side-project of Rotor,a Brussels-based non-
Bouwcarrousel	Netherlands	Construction	N/A	Facilitating reuse of building components by means of
A. Van Liempd Demolition Companies	Netherlands	Construction	N/A	Demolition company with circular business components: to use the
Erasmus MC	Rotterdam, Netherlands	Construction	N/A	Demolition and new construction by trying to minimise waste and
Government Real Estate Agency	Netherlandss	Construction	N/A	Circular demolition and by extension components reuse is





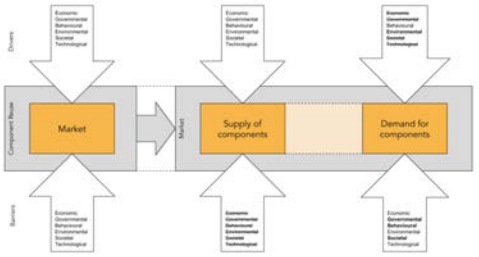
Analytical Framework for the case study analysis

By taking economics as a starting point the supply chain of reused components becomes the centre of the framework. This places supply opposite of demand within the economic dimension. Without outside factors to influence the supply and demand they are expected to balance each other out due to regular workings of the economy.



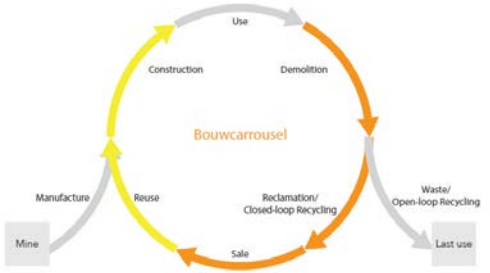
Technospheric stocks and flows

The place of urban mining in a circular economy based on Lederer et al. (2016)



Barriers and enablers identified in the cross-case analysis

Barriers are enablers are placed in the analytical framework. Barriers are concentrated in the behavioural dimension on the demand side, while drivers are concentrated in the governmental dimension on the supply side.



Case study Bouwcarrousel

Places in the supply chain where the case of Bouwcarrousel is active as a facilitator case.

Circular Business Model Patterns and their Relevance towards a more Circular Economy

A case survey of 34 circular companies

Author Lianne Huitema **Year** 2018 **MSc programme, Faculty** Management of Technology Programme
Advisors Quist, J.; de Reuver, M. **Company** N/A **Project** N/A **Link** https: //repository.

FOCUS

BE — *CIRCULAR ECONOMY*: Materials; Component; Buildings; Cities; ✓ N/A

TOOLS & METHODS: Technology; Design; ✓ Economy; ✓ Management; Flows and resources; Society and stakeholders

NEW BUSINESS MODELS: Supply-driven; ✓ Demand-driven

BM COMPONENTS: ✓ Customer segments; ✓ Value propositions (VP); Channels; Customer relationships; ✓ Revenue Streams (R$); ✓ Key Resources; ✓ Key activities (KA); ✓ Key partnerships (KP); Cost structure (C$)

APPROACH

METHODOLOGY: ✓ Literature review; ✓ Case study; Design/proposal

PRODUCT: ✓ Conceptual framework; Operational model; ✓ Assessment model; Policy/practice; Design/Prototype

KEY WORDS

circular economy; business models; circular business models; circular business model patterns; case survey

SUMMARY

The current economy, or linear economy, is still the status quo where products are used in a take-make-use-dispose manner. It is time for businesses to become part of the Circular Economy by designing circular business models (CBMs). This thesis studied circular business model patterns (CBMPs) in scientific literature and in business practice. Circular Business Model Patters are building blocks of Circular Business Models and considered powerful and useful tools for business model innovation. The most important outcomes of the literature study are a list of 26 Circular Business Models, 18 barriers for their implementation and 11 Circular Business Model Patterns. By using this framework, the case survey methodology analyzed 34 companies based on information resources online and in scientific literature . Additionally, two semi-structured interviews were conducted. Hierarchical clustering analysis and chi-square tests were used for data analysis. The result of this thesis is a more comprehensive list of Circular Business Model Patterns (13 in total). For Circular Economy to happen, many changes are needed and currently the principles of CE are not widely adopted. With the arrival of CE companies and their business models need to change. Circular Business Model Patterns can help the Business Model Innovation process by giving the process the

PROBLEM STATEMENT

Managers of companies that that need to implement circular principles and activities can, with help of CBMPs, generate new business models systematically or adapt existing business models. The industries where the companies in this research operate in are not new, but with the arrival of CE much in business processes needs to change. It is argued that more knowledge of CBMs, its patterns and its implementation barriers can enhance the CE transition

GOAL

To identify which circular business model patterns exist and what their relation is to circular business models and implementation barriers that circular companies experience. Besides, to investigate what implications circular business model patterns have for companies and how they are placed in the transition from a linear to a more circular economy.

CONCLUSIONS & SCIENTIFIC RECOMMENDATIONS

Managers of companies that need to implement circular principles and activities can, with help of Circular Business Model Patterns, generate new business models systematically or adapt existing business models. Furthermore, Business Model Patterns help to describe and understand the logic of new, unknown markets.

Small and bigger relations exist between Circular Business Model Patterns and Circular Business Models with limitations. There is e.g. Circular Business Model 'Encourage efficiency' and Circular Business Model Pattern 'Adopt a stewardship role' that were correlated.

Decision makers that want to positively influence the CE could have a look at the list of implementation barriers that were identified in companies. The work of this thesis is relevant for the transition to a CE. It is argued that more knowledge of Circular Business Models, its patterns and its implementation barriers can enhance the CE transition

KEY CONCEPTS / AUTHORS

Business Models (Business Model Canvas)
Osterwalder &

Business Model Patterns (BMP)
Alexander et al. (1977) Remane et al., 2017) Osterwalder &

Gassmann et al., Lüdeke-Freund et al. Bocken et al. (2014)

Circular Business Models (CBM)
Bocken et al., (2016) Oghazi & Mostaghel Lüdeke-Freund et al.

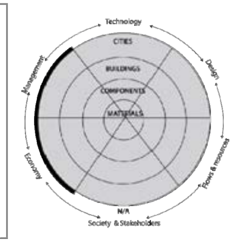
CBM Implementation Issues
Linder & Williander, Oghazi & Mostaghel Roos (2014)

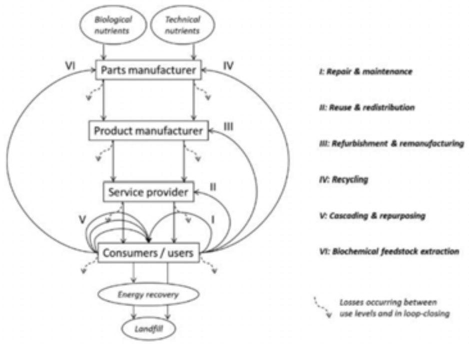
PRODUCT/BUSINESS MODEL DEVELOPMENT

TECHNOLOGICAL READINESS		BUSINESS MODEL	
1. N/A	N/A	1. Business Model Canvas	✓ Theory; Developed; Used; Evaluated
		Osterwalder & Pigneur (2010)	
2. N/A	N/A	2. Business Model Patterns	✓ Theory; Developed; ✓ Used; Evaluated
		Lüdeke-Freund et al. (2018), Bocken et al.	

CASE STUDIES

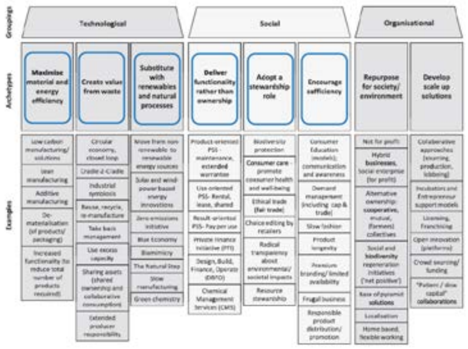
CASE STUDY	LOCATION	SECTOR	BUILDING TYPE	RELEVANCE
Philips Lighting	The Netherlands	Consumer	N/A	Light as a service. Large company. Company phase: established
Desso	The Netherlands	Consumer	N/A	Carpet manufacturing. Large company. Company phase:
Ecovative	United States	Consumer	N/A	The company produces packaging products that are fully
Park 20/20	The Netherlands	Construction	Corporate	Industrial park. Small company. Company phase: start-up
Maersk Line	Denmark	Services	N/A	Container shipping. Large company. Company phase:





Circular Business Models patterns

Six Circular Business Models Patterns by Lüdeke-Freund et al. (2018). These Circular Business Models patterns were adapted to develop a final list of 11 patterns including also CBMPs by Bocken et al. (2016), and Bocken et al (2014)



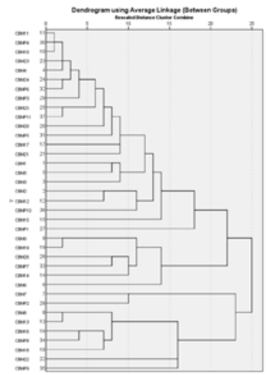
Business model archetypes for sustainability

Business model archetypes for sustainability from Bocken et al. (2014). The archetypes are grouped in three main clusters: technological, social and organisational.

	Percentage of N	Corresponding case numbers
Adopt a stewardship role	88.2%	1, 2, 4, 5, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 30, 31, 32, 33, 34
Recycling/create value from waste	52.9%	1, 2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 17, 20, 22, 24, 25, 29, 34
Refurbishment and remanufacturing	41.2%	3, 5, 7, 8, 10, 16, 17, 19, 21, 22, 27, 29, 31, 32
Access and performance model	32.4%	2, 10, 14, 15, 18, 19, 23, 24, 26, 27, 32
Repair and maintenance	29.4%	2, 5, 7, 13, 16, 21, 24, 27, 29, 31
Reuse and redistribution	26.5%	5, 7, 8, 10, 16, 19, 28, 32, 33
Maximize material and energy efficiency	17.6%	8, 11, 19, 20, 25, 30
Substitute with renewable and natural processes	14.7%	10, 11, 19, 20, 25
Organic feedstock	11.8%	6, 12, 20, 34
Cascading and repurposing	8.8%	12, 20, 30
Industrial symbiosis	5.9%	20, 34

Circular Business Model Patterns assigned

The most assigned pattern is 'Adopt a stewardship role'. This is a broad pattern and was assigned to all companies that state on. The second most assigned option is 'Recycling/create value from waste' and the third 'Refurbishment and remanufacturing'. More than half of the companies create something out of their own waste or waste from others.



Dendrogram that shows clustering relations between Circular Business Patterns

The closer the variables are grouped, the more similar they are. Starting with reading the diagram from above, CBM11, CBMP4 and CBMP10 are in this diagram the closest to each other. These variables are 'Online waste exchange platform', 'Industrial symbiosis' (the pattern) and 'Industrial symbiosis' (the business model) respectively.

Circular Supply Chain Collaboration In the Built Environment

A process tool to enhance Circular Supply Chain Collaboration when applying the aim of the Circular Economy in the building sector

Author Eline Leising **Year** 2016 **MSc programme, Faculty** MSc in Industrial Ecology Programme

Advisors Quist, J.; Bocken, N **Company** KPMG Sustainability **Project** N/A **Link** https://repository.

FOCUS

BE: Materials; Cities; Component; N/A; ✓ Buildings

TOOLS & METHODS: Technology; Design; ✓ Economy; ✓ Management; Flows and resources; Society and stakeholders

CIRCULAR ECONOMY

NEW BUSINESS MODELS

BM COMPONENTS: Supply-driven; Demand-driven; Customer segments; ✓ Value propositions (VP); Channels; Customer relationships; Revenue Streams (R$); Key Resources; Key activities (KA); Key partnerships (KP); Cost structure (C$)

APPROACH

METHODOLOGY: ✓ Literature review; ✓ Case study; Design/proposal

PRODUCT: ✓ Conceptual framework; Operational model; Assessment model; ✓ Policy/practice Design/Prototype

KEY WORDS

Circular Economy, Supply Chain, Industrial Ecology, Built Environment, Business Model

SUMMARY

The concept of the Circular Economy is gaining momentum in mainstream business, but knowledge and tools for bringing this Circular Economy into practice still need to be developed. The main purpose of this thesis is to examine in what way supply chain collaboration in the built environment can contribute to the transition to a Circular Economy in the Netherlands. The study is structured in three main parts. Firstly, the conceptualisation part which ends with the proposal of a conceptual framework for circular supply chain collaboration. Secondly, the case study analysis where this framework is applied in three cases: park 20|20, Alliander and Heerema Head Office. Finally, a process tool is developed in order to enhance circular supply chain collaboration in five main stages: (1) preparation and vision development, (2) involve market and supply chain, (3) process design and collaboration, (4) business model and implementation and (5) usage and prepare for next use. Main results showed that circular supply chain collaboration can contribute to a transition towards a Circular Economy by actually implementing solutions in real life projects.

PROBLEM STATEMENT

The concept of the Circular Economy is proposed to change this situation by closing material loops - using "waste" as a resource again. This concept is now gaining momentum in mainstream business, but knowledge and tools for bringing this Circular Economy into practice still need to be developed.

GOAL

The main purpose of this study is to examine in what way supply chain collaboration in the built environment can contribute to the transition to a Circular Economy in the Netherlands. How can new ways of supply chain collaboration in the built environment contribute to the transition towards a Circular Economy in the Netherlands?

CONCLUSIONS & SCIENTIFIC RECOMMENDATIONS

A new process design is needed where a variety of disciplines in the supply chain is integrated upfront. The responsibilities of these disciplines moreover need to be extended along larger parts of the supply chain in new ownership models around materials to actually close supply chains.

Collaboration depends on personal preferences. When clients or market parties have different personal preferences that do not reflect high circular ambitions, circular supply chain collaboration cannot be established.

The main value in the conceptual framework is its connection between more abstract organisational concepts and the practical level of businesses models. This framework provides a starting point for investigating this connection, but additional conceptualisation into business models for integrated supply chains is recommended.

KEY CONCEPTS / AUTHORS

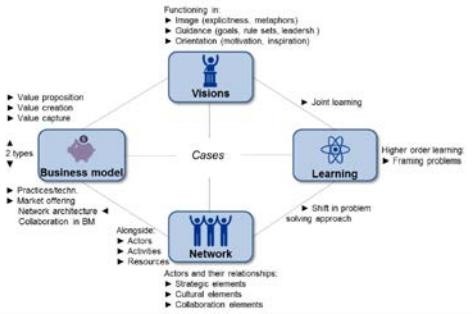
Circular Business Models		
Bocken et al. (2014)	Bocken, Bakker &	Bakker et al. (2014)
Mentink (2014)	Mason & Spring(2011)	Richardson (2008)
Circular Economy barriers and enablers		
Kok et al. (2013)	EMF (2014)	Dobbs et al. (2012)
Supply chain management		
Noordhuis & Vrijhoef	Vrijhoef & Koskela	Ceron (2006)

PRODUCT/BUSINESS MODEL DEVELOPMENT

	TECHNOLOGICAL READINESS	BUSINESS MODEL
1.	N/A	N/A	N/A — Theory; Developed; Used; Evaluated
2.	N/A	N/A	N/A — Theory; Developed; Used; Evaluated

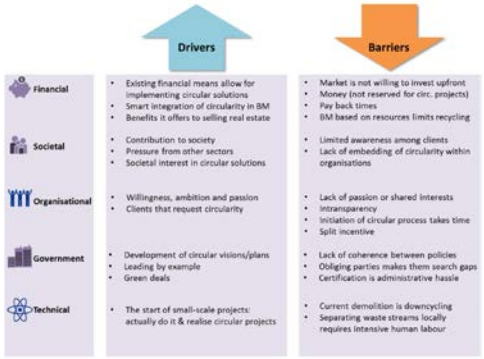
CASE STUDIES

CASE STUDY	LOCATION	SECTOR	BUILDING TYPE	RELEVANCE
Park 20/20	Hoofddorp, the Netherlands	Construction	Corporate	Newly built Cradle to Cradle® inspired business park. The
Alliander		Construction	Corporate	Renovation of an existing offices complex. It is an almost
Heerema Head Office	Leiden, the Netherlands	Construction	Corporate	Before realising the new office building, the old abandoned HMC



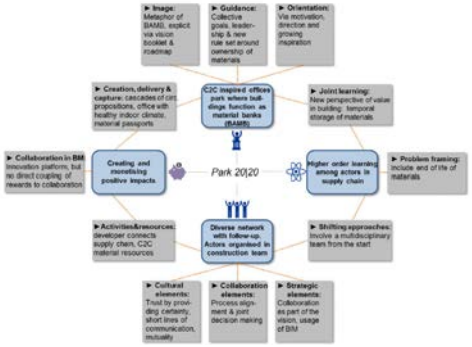
Conceptual framework for circular supply chain collaboration

The framework consists on four man concepts: Visions concepts, learning processe, networks and integration of business models.



Drivers and barriers for a circular built environment identified from literature review

Although quite some drivers for the CE are present, some major barriers currently inhibit many businesses in implementing CE in their practices. In order to be able to assist in the transition to a CE, practical tools are required to provide support.



Analysis of the case part 20|20 to understand supply chain collaboration

Looking at the four different concepts analysed in this case and their contribution to circular supply chain collaboration, it can be concluded that they all had their share at Park 20|20.

	Park 20|20	Alliander - Duiven	Heerema Head Office
Value creation	BM focused on creating positive impacts: cascades of circular value propositions.	BM focused on (almost) circular building with an iconic value in surrounding area.	Contribution to demolition sector and building that fits needs of its user (for coming 20 years).
BM strategies applied	• Create value from waste: C2C materials • Deliver functionality: both result, product and use oriented • Increasing functionality • Dematerialisation • Repurpose for society • Alternative ownership	• Create value fr. waste: IS, recycle, reuse, take back • Delivering functionality: PSS lighting system & DBMs contracts • Adopting a stewardship role • Substitution with renewables • Encourage sufficiency: ESCo construction • Co-creation	• Create value fr. waste: some C2C materials&demolition • Deliver functionality: energy supply • Adopting a stewardship role • Repurpose for society
Collaboration as part of BM	Not directly: suppliers were provided guarantee for purchasing via sponsoring programme.	Collaboration was not embedded in BM.	Collaboration was not embedded in BM.
Value missed/ improvements	• Create value fr. waste: optimise material bank concept in monetising mat. value and software solutions • Adopting stewardship role: expand C2C certification and thus transparency. • Repurpose for society: additional research into effects on people and productivity. • Co-creation via incentive scheme.	• Create value fr waste: even more follow-up in surroundings. • Optimise energy efficiency: condition only part of building. • Functionality over ownership: add incen-tive to guard mat. performance/maintenance. • Co-creation via incentive scheme.	• Create value fr. waste: improve take back of demolition materials. • Adopt a stewardship role: use material passports • Substitute with renewables: also green electricity • Deliver functionality: improve image of lease/use options • Co-creation via incentive scheme.

Table 24 - Comparison of BM strategies used and improvements to be made for three case studies.

Business Model Strategies in case studies

The main differences and similarities for BM strategies in the three different cases are summarised in the table

Steel curtain walls for reuse

Author Rebecca Leising **Year** 2017 **MSc programme, Faculty** Architecture, Urbanism & Building Sciences Programme

Advisors Klein, T.; Geldermans, B.; Azcárate-Aguerre, J **Company** Klöckner Metales ODS Nederland (ODS NL) **Project** N/A **Link** https: //repository.

FOCUS

BE: ✓ Materials ✓ Component ☐ Buildings ☐ Cities ☐ N/A

TOOLS & METHODS: ✓ Technology ✓ Design ☐ Economy ☐ Management ☐ Flows and resources ☐ Society and stakeholders

CIRCULAR ECONOMY

NEW BUSINESS MODELS

✓ Supply-driven ☐ Demand-driven

BM COMPONENTS: ✓ Customer segments ✓ Value propositions (VP) ☐ Channels ☐ Customer relationships ☐ Revenue Streams (R$) ✓ Key Resources ☐ Key activities (KA) ✓ Key partnerships (KP) ☐ Cost structure (C$)

APPROACH

METHODOLOGY: ✓ Literature review ✓ Case study ✓ Design/proposal

PRODUCT: ☐ Conceptual framework ✓ Operational model ✓ Assessment model ✓ Policy/practice ✓ Design/Prototype

KEY WORDS

Circular Economy; Steel curtain walls; Facade Design; Built Environment; Business strategies

SUMMARY

Companies in the building sector like Klöckner Metales ODS Nederland (ODS NL) are looking to develop new circular strategies to prolong their involvement in the building process, however, their current products do not support circular models. The main purpose of this study is to make the circular economy principles applicable for the company ODS NL by designing suggestions for improvements of their current Jansen VISS steel curtail wall system. This manifests in a literature study on the Circular Economy concept, and an analysis of the company, followed by design suggestions for improvements of their current Jansen VISS steel curtail wall system. The second part of this thesis focusses on the development of an assessment method to evaluate the circularity of facades and to compare the selected design to existing curtain wall systems. The design phase has resulted in the development of a hybrid system, which is based on an exchangeable modular panel system that enhances the adaptation and transformation capacity of buildings. The study showed that in order to contribute to a future sustainable steel (curtain wall) market, ODS NL has to change their role in the overall process, whereby their focus should lay more on the user phase and the end-of-life phase.

PROBLEM STATEMENT

Companies like ODS NL needs to establish a better contact with the end-user to bring circular ambitions into practice. ODS NL hopes to accomplish this by developing a new circular strategy, to prolong its involvement in the building process and make the company more sustainable at the same time. However, the current Jansen VISS facade system does not support a circular model. In order to make this approach feasible not only a new business strategy has to be developed, but also a new design strategy.

GOAL

The main purpose of this study is to make the circular economy principles applicable for ODS NL by designing suggestions for improvements of their current Jansen VISS steel curtail wall system.

CONCLUSIONS & SCIENTIFIC RECOMMENDATIONS

To contribute to a future sustainable steel market, ODS NL has to change their role in the overall process, whereby their focus should lay more on the user phase and the end-of-life phase. For a complete transition, they should change their business strategy, from sell more sell faster model to a more service based approach that integrates end-of-life phase.

In order to participate in a circular construction industry ODS NL has to: create a cost-efficient reverse logistics; offer a full service, a buy back guarantee, maintenance/repair services, and alternative products; resell their steel parts or transport them back for reuse or recycling; and create new partnerships and establish a more integral supply chain collaboration.

Regarding the effects on a larger scale there can be concluded that improving the curtain wall system and strategy of ODS NL can contribute to the reduction of virgin material use, related global transportation and enhance local reuse and recycling.

KEY CONCEPTS / AUTHORS

Obstacles for implementing the CE in the building industry		
Kok et al. (2013)	van den Brink, 2016	Damen (2012)
Circular business strategies		
Bocken et al., 2015	Bakker et al., 2014	Mentink, 2014
Leising 2016	Arup, 2016	Bocken and Short
Circular design strategies		
Bocken, Bakker & Leising 2016	Bakker et al., 2014	Mentink, 2014

PRODUCT/BUSINESS MODEL DEVELOPMENT

TECHNOLOGICAL READINESS		BUSINESS MODEL	
1. Modular panels system	2. Test/Pilot	1. N/A	☐ Theory ☐ Developed ☐ Used ☐ Evaluated
N/A	N/A	2. N/A	☐ Theory ☐ Developed ☐ Used ☐ Evaluated

CASE STUDIES

CASE STUDY	LOCATION	SECTOR	BUILDING TYPE	RELEVANCE
– ODS NL and Jansen VISS steel curtain	Netherlands	Construction	Commercial	Real life case to test circular economy possibilities with one of
– Port City III	Rotterdam, Netherlands	Construction	Corporate	Used to determine the transformation capacity of each
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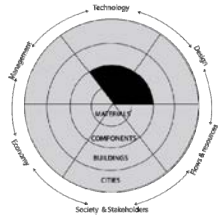
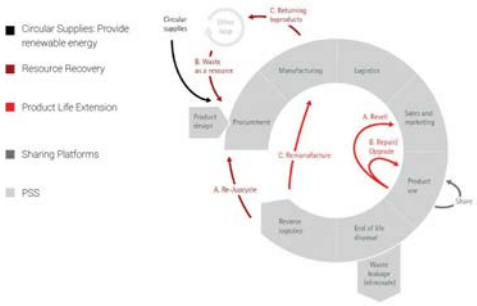




Overview of where in the value chain certain strategies can be carried out

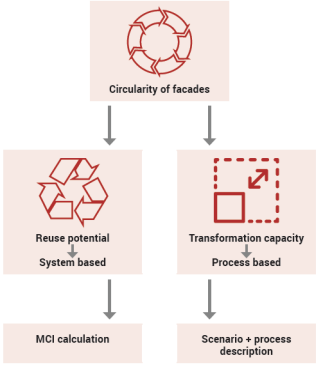
A new business model like a PSS is not linked to a specific part of the process, but tries to provide a complete new sustainable structure and influences the whole process. These strategies show that to become circular, the supply side has to start offering a service that is based upon a delivered product, whereby revenue is not only gained from the product , but also from services regarding the product.

Main technical/design strategies related to the CE

For slowing resource loops (designning long-life products, design for product-life extension, design for standarization and compatibility); for closing resource loops (design for technological cycle, design for biological cycle, design for recycling in a linear economy). Strategies developed from Bocken, Bakker & Pauw, 2015; Bakker et al., 2014; Mentink, 2014, Leising 2016.

Panel options that shows the principle of the system

Four different panel options have been worked out in detail: standard glass panel, closed panel, panel with operable window and a glass panel with integrated PV-cells and sun shading system. All panels can be replaced or upgraded individually. The mock-up has a size of 443 x 643 mm and shows a fragment of the four different panels. It shows how the system works and what it looks like in reality.



Schematic visualisation of the assessment methodology

The method considers two main variables: the transformation capacity (of the complete facade) and the reuse potential (of the system/components). The reuse potential is assessed using the Material Circularity Indicator (MCI), while the transformation capacity is measure using three future scenarios for a possible development of the building Port City III.

Circular Business Model Innovation

A process framework and a tool for business model innovation in a circular economy

Author Bas Mentink **Year** 2014 **MSc programme, Faculty** MSc in Industrial Ecology Programme

Advisors Peck, D.; Tukker, A. **Company** N/A **Project** N/A **Link** https: //repository.

FOCUS

CIRCULAR ECONOMY

BE
- Materials
- Component
- Buildings
- Cities
- ✓ N/A

TOOLS & METHODS
- ✓ Technology
- Design
- ✓ Economy
- ✓ Management
- Flows and resources
- Society and stakeholders

NEW BUSINESS MODELS

- ✓ Supply-driven
- ✓ Demand-driven

BM COMPONENTS
- ✓ Customer segments
- ✓ Value propositions (VP)
- ✓ Channels
- ✓ Customer relationships
- ✓ Revenue Streams (R$)
- ✓ Key Resources
- ✓ Key activities (KA)
- ✓ Key partnerships (KP)
- ✓ Cost structure (C$)

APPROACH

METHODOLOGY
- ✓ Literature review
- Case study
- ✓ Design/proposal

PRODUCT
- ✓ Conceptual framework
- ✓ Operational model
- ✓ Assessment model
- Policy/practice
- Design/Prototype

KEY WORDS

Circular Economy; Business Model; Business Model; Innovation; Resource efficiency; Industrial Ecology; Circular business model

SUMMARY

Companies need new business models to grasp the opportunities of a circular economy. This thesis investigates to what extent existing frameworks, methods and tools for business model innovation are useful to cope with the challenges of designing and implementing circular business models. Based on literature review, the thesis developed a Circular Model Innovation framework which outlines a process of 18 typical obstacles – or challenges – which should be taken into account by companies. The framework is used to identify the gaps in existing Circular Business Model Innovation tools. A tool: Business Cycle Canvas, is proposed to support practitioners to think in systems and develop supply chains with a closed material loop, one the most important challenges when designing a circular business model. Both, the framework and the tool, are recommended to use in order to innovate in circular business models. The validation session with stakeholders, confirms that using a Business Cycle Canvas improves the quality of Circular Business Model concepts considerably, based on a newly developed list of selection criteria.

PROBLEM STATEMENT

The increased attention for CE stresses the (growing) need for new BMs. Frameworks, methods and tools from the field of BMI could offer a possible solution and therefore their potential support to the development and implementation of CE will be investigated.

GOAL

This master thesis aims to further develop existing methods for BMI to improve the innovation process of companies towards a CBM. How can new or existing methods for business model innovation be used to improve circular business model concepts?

CONCLUSIONS & SCIENTIFIC RECOMMENDATIONS

The tool 'Business Cycle Canvas' drives and supports practitioners to “broaden their horizon” and take into account all BMs of relevant stakeholders. This enables to design solutions optimized for the whole supply chain instead of for an individual BM and yield additional profits or create other values which were previously out of reach.

Our current economy is not completely linear, however, a completely CE is almost impossible. One or more system innovations may push the boundaries of what is possible, but the next best implementations of CBM remain to be transitional. The final solution cannot be found yet and this should be kept in mind when defining (SMART) goals for CBMI.

The goals of companies with implementing CE are to secure the supply of (critical) resources, anticipate governmental intervention or attract new customers. Some risks/barriers are: complexity of organization and management often increases, including issues of confidentiality and trust, and difficulties to seek a benefit for every stakeholder involved.

KEY CONCEPTS / AUTHORS

Business model

Osterwalder and Frank Boons and Frankenberger et al.

Circular Business model innovation(CBMI)

Amit & Zott (2012) Baden-Fuller & Sempels (2014)

CMBI 4I-framework

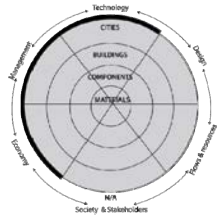
Frankenberger

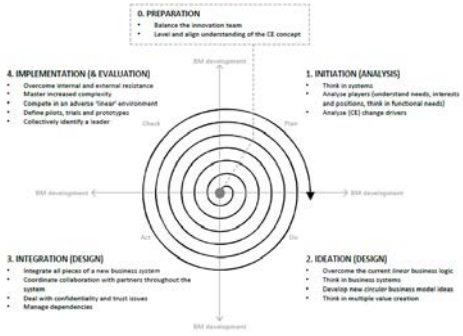
PRODUCT/BUSINESS MODEL DEVELOPMENT

	TECHNOLOGICAL READINESS	BUSINESS MODEL
1.	N/A	1. Business Cycle Canvas — ✓ Theory, ✓ Developed, ✓ Used, Evaluated
		Based on BMC (Osterwalder and Pigneur,
	N/A	2. N/A — Theory, Developed, Used, Evaluated

CASE STUDIES

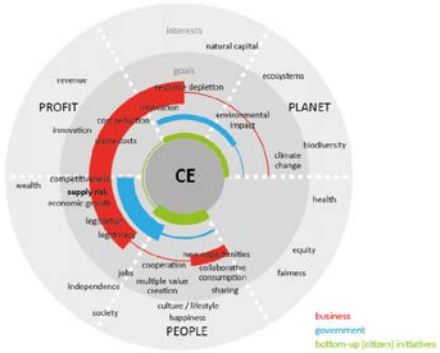
CASE STUDY	LOCATION	SECTOR	BUILDING TYPE	RELEVANCE
N/A				





Circular Business Innovation Framework

The framework has four main phases: preparation, initiation (analysis), ideation (design), integration (design) and implementation (& evaluation). This framework is proposed as an extended and adapted version of the 4I-framework. The CBMI framework helps companies to distinguish particular phases and understanding certain challenges beforehand. It can also be used as an analytical framework.

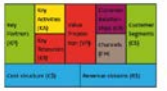


Radar of differences in goals and interests in the concept of Circular Economy.

CBMI framework phases → / Method or tool ↓	Preparation	Initiation	Ideation	Integration	Implementation
Business Model Generation	No CE	Much analysis, but no CE	Well-developed, but no system-orientation	Almost nothing on collaboration issues	Only very high-level
STOF method	Nothing	Only Service Design	Too little	Elaborate and systemic, but nothing on collaboration issues	Only CSFs and CSIs
New framework on circular design	Only tips for starting innovation process	Only focus on material flows	Only a panacea and high-level building blocks	Nothing on collaboration issues	Not practical
Practical guide for PSS development	PSS, but no CE	No explicit system thinking	Only step by step system modelling missing	Not practical on collaboration issues	Practical, but very briefly
Circular Economy Toolkit	Too little	No method, only referrals	Only CE theory and case studies	Nothing	Nothing
Guided choices towards circular business models	Not integrated (links to tools)	Comprehensive, but very high-level	Not practical	Not practical on collaboration issues	Only very high-level
Sustainable Business Model Canvas	Nothing	Almost nothing	Only SBMC and change descriptions per block	Not practical on collaboration issues	Nothing
Play it forward	No CE; no strategy for ext. partners	Only cards with possible drivers	focus on individual BM	Nothing on collaboration issues	Nothing

Summary of gap analysis in existing CBMI methods by applying the framework

In green, the challenges mostly addressed with practical guidelines; in orange, challenges not addressed, or only at an abstract/high-level; and in red, challenges not addressed, or only at an abstract/high-level. Two important gaps: the practical application of systems thinking to the integration of all BMs into a CBM concept, and guidance in managerial and organizational challenges during implementation



Business Cycle Canvas. Transformation of Osterwalder's BMC to a canvas with boxes and arrows. This is a tool which must support practitioners to think in business systems and beyond the individual BM. To manage the quantity of information, the BCC has four components (who, what, how and why)

Circular demolition process

Enhancing the reuse potential of components and materials in the building industry

Author Polina Michael **Year** 2018 **MSc programme, Faculty** Construction, Management and Engineering Programme

Advisors Klein, T.; Straub, A. **Company** N/A **Project** N/A **Link** https: //repository.

FOCUS

BE
- ✓ Materials
- ✓ Component
- Buildings
- Cities
- N/A

TOOLS & METHODS
- ✓ Technology
- ✓ Design
- Economy
- Management
- Flows and resources
- Society and stakeholders

CIRCULAR ECONOMY

NEW BUSINESS MODELS

- ✓ Supply-driven
- Demand-driven

BM COMPONENTS
- Customer segments
- Value propositions (VP)
- Channels
- Customer relationships
- Revenue Streams (R$)
- Key Resources
- Key activities (KA)
- Key partnerships (KP)
- Cost structure (C$)

APPROACH

METHODOLOGY
- ✓ Literature review
- ✓ Case study
- Design/proposal

PRODUCT
- Conceptual framework
- ✓ Operational model
- Assessment model
- ✓ Policy/practice
- Design/Prototype

KEY WORDS

Demolition;
Reuse;
Circular Demolition;
Circular Economy

SUMMARY

The current demolition process in the Netherlands does not enable the retrieval of components and materials for reuse. While the materials are damaged in the process, the demolition contractors don't make an effort to retrieve them properly. This thesis focuses on improving the reuse potential of components and materials to improve circularity in the building industry. The main goal is to develop a new demolition process flowchart and provide recommendations to the actors involved that will enhance the reuse potential of the components and materials. To find answers, literature study, a case study (project Superlocal) and expert interviews with frontrunners were used. Base on the literature review findings, an initial flowchart was developed and thereafter, improved using the empirical input from the case study and the interviews. The flowchart starts from the traditional flowchart for demolition, but additional steps are included related to sustainability tender criteria, site visits, detailed inventory, buyers through the network, deconstruction, and separation in different material streams. By adopting the proposed changes the actors involved could retrieve more components and material from the demolition sites and provide them for reuse.

PROBLEM STATEMENT

In the Netherlands, only 3-4% of the materials being used in the building industry are secondary materials, which shows that the building industry is not circular. To change that, more materials need to become available for reuse. However, the current demolition process doesn't allow the retrieval of materials and components that can be reused. Most of the components are destroyed in the process, and they end up together in the same streams without proper separation.

GOAL

The objective of this research is to develop a new demolition process flowchart and provide recommendations to the actors involved that will enhance the reuse potential of the components and materials. In order to achieve that the following research question is formulated as: ''How could the demolition process in the building industry be adjusted in order to enhance the reuse potential of the building components and materials?''

CONCLUSIONS & SCIENTIFIC RECOMMENDATIONS

The new circular demolition process incorporates steps that will allow the demolition companies to retrieve components and materials for reuse. The flowchart includes more activities that will help the actors to behave more circular. In all the project stages some actions are required in order to be able to retrieve components and materials for reuse.

Recommendations to the actors for a circular demolition process : The clients should consider demolishing circularly and reusing components and materials in their new projects; Demolition companies should try to take materials for reuse; The government should adopt laws and regulation regarding circular demolition and reuse of materials.

The demolition process flowchart and the recommendations can be used by the actors involved to help them adopt circular demolition process and take more material for reuse. Even if only some of the recommended steps are adopted, the demolition companies will be able to retrieve materials for reuse.

KEY CONCEPTS / AUTHORS

Demolition process

Liu et al. (2005)	Abdullah et al., (2003)	Kühlen et al. (2016)
Bergman & Lundberg,	Volk (2017)	Bhandari et al., 2013).
Kibert et al. (2001)	Ge et al.,(2017)	

Circular demolition process

Aidonis et al. (2008)	Iacovidou & Purnell,	Zahir (2015)
Dantata et al. (2005)	Tatiya et al (2017)	Van Dijk et al., (2000)

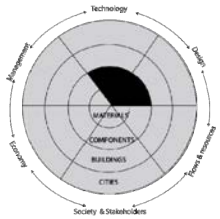
PRODUCT/BUSINESS MODEL DEVELOPMENT

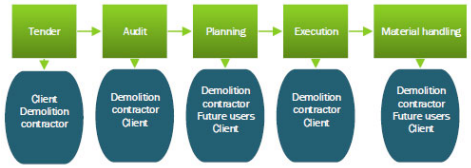
	TECHNOLOGICAL READINESS	BUSINESS MODEL
1.	N/A	1. Demolition process flowchart — ✓ Developed
2.	N/A	2.

BUSINESS MODEL: Theory; ✓ Developed; Used; Evaluated

CASE STUDIES

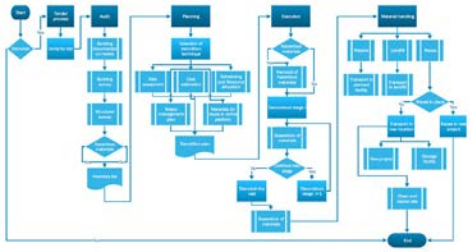
CASE STUDY	LOCATION	SECTOR	BUILDING TYPE	RELEVANCE
SUPERLOCAL project, demolition company HEEMwonen	Kerkrade, The Netherlands	Construction	N/A	To find out the how in practice they deconstructed and





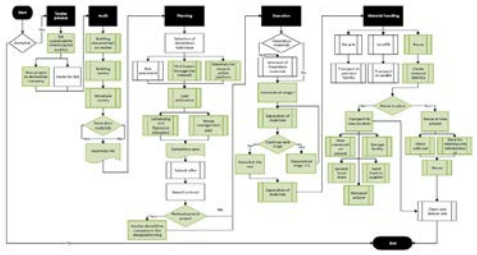
Involved actors in each stage of the demolition process

The client is involved in the whole process, but his role is of the highest importance in the tender stage. The demolition contractor is involved in every step of the project and he is the actor with the major impact. The future users are involved in the planning and the material handling stage. In the material handling stage, the components are taken over by the new users.



New demolition process flowchart

Proposed demolition process flowchart based on the literature review and the analysis of each step of traditional demolition processes.



Final circular demolition flowchart

This new flowchart includes more activities that will help the actors to behave more circular. In all the project stages some actions are required in order to be able to retrieve components and materials for reuse.

Barrier	Ways to reduce it
Missing building documentation and unknown quality of materials	Site visits and detailed auditing
Lack of regulations	The demolition parties and new users can be creative with the current regulations. The government should take the opportunity to create regulation for circular buildings and reused materials
Limited separation of material	Separate the material in several streams
Architect has restrictions in the design	The architect has the opportunity to explore his creativity by making a design with materials that he has available, changing their function and purpose.
The cost involved with deconstruction and reuse is too high.	The companies can take the opportunity to investigate more their options. They can try to see if they can make a small change and start taking a small number of materials for reuse to see how it will affect their costs and profits. Each company has a different system of calculating so a small change might be possible, and it will contribute to the circular economy.
More time is needed	The demolition companies can make the clients understand the importance of deconstruction in order to convince them to give more time
Buyers prefer new materials	QR-code, materials that can tell a story. This can be used as a marketing strategy in order to promote them.
Lack of cooperation between the parties	In order to be able to maximize reuse in circular demolition, the parties need to cooperate form the beginning and have a common vision of reuse. If not, the process will not be successful.
Components not designed for disassembly	The producers of the materials and components need to take this opportunity and design them in a way that can be deconstructed and reused.
Uncertainty of demand and supply	The online marketplace can help to balance the demand and supply of the materials.
Timing the materials come out delay the process	The companies can cooperate to create a cloud that they can deliver their materials

Barriers and opportunities identified in the interviews

Some of the barriers can be reduced when the actors can take the opportunity that is presented to change the situation, or they can use the proposed ways to reduce them.

Product to Service in Circular Economy

A critical assessment

Author Eleni Michael **Year** 2018 **MSc programme, Faculty** Construction, Management and Engineering Programme

Advisors van Oel, C.; Chao-Duivis, M.; Ploeger, H. **Company** N/A **Project** N/A **Link** https: //repository.

FOCUS

BE: ✓ Materials; Component; Buildings; Cities; N/A

TOOLS & METHODS: Technology; Design; ✓ Economy; ✓ Management; Flows and resources; Society and stakeholders

CIRCULAR ECONOMY

NEW BUSINESS MODELS

BM COMPONENTS: ✓ Supply-driven; ✓ Demand-driven; Customer segments; ✓ Value propositions (VP); Channels; ✓ Customer relationships; ✓ Revenue Streams (R$); ✓ Key Resources; Key activities (KA); ✓ Key partnerships (KP); ✓ Cost structure (C$)

APPROACH

METHODOLOGY: ✓ Literature review; ✓ Case study; Design/proposal

PRODUCT: Conceptual framework; Operational model; Assessment model; ✓ Policy/practice; Design/Prototype

KEY WORDS

Circular Economy; Product to Service; Ownership; Cost; Duration

SUMMARY

In the context of Circular Economy, Product to Service model can offer new opportunities in resetting the way we see ownership and what should be considered waste. However, questions have arisen about the efficiency of the model and risk allocation between owner and user during its implementation. Therefore, the main goal of this thesis is to identify what are the risks in circular leases associated with the duration and cost of the lease and the ownership of the product. After conducting literature review on Circular Economy, Product to Service and relevant legal aspects, two case studies were analysed to confront theoretical findings with empirical information. The findings were used to develop an understanding of risks occurring in circular leases in which the ownership model stays with the manufacturer/supplier. Findings shows that the main bearer of risks is the owner of the product. First, owner have to secure that ownership remain on his/her side. Second, must also take care of the after-end treatment of the product and arrange for a new circle for it. Long duration leases require a strong alliance between owner and client, but also trust that both parties will be able to fulfill their responsibilities. On the client side, they may pay to avoid taking risks, but some risks are still there.

PROBLEM STATEMENT

To realise the goals of CE, many methods are implemented. One of the most interesting is the "Product to Service" model (PtS), where the products are returned after the end of the lease to continue their lifecycle. However, this method entails important risks and legal challenges in its implementation. The legal risks are not yet cleared and especially the risk of retaining ownership. On the side of the client, duration and cost of the lease might not be actually beneficial. Furthermore, clients agree on a circular deal but what does "circular" entails?

GOAL

The main goal of this thesis is to identify what are the risks in circular leases associated with the duration and cost of the lease and the ownership of the product. Three main goals are identify: (1) To develop an understanding of how Circular Economy (CE) and Product to Service (PtS) is applied in practice, (2) To identify the risks involved in a PtS/CE project on a legal, cost and duration aspect, (3) To find out how companies face the above risks.

CONCLUSIONS & SCIENTIFIC RECOMMENDATIONS

The main bearer of risks is the owner of the product.Owners have to secure that ownership remain on their side. Although they have a constant income during the lease, owners must be prepared to pay in case of malfunction and any need occurring from the close maintenance offered to the client. They must also take care of the after-end treatment of the product.

Long duration leases require a strong alliance between owner and client, but also trust that both parties will be able to fulfill their responsibilities. On the client side, they may pay to avoid taking risks, but some risks are still there. For instance, committing to same level of needs especially if the type of product is a fast-evolving technology or if the needs are not steady.

Finally, the price point is also at risk, in case an intermediate is involved.

KEY CONCEPTS / AUTHORS

Product to Service(PtS) business model

Robotis,Zhattacharya, Baines et al. (2007) van den Brink et al.

Souza (2013) van Loon, Delagarde, Mahut, Daaboul,

Legal frameworks -Movable and immovable things, principle of

H. D. Ploeger et al. Mostert et al. (2010) Dutch Civil Law (DCL)

van Vliet (2002) Knobel (2011) van der Walt & Sono

Akkermans (2008) H. Ploeger, Mes, &

PRODUCT/BUSINESS MODEL DEVELOPMENT

	TECHNOLOGICAL READINESS	BUSINESS MODEL
1.	N/A	1. Product to service: ✓ Theory; Developed; ✓ Used; Evaluated
	N/A	2. Theory; Developed; Used; Evaluated
	N/A	

CASE STUDIES

	CASE STUDY	LOCATION	SECTOR	BUILDING TYPE	RELEVANCE
–	Solar panels on the roof of frigoCare (ZEN)	Rotterdam, Netherlands	Construction	N/A	Example of non-circular leasing model to test theoretical findings
–	M-Use® Elevators- Mitsubishi Electric Europe	Europe	Construction	N/A	Example of a circular leasing model to test theoretical findings
–					
–					
–					

Main steps included in a Product to Service Process

First: Credit check of potential user, Signing of lease contract, Forward transport, Lease of product. Second, when the lease product return to the warehouse of the PtS company :Full disassembly, Quality check, Cleaning of each component, Disposition decision for each part, Refurbish parts to restore functionality, (6) Reassembly, (7) Testing. Based on van Loon et al. (2018), and Souza (2013).

High capacity High remanufacturing saving	Low capacity Low remanufacturing savings
Long product lifecycle	
Longer leasing period Low initial price Price skimming	Medium leasing period High initial price Price skimming
Short product lifecycle	
Medium leasing period Intermediate initial price Price skimming	Short leasing period High initial price Price skimming

Const and duration of lease

Cost and duration of lease in respect to capacity and lifecycle based on Robotis et al. (2012)

	Traditional	Circular
Price	100% purchase at start	Installation costs (50%) Financing components (35%) Residual value (15%)
Ownership	Client	Company
Stakeholders	Multiple stakeholders	Company and external inspectors
Risks	On customer (stakeholders)	Mostly on company (insurance and increase of price)
Costs	Fluctuating	Fixed amount per year
Contract period	Free	20 years with option of extension
Quality	Uncertain (stakeholders)	Guaranteed with KPIs
Results	Av. 2,7 disturbances and 88 hrs of immovability/year	Max.1 disturbance and 17,5 hours of immovability/year

Comparison between traditional and Circular elevator

Comparison of characteristics between traditional and M-Use® model based on price, ownership, stakeholders, risks, costs, contract period, quality and results.

	MEE	ZEN
LIFECYCLE EXTENSION	Guarantee of 100% increase of the lifecycle (questionable)	No interest in extending the lifecycle
ENVIRONMENTAL MOTIVES	Collaborating with sustainable parks	Improving companies' sustainable profile
FINANCIAL MOTIVES	Make company market competitive	Leasing provides flexibility and fast growth
SOCIETAL MOTIVES	Security of long collaboration	The collaboration is a win win situation
CIRCULARITY	At the present, only seen on material's choice	Not attractive to their target group
END LEASE POLICY	Retrieval of components for recycling or reuse	Gift to the clients or removal and reinstallation to other projects
CULTURE	Providing brochures to inform about CE	Affects the difficulty of doing projects
TECHNICAL HINDRANCES	None so far	Fast upgrade of technology
MAINTENANCE	Use of advanced technology to collect data and keep constant functionality	Use of advanced technology to collect data and keep constant functionality
EASY DISASSEMBLY	Project designed with this factor in mind	Minimum damage on building during installation
BANKRUPTCY	MEE: client can buy the elevator at a discount Client: MEE continues with the new building owner	ZEN: bank seizes the panels Client: ZEN continues with the new building owner
OWNERSHIP	Superficies solution In some cases economic ownership (by a lease)	Superficies solution
PAYMENT	According to the usage level	According to the usage level

Summary of comparison points between the case studies

MEE (M-Use® Elevators- Mitsubishi Electric Europe) and ZEN (Solar panels on the roof of frigoCare)

Suppliers going circular

An examination of the transition from product-based business models to a performance-based business model in the construction industry

Author Ruud Stigter **Year** 2016 **MSc programme, Faculty** Architecture, Urbanism & Building Sciences Programme

Advisors Prins, M.; Straub, A. **Company** N/A **Project** N/A **Link** https: //repository.

FOCUS

BE
- [x] Materials
- [x] Component
- [ ] Buildings
- [ ] Cities
- [ ] N/A

TOOLS & METHODS
- [ ] Technology
- [ ] Design
- [x] Economy
- [x] Management
- [x] Flows and resources
- [ ] Society and stakeholders

CIRCULAR ECONOMY

NEW BUSINESS MODELS

- [x] Supply-driven
- [x] Demand-driven

BM COMPONENTS
- [x] Customer segments
- [x] Value propositions (VP)
- [x] Channels
- [x] Customer relationships
- [x] Revenue Streams (R$)
- [x] Key Resources
- [x] Key activities (KA)
- [x] Key partnerships (KP)
- [x] Cost structure (C$)

APPROACH

METHODOLOGY
- [x] Literature review
- [ ] Case study
- [x] Design/proposal

PRODUCT
- [x] Conceptual framework
- [x] Operational model
- [ ] Assessment model
- [ ] Policy/practice
- [ ] Design/Prototype

KEY WORDS

circular economy; suppliers, business models; construction industry; implementation; case study

SUMMARY

The circular economy concept is gaining popularity. In the recent years a lot has been written about the benefits and challenges of the topic. Despite the growing interest on both political and market level, the terminology is unclear. This research examines the circular economy concept as posed by the Ellen MacArthur Foundation. The aim of this research is to design a financial section of a business model in a circular economy. Literature review, interviews and aspect studies on both the circular economy concept and the construction industry have resulted in a new definition of circular economy with corresponding boundary conditions. With these boundary conditions, the research assesses conventional business models of building product providers (suppliers). The assessment led to the identification of 13 costs and risks and their subsequently incorporation in the design of the financial section of a business model. At last, the business model has been assessed by means of a case study: providing the structure of a steel beam. It can be concluded that the key variable that determines the financial viability is the circular economy axiom of rising resource prices.

PROBLEM STATEMENT

If the circular economy theory as promoted by the Ellen MacArthur foundation is examined, financial, legal, social, mental and operational challenges arise on the practical implementation; the business structure needs to change. Despite the significant amount of reports about the circular economy, empirical scientific research on the implementation of circular economy, especially in the construction industry, is lacking and it seems to the author that the terminology is used rather diffused and incoherent when different sources are examined.

GOAL

This research will critically examine the circular economy theory as posed by the Ellen MacArthur foundation. This paper will discuss the issues concerning the implementation of the circular economy theory in the built environment and will design the financial part of a business model in which building product providers can operate within the set boundary conditions of the circular economy in order to show its financial potential.

CONCLUSIONS & SCIENTIFIC RECOMMENDATIONS

Two type of boundary conditions have been set up and actors involved in a circular economy have been identified. The 'hard' conditions need to be fulfilled to meet the requirements of a circular economy. The 'soft' conditions need to be fulfilled to create a more sustainable economy.

The implementation of CE principles will cause a shift for building product providers from short-term to long-term governance, adding new risks and costs. Furthermore, the responsibility for the performance cause the chain partner to implement maintenance, management, transport and (dis)assembly in the business model.

The financial uncertainties of implementing circular economy in practice can be brought down to two factors. First, the profitability of lease-solutions depends heavily upon resource prices. Second, the financial value of materials inserted in a construction project depends on their usability at the end-of-loop situation.

KEY CONCEPTS / AUTHORS

Circular Economy

Kok et al. (2013) Mentink (2014) De Graw (2015)

Construction industry and organizational barriers

Kok et al. (2013) Ten Wolde (2013) Loppies (2015)

Building product provider

Mohammadi, Prins

Construction industry characteristics

Vrijhoef, R. (2011). Prins (1992) Segerstedt, A., &

PRODUCT /BUSINESS MODEL DEVELOPMENT

TECHNOLOGICAL READINESS	BUSINESS MODEL
1. N/A	1. Financial business model — [ ] Theory, [x] Developed, [x] Used, [ ] Evaluated
	Developed by the student
2.	[ ] Theory, [ ] Developed, [ ] Used, [ ] Evaluated

CASE STUDIES

CASE STUDY	LOCATION	SECTOR	BUILDING TYPE	RELEVANCE
Steel beem	N/A	Construction	N/A	Used to test the financial model

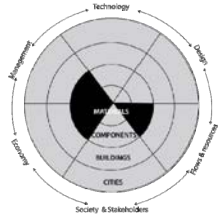


Figure 16 circular situation (own image)

Step 1	Check current supply
Step 2	Start production process/renew building product for new service
Step 3	Assemble products, components or elements to final building product
Step 4	Provide the service to the customer, including maintenance, monitoring and managing the customer relationship
Step 5	Disassemble products
Step 6	Return to building product provider
Duration: few years to 20 years or more	

Table 7 circular process (own table)

Challenges of a circular situation

Challenges that arise with the implementation of the boundary conditions (based on Mohammadi at al., 2015) of a circular economy for building product providers. The building product provider is shown on top of the circle. This example will illustrate the issues arising in a circular economy on the services and performance market. The chain market is left out of this example.

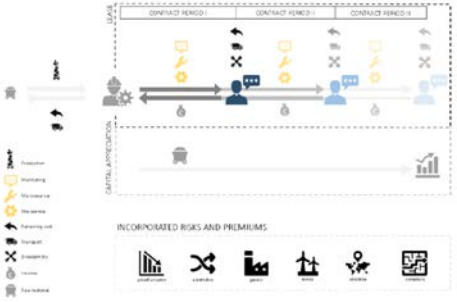
Figure 17 circular situation finance (own image)

Step 1	Acquire finance
Step 2	Earn lease
Step 3	Pay debt service every year
Step 4	Profit
Step 5	Pay for disassembly, transport and storage
Duration: few years to 20 years or more	

Table 8 circular process finance (own table)

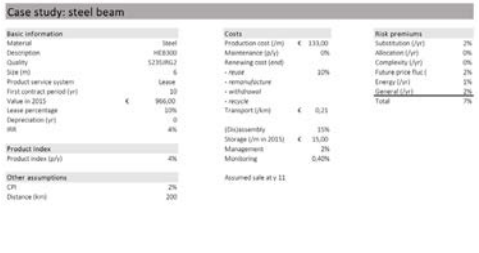
Circular situation finance

Challenges that arise with the implementation of the boundary conditions (based on Mohammadi at al., 2015) of a circular economy for building product providers. The building product provider is shown on top of the circle. This example will illustrate the issues arising in a circular economy on the services and performance market. The chain market is left out of this example.



Financial section of a Circular Business Model

The main focus is the sale of services instead of products. In this business model the building product provider provides a service to a customer. The assembly, maintenance and disassembly is completely taken care of, leaving the customer with the thing he wants most: the performance. With this approach, a customer does not need high up front cost for something he does not need.



Case study to test the model: a steel beam

A customer demands the performance 'structure' for a new building. The aim of the case study is to determine to what extent the designed business model is able to determine the (financial) viability of providing the service 'structure' in a circular economy. The steel beam is chosen to test the mode since it is believed that steel structure products are well suited for a circular economy. The conclusion is that the

At your service!

Circular business model prototypes for a service provider in the construction industry

Author Robert van den Brink **Year** 2016 **MSc programme, Faculty** Architecture, Urbanism & Building Sciences Programme

Advisors Prins, M; Straub, A. **Company** N/A **Project** N/A **Link** https: //repository.

FOCUS

BE: Materials; Cities; Component; N/A; Buildings

TOOLS & METHODS: Technology; Design; Economy; Management; Flows and resources; Society and stakeholders

CIRCULAR ECONOMY

NEW BUSINESS MODELS

BM COMPONENTS: Supply-driven; Demand-driven; Customer segments; Value propositions (VP); Channels; Customer relationships; Revenue Streams (R$); Key Resources; Key activities (KA); Key partnerships (KP); Cost structure (C$)

APPROACH

METHODOLOGY: Literature review; Case study; Design/proposal

PRODUCT: Conceptual framework; Operational model; Assessment model; Policy/practice Design/Prototype

KEY WORDS

Circular economy; Service provider; Business model prototype; Construction industry; Built environment;

SUMMARY

There is a need for a practical translation of the concept of circular economy in the construction industry . This research makes this translation through the development of business model prototypes for a circular construction industry. The research focuses on the organisational effects of a certain business models and deals with with the organisational setup of the service provider and two different transactions; one between the user and the service provider, and one between the service provider and the supplying parties. The five business model prototypes provide insights on how the service provider will deal with the 'new' circular context for the supplying parties in the construction industry. The variants are presented using the sustainable business model framework by Bocken & Short (2015). The results were contrasted with interviews to four companies involving different parties from the supply-side spectrum. Main findings from the interviews indicate that although the Business Model prototypes are not seen as directly applicable in the construction industry, they were seen as probable on the long term. Given this fact, the implementation of the circular economy would likely be restrained to basic-to intermediate services business models.

PROBLEM STATEMENT

In order to be able to implement the circular economy in the construction industry, a new entity at the building level is needed. This new entity, named services provider, offers the opportunity to study what the supply side needs to offer in a circular construction industry without being hindering by current conventions.

GOAL

The main goal is to develop business models prototypes that organise the role of a service provider at the building level, and analyse their organisational effects. The research deals with the organizational setup of the service provider and two different transactions; one between the user and the service provider, and one between the service provider and the supplying parties.

CONCLUSIONS & SCIENTIFIC RECOMMENDATIONS

Given the fact that the developed business model prototypes are (arguably) not likely to be implemented in the short-term, the implementation of the circular economy would likely be restrained to basic-, to intermediate services business models.

From the map of consequences for the different stakeholders it became clear that the choice for or against a consortium could have significant consequences for the current stakeholders in a construction project. The entrance of an external party with a high degree of competences could therefore have a profound impact as well.

If supply side parties opt to experiment with advanced circular services, it could be wise to start with a project that: Focuses on product-based project delivery, allows for a limited amount of total participating stakeholders, focuses on a new-built solution to avoid judicial obstacles,and studies the possibilities of the amount of rigidity vs. flexibility in the design.

KEY CONCEPTS / AUTHORS

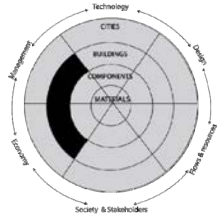
Sustainable Business Models		
Bocken, N. M. P.,	Bocken and Short	
Product Service Systems		
Baines and Lightfoot	De Grauw (2015)	Tukker (2004)
Service provider role		
Bygballe et al., (2010)	Ellen MacArthur	Biege et al. (2012)
Baines and Lightfoot	Tukker (2004)	

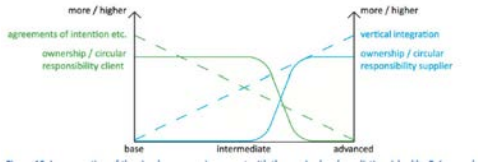
PRODUCT/BUSINESS MODEL DEVELOPMENT

	TECHNOLOGICAL READINESS	BUSINESS MODEL
1.	N/A N/A	1. Circular business models prototypes: Theory; ✓Developed; Used; Evaluated. Using Bocken & Short (2015) framework
2.	N/A N/A	2. Theory; Developed; Used; Evaluated

CASE STUDIES

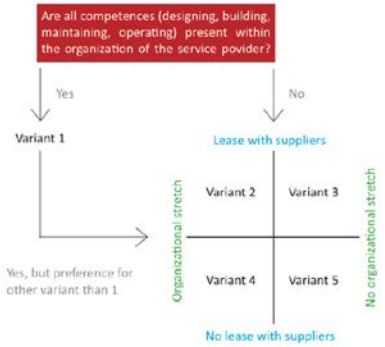
CASE STUDY	LOCATION	SECTOR	BUILDING TYPE	RELEVANCE
Lewan	Lent, The Netherlands	Construction	Residential	New-built, traditional supply-side organisations, Base circular
Growing Green	Delft, The Netherlands	Construction	Residential	Renovation, supply-side organisation by consortium, base-
Alliander	Duiven, The Netherlands	Construction	Corporate	Renovation, supply-side organisation by consortium,
Heijmans One	Movable units, The Netherlands	Construction	Residential	New built, , sole operator in the supply-side organization,





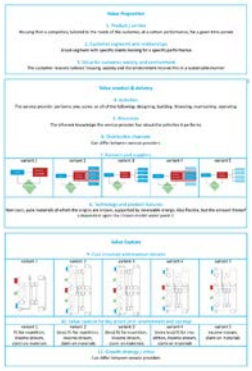
Circular Economy and Service levels

incorporation of the circular economic concept with the service levels as distinguished by Baines and Lightfoot (2013). There are multiple ways to go about the circular economy. These ways are dependent upon what service a client wants to receive with a certain product, these could either be base, intermediate, or advanced services.



Underlying aspects and variables beneath the different variants of the business model

The first variable deals with the competencies that are present within the organization of the service provider (as it follows from the literature study that a service provider should only pursue the offering of services in those areas that are part of its core business). The second variable is the earlier described organizational stretch. The third variable is the relationship with suppliers.



Business model prototypes

Five different business model prototypes with both the common and different aspects in the sustainable business model framework (based on Bocken & Short, 2015). Elements are value proposition (product/service, customer segments and relationships, value for customer, society and environment), value creation and delivery (activities, resources, distribution channels, partners and suppliers, technology

	Variant 1	Variant 3 No consortium	Variant 3 Consortium	Variant 5 No consortium	Variant 5 Consortium
User	Unchanged	Unchanged	Unchanged	Unchanged	Unchanged
Owner	Disappears	Disappears	Disappears	Disappears	Disappears
Financier	Disappears / or recipient of income stream	Disappears / or recipient of income stream	Disappears / or recipient of income stream	Disappears / or recipient of income stream	Disappears / or recipient of income stream
Main contractor	Disappears	Disappears / Service provider	Part of service providing consortium	Disappears / Service provider	Part of service providing consortium
Project Developer	Disappears	Disappears / Service provider	Part of service providing consortium	Disappears / Service provider	Part of service providing consortium
Supplier	Disappears	Supplier	Supplier / Part of service providing consortium	Supplier	Supplier / Part of service providing consortium
Sub-supplier	Disappears	Supplier	Supplier	Supplier	Supplier
Architect	Disappears	Supplier (product designer/ composer)	Supplier (product designer/ composer)	Supplier (product designer/ composer)	Supplier (product designer/ composer)
Specialist	Disappears	Supplier	Supplier / Part of service providing consortium	Supplier	Supplier / Part of service providing consortium
Facility manager	Disappears	Disappears	Disappears	Disappears	Disappears

consequences of the choice for one of the variants for the stakeholders of the current

The consequences that the delivery of advanced circular services might have on the current construction industry stakeholders are mapped in the table. These consequences follow the findings done in this research, and with acknowledgement that this question remains somewhat unanswered through this research, they therefore form a (controlled) prediction.

Stimulating Circular Building Methods

A cross-case analysis to identify the role of the general contractor

Author Lieke van der Wijk **Year** 2018 **MSc programme, Faculty** Construction, Management and Engineering Programme

Advisors V. Gruis; E. Mlecnik; T. Hoppe **Company** Dura Vermeer **Project** N/A **Link** https: //repository

FOCUS

BE
- Materials
- Component
- ✓ Buildings
- Cities
- N/A

TOOLS & METHODS
- Technology
- Design
- Economy
- ✓ Management
- Flows and resources
- ✓ Society and stakeholders

CIRCULAR ECONOMY

NEW BUSINESS MODELS

- ✓ Supply-driven
- ✓ Demand-driven

BM COMPONENTS
- ✓ Customer segments
- ✓ Value propositions (VP)
- Channels
- Customer relationships
- Revenue Streams (R$)
- Key Resources
- Key activities (KA)
- ✓ Key partnerships (KP)
- Cost structure (C$)

APPROACH

METHODOLOGY
- ✓ Literature review
- ✓ Case study
- Design/proposal

PRODUCT
- ✓ Conceptual framework
- Operational model
- Assessment model
- ✓ Policy/practice
- Design/Prototype

KEY WORDS

Circular; General contractor; Collaboration; adoption of innovation; Building sector

SUMMARY

The role of the contractors in the building sector is relevant to foster the adoption of circular buildings methods. However, this role remains unclear and requires a better definition in the context of circular economy. The main goal is to identify the main factors and give recommendations on how the role of the general contractor can have a stimulating influence on the adoption of circular methods, within its inter-firm network. Using a multi-level perspective approach, the research developed a conceptual framework to analyse two case studies of buildings projects (Bellevue building and Fijn Wonen) that aimed to use circular building methods. The cross-case analysis led to six barriers for the adoption of circular business methods: the perception of high costs, limited regulation, lack of a circular business model, unattractive esthetics, negative attitude from actors involved, and lack of integrality within the building process. Main findings showed that the general contractor may take the role of an integral manager to manage the social network, supply chain, and building process and facilitate the learning process in order to influence on the adoption of circular building methods.

PROBLEM STATEMENT

Circularity in the building sector struggles to make it to the mainstream market. This is mainly due to the fact that the building sector has a project-based nature. A general contractor is a project-based firm who has a central role between all the actors involved. Therefore it is currently unclear what the role of the general contractor can be to have a positive influence on the adoption of circular building methods in building projects.

GOAL

This research aims to identify what factors can stimulate the adoption of circular building methods by the general contractor. The goal is to give recommendations on how the role of the general contractor can have a stimulating influence on the adoption of circular methods, within its inter-firm network. Which actions can be executed by the general contractor to have a stimulating influence within its inter-firm network on the adoption of circular building methods in the Dutch housing industry?

CONCLUSIONS & SCIENTIFIC RECOMMENDATIONS

The research shows that mainly the business model, costs, regulations, integrality, attitude, and esthetics are identified as barriers for circular building methods.

To have a positive influence on the adoption of circular building methods, and resolve the identified barriers, the general contractor may take the role of an integral manager to manage the social network, supply chain, and building process and facilitate the learning process.

When taking this role it is suggested that the general contractor works together with other actors to develop a new business model. This new business model should aim to take away the current barriers for circular building methods.

KEY CONCEPTS / AUTHORS

Multi-Level Perspective (MLP)

Geels (2002) Geels & Deuten (2006)

Strategic Niche Management (SNM)

Loorbach & van Raak

Inter-firm learning

Geels & Raven (2006) Caniels & Romijn Blayse & Manley

Innovation

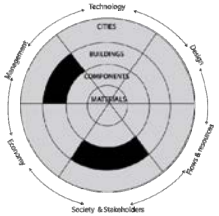
Mlecnik (2014)

PRODUCT/BUSINESS MODEL DEVELOPMENT

	TECHNOLOGICAL READINESS		BUSINESS MODEL	
1.	N/A	N/A	1. N/A	☐ Theory ☐ Developed ☐ Used ☐ Evaluated
	N/A	N/A	2. N/A	☐ Theory ☐ Developed ☐ Used ☐ Evaluated

CASE STUDIES

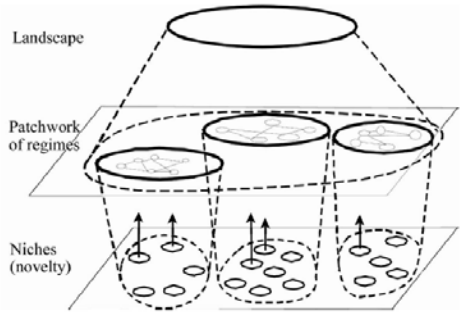
	CASE STUDY	LOCATION	SECTOR	BUILDING TYPE	RELEVANCE
–	Bellevue building (regional energy grid operator Alliander)	Arnhem, The Netherlands	Construction	Corporate	Building renovation with circular ambitions. Developed by the
–	Fijn Wonen (contractor Van Wijnen)	The Netherlands	Construction	Residential	Project that aims at having 70% circular houses by general
–					
–					
–					



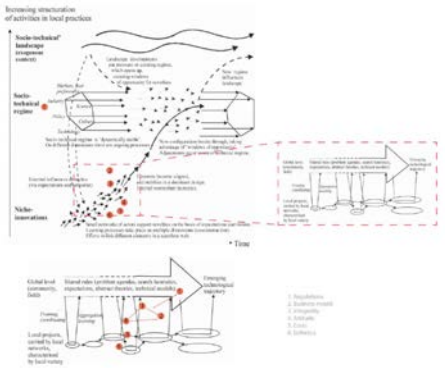
Hypotheses	Indicators	Influence on circular building methods
Managing the inter-firm network	Broad	To be filled in by the case studies
	Interaction	
	Nature of relationship	
Managing the supply chain	Trust	
	Dedication to common goals	
	Understanding & expectations of core values	
	Equality and timing involvement	
Managing building process	Protection of core values	
	Progress & momentum	
	Quality of results	
	Room for problems & solutions	
	Appealing to participate	
Facilitating the learning processes	Knowledge sharing	
	Focus	
	Environment	
	Techniques	

Theoretical framework for case study analysis

The framework is structured in four hypothesis related to: (1) Managing the inter-firm network, (2) Managing the supply chain, (3) Managing building process, (4) Facilitating the learning processes



Multi-level perspective. A transition which is seen as a non-linear process that results from the interplay of development at the analytical level: niches, socio-technical regimes, and socio-technical landscapes (Source: Geels, 2002).



Barriers in Multi-level Perspective

Barriers in Multi-level Perspective and knowledge management adapted from Geels, 2002 and Geels & Deuten, 2006.

Barrier	Case I	Case II	GC	SC	Advisor	Client
Costs						
Regulations						
Business model						
Esthetics						
Attitude						
Integrality						

GC = general contractor SC = Sub-contractor Adv = advisor Cli = Client

Barriers identified by cases and roles

Afstudeerrapport 'Circulair aanbesteden'

DNA-match: het geheim achter een spraakmakende circulaire aanbesteding

Author Floris van Haagen **Year** 2018 **MSc programme, Faculty** Architecture, Urbanism & Building Sciences Programme
Advisors Straub, A.; Chao-Duivis, M.; Prins, M. **Company** N/A **Project** N/A **Link** https: //repository.

FOCUS

BE
- Materials
- Component
- ✓ Buildings
- Cities
- N/A

TOOLS & METHODS
- Technology
- Design
- Economy
- ✓ Management
- Flows and resources
- Society and stakeholders

CIRCULAR ECONOMY

NEW BUSINESS MODELS

BM COMPONENTS
- Supply-driven
- ✓ Demand-driven
- Customer segments
- Value propositions (VP)
- Channels
- Customer relationships
- Revenue Streams (R$)
- Key Resources
- Key activities (KA)
- Key partnerships (KP)
- Cost structure (C$)

APPROACH

METHODOLOGY
- ✓ Literature review
- ✓ Case study
- Design/proposal

PRODUCT
- Conceptual framework
- Operational model
- Assessment model
- ✓ Policy/practice
- Design/Prototype

KEY WORDS

Circular economy, Procurement, Procurement law, Circular procurement, DNA-match, Collaboration

SUMMARY

The circular economy is a hot topic and seen as the solution to the depletion of the earth. According to multiple researchers procurement is an important mean to stimulate circularity, thereby boosting the transition towards a circular economy. This research focusses on how circularity can be implemented in a tender, and if the Dutch procurement law is indeed obstructive to circular procurement. This explorative qualitative research used different research methods; literature review, explorative interviews, semi structured in-depth interviews and a case study. Based on this research it is concluded that the Dutch procurement law is not obstructive in any way or form to integrally implement circularity in tenders. Within a circular tender, three aspects are of crucial importance; (1) a DNA-match between contracting entity and contractor needs to be found, (2) vulnerability, transparency, communication and collaboration are important during the procurement process, and (3) circularity is not a goal on itself, but merely a mean to achieve higher objectives.

PROBLEM STATEMENT

At this moment, there are multiple barriers in regards to circular procurement, whereby (semi)public governments are experiencing difficulties in setting up a proper circular tender.

GOAL

The main goal is to understand to what extent current Dutch procurement law offers room for circular procurement, and to identify the ways to which (semi) public governments should incorporate circularity in a tender. How can (semi)public governments, within the framework of procurement law, use the opportunities to set up a circular tender?

CONCLUSIONS & SCIENTIFIC RECOMMENDATIONS

DNA-match - One of the most crucial aspects of successful circular projects is intensive cooperation and collaboration, rather than contractual agreements. The base of this cooperation is founded in the procurement process. It is vital that a contracting party has the same circular vision and ambitions as the contracting entity.

Vulnerability and transparency - In order to find that DNA-match a (semi)public government/-organisation needs to have a vulnerable attitude, dare to be transparent and honest about they knowledge. This research has shown that a vulnerable attitude of the contracting entity, subsequently leads to a vulnerable and transparent attitude of the tenders as well.

Circularity as a mean, not as a goal. Circularity is merely a mean to a greater cause, namely the minimization of raw virgin material extraction and waste production.(semi)public governments and organisations need to start with their strategic goals in which circularity can help achieving them, in stead of simply wanting a circular building.

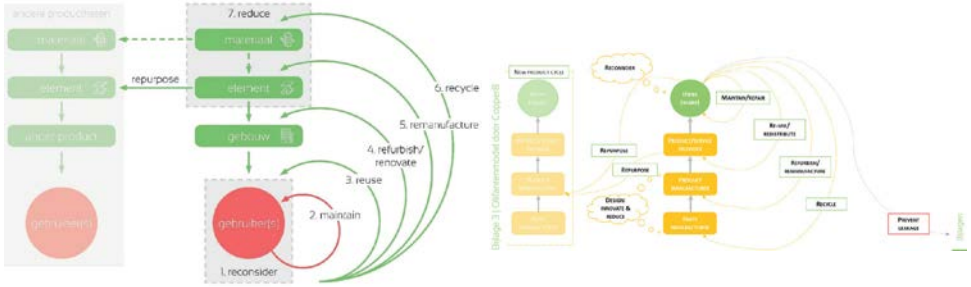
KEY CONCEPTS / AUTHORS

PRODUCT/BUSINESS MODEL DEVELOPMENT

	TECHNOLOGICAL READINESS		BUSINESS MODEL	
1.	N/A	N/A	1. N/A	Theory, Developed, Used, Evaluated
	N/A	N/A	2. N/A	Theory, Developed, Used, Evaluated

CASE STUDIES

CASE STUDY	LOCATION	SECTOR	BUILDING TYPE	RELEVANCE
Town-hall of municipality Brummen	Brummen, The Netherlands	Construction	Public	Circular tender
Alliander Duiven and Circular furniture for Alliander	Duiven, The Netherlands	Construction	Corporate	Circular tender
Temporary Courthouse Amsterdam	Amsterdam, The Netherlands	Construction	Public	Circular tender
Alliander Bellevue	Arnhem, The Netherlands	Construction	Corporate	Circular tender
Circular furniture for UMC Utrecht	Utreacht, The Netherlands	Construction	Public	Circular tender

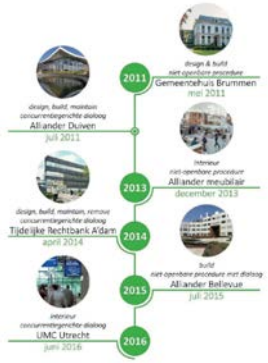


Practical adaptation of the elephant model for the built environment

Copper8 has made an in-depth look at the original butterfly model of the Ellen MacArthur Foundation. Both models have the highest possible level of abstraction in order to be applicable to any sector. For this research, the elephant model has been translated into a model specific to the built environment

Elephant model developed by Copper8 (2016)

Elephant model developed by Copper8 (2016)



Timeline of the cases studies

Identification of type of assignment, procedure used and date of publication selection guide.

Result of the analysis of the tender documents of Alliander Duiven

Result of the analysis of the tender documents of Alliander Duiven

Economic circularity in the built environment

An assessment and decision-making supporting model for the real estate sector & construction industry

Author Bram van Hemmen **Year** 2016 **MSc programme, Faculty** Architecture, Urbanism & Building Sciences Programme

Advisors Prins, M.; De Jong, P. **Company** OVG Real Estate **Project** N/A **Link** https://repository.

FOCUS

BE
- [x] Materials
- [x] Component
- [ ] Buildings
- [ ] Cities
- [ ] N/A

TOOLS & METHODS
- [ ] Technology
- [ ] Design
- [x] Economy
- [x] Management
- [x] Flows and resources
- [ ] Society and stakeholders

CIRCULAR ECONOMY

NEW BUSINESS MODELS

BM COMPONENTS
- [ ] Supply-driven
- [x] Demand-driven
- [ ] Customer segments
- [ ] Value propositions (VP)
- [ ] Channels
- [ ] Customer relationships
- [x] Revenue Streams (R$)
- [x] Key Resources
- [ ] Key activities (KA)
- [ ] Key partnerships (KP)
- [ ] Cost structure (C$)

APPROACH

METHODOLOGY
- [x] Literature review
- [x] Case study
- [x] Design/proposal

PRODUCT
- [ ] Conceptual framework
- [ ] Operational model
- [x] Assessment model
- [ ] Policy/practice
- [ ] Design/Prototype

KEY WORDS

Circular economy
assessment model
built environment
decision-making model
reuse
components

SUMMARY

There is a need for assessment and decision-making supporting circular economic models in the construction sector. This study proposes a model that assesses the extent to which interventions in the built environment are in accordance with a circular economy and discloses the financial variables behind reuse. The model is developed using the MTPEB framework, which refers to mass, time, performance, environment and business. The model assesses the quantity of flows of materials (kg/year) that are necessary for the delivery of the performance usable floor area (1m2 UFA). The model places a binary verdict on material flows, in which they are either capable or incapable of continuous recursion. The result shows that material flows are considered to be an indicator for environmental impact. The assessment is supplemented by a financial overview of material and component reuse values, that supports the decision-making processes that can enable a Circular Economy from a business perspective.

PROBLEM STATEMENT

The real estate sector & construction industry is currently unable to assess the economic circularity of their interventions in the built environment and are unable to effectively and accurately incorporate economic circularity in their decision-making.

GOAL

To develop a model that assesses the extent to which interventions in the built environment are in accordance with a circular economy (CE) and discloses the financial behind reuse.

CONCLUSIONS & SCIENTIFIC RECOMMENDATIONS

The decision-making supporting capabilities of the model are threefold. First of all the assessment of the accordance with a CE is an important factor for decision-making in itself. It allows for comparing and improving on the matter.

Second of all the supplemented component reuse values and material reuse values offer the financials based upon which decisions for reuse now can be made disclose the value components and materials have in a development process. As practice is currently unaware of these values, they not only create awareness, they also support the decision-making that can enable a CE. Same goes for the projections of reuse values in the future. Knowing this values allows for the anticipation on reuse in the future.

Three practical suggestions for improving economic circularity: A, change the materials a floor is made up of. Wooden hollow core slabs are a good example of a floor slab that is made up entirely of continuously recursive (green) materials (timber). B, use old floors longer, by means of refurbishment projects. C, built with floors that have a longer life expectancy.

KEY CONCEPTS / AUTHORS

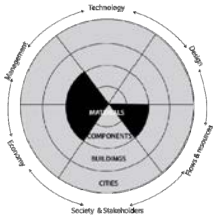
Normative theory

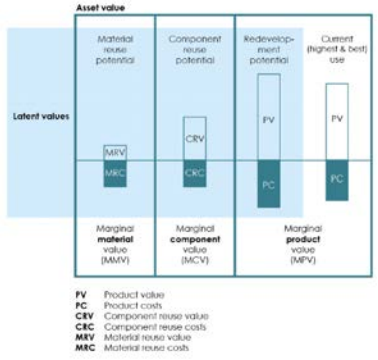
PRODUCT/BUSINESS MODEL DEVELOPMENT

	TECHNOLOGICAL READINESS	BUSINESS MODEL
1.	N/A	1. MTPED
		[ ] Theory [x] Developed [x] Used [ ] Evaluated
2.	N/A	2.
		[ ] Theory [ ] Developed [ ] Used [ ] Evaluated

CASE STUDIES

CASE STUDY	LOCATION	SECTOR	BUILDING TYPE	RELEVANCE
Olimpic Plaza	Amsterdam, Netherlands	Construction	Corporate	



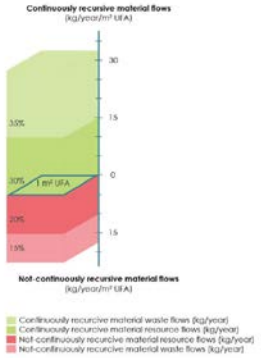


The different values of an asset.

In a circular economy where products components and materials are all continuously subjected to use and reuse, it is important to design and assess a products value on the level of the product. This considers a latent value, which is the redevelopment potential of an asset.

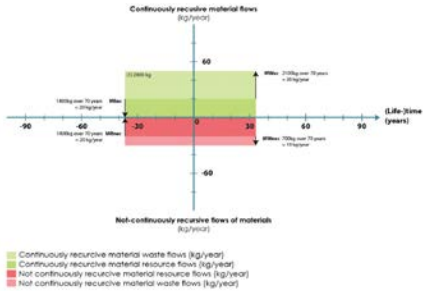
5 subtopics of CE	Variables	Unit
(1) Mass	Continuous recursive material waste	Kilogram
	Continuous recursive material resources	Kilogram
	Not continuous recursive material resources	Kilogram
	Not continuous recursive material waste	Kilogram
(2) Time	(Life-)time	Years
(3) Performance	Usable floor area	m2 UFA
(4) Environment	Environmental impact	Indication + EPC
(5) Business	Financial	€

Table showing the variables and units given to the first four topics of circular economy



The amount of flows produced by a building per square meter usable floor area

The concept of performance is added to the assessment, which allows for the comparison of different products on the flows of materials (kg/year) needed for the delivery of a performance (1m2 UFA).



Material flows plotted against time for a component c1

A Best Value approach to public procurement

Stimulating the transition towards a circular infrastructure sector in the Netherlands

Author Anna van Veenen **Year** 2018 **MSc programme, Faculty** Construction, Management and Engineering Programme

Advisors Chao-Duivis, M.; Kuitert, L. **Company** N/A **Project** N/A **Link** https://repository.

FOCUS

BE
- [ ] Materials
- [ ] Component
- [ ] Buildings
- [x] Cities
- [ ] N/A

TOOLS & METHODS
- [ ] Technology
- [ ] Design
- [ ] Economy
- [ ] Management
- [ ] Flows and resources
- [x] Society and stakeholders

CIRCULAR ECONOMY

NEW BUSINESS MODELS

BM COMPONENTS
- [x] Supply-driven
- [x] Demand-driven
- [ ] Customer segments
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APPROACH

METHODOLOGY
- [x] Literature review
- [x] Case study
- [x] Design/proposal

PRODUCT
- [x] Conceptual framework
- [ ] Operational model
- [ ] Assessment model
- [x] Policy/practice
- [ ] Design/Prototype

KEY WORDS

Public procurement; Circular Economy; Best Value; Infrastructure; Procurement law

SUMMARY

In the infrastructure sector, circular ambitions are only partly reached after the realization of the projects, which evidences an ineffective procurement process. Therefore, the research focuses on the possible contribution of the Best Value Approach towards effective public procurement of circular infrastructure. The main goal is to create a guideline for Dutch public authorities about how they can procure circular infrastructure more effectively. The research conducts a literature review to provide insight into the concepts of public procurement in the Netherlands, procurement of circular infrastructure and the Best Value Approach. Additionally, interviews with Dutch public authorities were held to define the current status of these concepts. The theoretical and empirical inputs are captured in a conceptual model which is subsequently validated by a focus group. Main findings show that the Best Value Approach and the proposed model can support public authorities to find the expert contractor who can realize their circular ambition. Nevertheless, the infrastructure sector is still at early development regarding circularity which makes difficult to exploit the benefits of Best Value Approach yet.

PROBLEM STATEMENT

Practice shows that in the infrastructure sector public authorities start with high circular ambitions, but throughout the procurement process these ambitions are only partly reached, making the process not very effective. A possible contribution to increase the effectiveness can be a specific procurement approach that focusses on utilizing the experience from the supply chain, called the Best Value Approach. However, no literature so far has described the opportunities of this approach to procure circular infrastructure in the Netherlands

GOAL

The goal of this research is to create a guideline for Dutch public authorities about how they can procure circular infrastructure more effectively by making use of the Best Value Approach (BVA).This results in the following research question: In what way, if any, can the Best Value approach contribute to the effectiveness of public procurement in order to stimulate the transition towards a circular infrastructure sector in the Netherlands?

CONCLUSIONS & SCIENTIFIC RECOMMENDATIONS

The BVA is a great approach for public authorities that want to find the expert contractor who can realize their circular ambition. It helps them to provide room for contractors through project goals, functional specifications, and awarding on quality.

The proposed model can be used by Dutch public authorities as a guideline to determine which BV elements can be used to procure circular infrastructure more effectively. The model helps to raise awareness within contracting authorities regarding attitude, type of circular project and conditions that are suitable for making use of the Best Value Approach

The more BV elements are used, the more effective the circular procurement process will be. However, the aim of the model is not to force contracting authorities to make use of as many BV elements as possible. Contracting authorities should not strive for the most effective approach available, but look at which approach suits the organisation and project best.

KEY CONCEPTS / AUTHORS

Public procurement in The Netherlands

Kuitert, Volker and Chao-Duivis, Koning, Essers & Lombert

Van Duren & Dorée Ten Haaf (2017) (Kuitert,

Best Value Approach (BVA)

Kashiwagi (2017) Snippert, Witteveen, Kashiwagi (2016)

Rijkswaterstaat (2013)

PRODUCT/BUSINESS MODEL DEVELOPMENT

	TECHNOLOGICAL READINESS	BUSINESS MODEL
1.	N/A N/A	1. N/A — [ ] Theory [ ] Developed [ ] Used [ ] Evaluated
2.	N/A N/A	2. N/A — [ ] Theory [ ] Developed [ ] Used [ ] Evaluated

CASE STUDIES

	CASE STUDY	LOCATION	SECTOR	BUILDING TYPE	RELEVANCE
–	N/A				
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–					
–					
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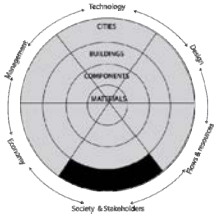


Best Value Approach procurement process

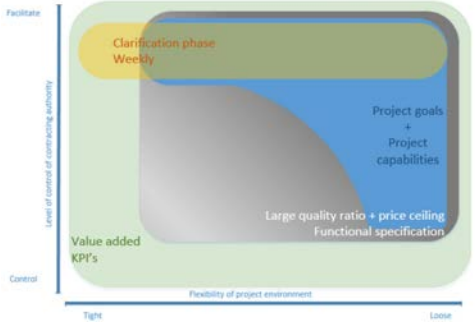
Process based on Kashiwagi (2016, 2017), and adjusted to the European and Dutch procurement legislation based on van de Rijt & Santema (2013),van de Rijt et al. (2016). The BVA is an approach to public procurement which uses the experience of the supply chain by looking for the expert contractor who is able to understand the needs, execute the contract and identify and mitigate risks.

Legend
Possible contributions
Neutral
Doubtable contribution

	Contractor is expert	Use of dominant information and metrics	Use of transparency
Life cycle approach	The expert contractor knows about life cycle approach and is able to oversee the whole project. He can identify risks for the contracting authority, which is especially useful in the long term. The expert contractor knows how to make optimal use of materials. He can optimize the design and maintenance approach.	Metrics about the whole life cycle of project can be used.	Use of transparency includes the execution phase. Besides time and costs, performance in terms of circularity can be monitored.
Collaboration with supply chain	The expert contractor takes the lead, but there is no close collaboration between contracting authority and contractor.	Metrics can be retrieved from suppliers, which enhances early contact within the whole supply chain.	Transparency enhances trust between contracting authority and contractor. This is good for collaboration.
Innovation	The expert contractor can determine additional value in relation to the project goals. He can come up with innovations.	Metrics and innovations can be troublesome, because new things do not have metrics yet.	Transparency can be used to measure the performance of the innovation

Comparison between circular procurementa and the Best Value Approach (BVA)

The Table show the comparison of three circular procurement aspects with three BVA aspects. They are cross-referred to see if the aspects contradict or not. So, it is analysed if BVA aspects contradict with circular procurement aspects. If aspects do not contradict, it is okay. Furthermore, in some cases the BVA can maybe even contribute to circular procurement.



Best Value elements for effective procurement of circular infrastructure

BV elements that have the potential to contribute to the effectiveness of the current practice: KPI's, project goals, project capabilities, value added, functional specifications, large quality ratio, price ceiling, clarification phase, and weekly risk report. The elements are captured in this model that can be used by Dutch public authorities as a guideline to procure circular infrastructure more effectively.

Legend
Positive relation
Neutral

SWOT / BVA	Risk averse mind-set prevents starting	It is hard to formulate circular project ambitions	Monitoring of project progress is hardly done	Technical specifications are most often used	Assessment of fit-for-functionally specified tenders is perceived hard	Price is dominant in award criteria	New tools can make circularity in projects measurable	There is a certain distrust towards the supply chain	There is little contact with the supply chain during tender
Financial and personal incentive									
Circular ambitions									
Life cycle approach									
Room for contractor									
Measure ability									
Collaboration with supply chain									
KPI's									
Value added									
Price ceiling									
Functional specification									
Large P/Q ratio									
Risks									
Project goals									
Project capabilities									
Clarification phase									
Weekly risk report									

.Comparison of Best Value Approaches to outcomes of SWOT analysis

Comparison of Best Value Approaches to outcomes of SWOT analysis (based on interviews)