The Circular Economy and Cities: Application, Barriers and Limits in the case study of Amsterdam

Kieran Campbell-Johnston (11658096)
Kieranc-j@hotmail.co.uk
11/06/2018
Word count: 20,939
University of Amsterdam
Master of Science Human Geography
Environmental Geography Track
Supervisor Joyeeta Gupta
Second reader Josh Maiyo

Executive summary

Introduction

The prolific and incessant consumption of finite raw materials is causing unprecedented environmental damage that is jeopardising the Earth's regenerative carrying capacity. This material use is tied to the present linear industrial economy, which is predicated on the continued use and eventual discharge of materials into the ecosystem. Urban spaces overwhelmingly exhibit these linear flows of materials and represent significant hotspots of material consumption and waste discharge. This is particularly apparent in the construction sector/built environment, which is estimated to be responsible for 33% of emissions, 40% of material consumption and 40% of waste from urban environments.

The circular economy has emerged as a potential sustainable solution to the dual challenge of resource scarcity and ecological degradation, due to its claim to overcome the present consumption/production model by decoupling economic activity from resource use through closing material and energy loops. This research examines how urban spaces are facilitating the transition to the circular economy and the barriers and limitations that have arisen during this process, using insights from the city of Amsterdam's circular strategy and the construction sector. If the circular economy can effectively contribute to a more sustainable urban environment, it is essential to examine the scale on which specific circular activities are feasible and the particular challenges that inhibit its adoption. Thus, this paper brings greater attention to the practical realities of strategically implementing a circular economy.

Based on the identified gaps in knowledge base the proposed research question is:

> *What circular economy activities are currently feasible within a city whilst transitioning to a sustainable form, and what are the barriers and limits to such a transition?*

Methodology

This research uses an explorative qualitative research design to answer the aforementioned question using the city of Amsterdam and the construction sector/built environment as an in-depth case study. The research followed four methodological steps: 1) literature review, 2) content analysis of city level and national circular strategies, 3) in-depth interviews with targeted stakeholders, and 4) data synthesis and triangulation.

Findings

The findings from these four steps indicate the following. At the national level, the Netherlands has set one overarching target, a 50% material reduction by 2050; five material chains have been prioritized (organics, manufacturing, plastics, construction and consumer goods); and pioneering cities are emphasised as the focus for circular transitions. The intended instruments to drive the circular ambitions and meet this target include: a) regulatory (e.g. changing waste definitions); b) market (e.g. tax incentives for circular practices); and c) knowledge exchange (e.g. collaborations between sectors/stakeholders). This strategy is ineffective because: 1) it has no baseline to measure material reduction from; 2) includes organic incineration as a sustainable measure; 3) the instruments are vague; and 4) it has no legally binding targets or assigned budget. The city of Amsterdam is experimenting with two material chains (organics and construction). The construction sector is at the innovation/take-off phase of the transition, whilst organics is being explored, and the other material chains are not currently prioritised. The city strategy for construction proposes the reuse and recycling of materials to create positive feedback loops and material stocks. The intention is to drive the transition through targeted measures including: regulation (e.g. circular zoning laws), market stimulation (e.g. procurement policies), knowledge exploration (e.g. collaborative knowledge hubs), capacity building (e.g. workshops/training), suasive (e.g. public announcements) and infrastructure development (e.g. renovating waste hubs) connected to these sectors. The strategy potentially contributes to the urban sustainability of the city through reduced consumption, reduced ecological footprint, waste recycling, and smart technologies. However, this process has met significant barriers that inhibit the effectiveness of the measures and prevent the acceleration of the transition, examples being: a) market quality for secondary materials; b) knowledge of usable materials within city boundaries; c) public tendering scope; and d) hesitancy and reluctance to adopt the circular mindset. The city level application is limited in its capacity to create a closed material cycle and circular economy due to: a) limited focus on end-of-pipe measures (reuse and recycle), when the inevitable degradation of materials necessities prioritising material reduction and systems redesign, b) instrumental scope for new circular development is limited to public land, which means the potential for circular (re)design is low, and c) technological capacity to substitute new input with output limited to 30% to 50%, as evidenced through the material reprocessing limits of concrete and cement.

Conclusions and suggestions

The research suggests that cities implementing a circular economy are limited in their capacity to transition to a complete circular economy, owing to their spatial/administrative focus and strategic instrumental scope. It highlights the differences between the conceptual imagination of circular economy and its reality during practical implementation. The distinction is most clearly evidenced through the present technological/material limits for concrete reuse, which prevent the creation of a full material cycle based on completely substituting output for input. Circularity at the city level is premised on a more efficient use of material to meet increased demands. This indicates that from the feasibility standpoint, cities can pursue a rudimentary form of circularity, which relates to creating positive feedback loops and stock for future use through material recycling and reuse. The city level, in comparison to industrial sectors, is not the most effective area to implement a circular economy, owing to the limited focus and strategic scope. Based on this assertion, this research presents two scenarios for the future transitional process to a circular economy. Scenario one follows the present application to its logical conclusion, arguing the examined strategy prevents further acceleration towards a circular economy, as cities can only create a reusing economy within their administrative boundaries. Scenario two argues for greater scalar cooperation and action at higher levels to assist the progression towards circularity. This necessitates cooperation along material value chains, which cannot be done at the city level. Presently, the Dutch Government is devolving responsibility for circularity to the municipal level. This research shows the limited effect this strategy will have in realising a full circular economy, which is primarily limited to end-of-pipe and waste processes and not material reduction. This indicates that greater emphasis needs to be placed on reducing material inputs and redesigning systems to use fewer materials. Thus, the national prioritisation to the city level is misplaced; instead greater inter-scalar cooperation is needed to move towards circularity.

To break through the present barriers, this research makes seven key suggestions – four national and three municipal – to assist acceleration within the construction sector. The national suggestions are: 1) devolving development legislation to the city level to compel the adoption of circular economy building practices; 2) adjusting direct and indirect taxation of primary and secondary material to encourage the greater use of secondary ones; 3) requirements for new concrete blends to include 30% recycled material; and 4) set a budget for circular economy. The city level suggestions are: 1) set targets for construction and demolition material retention and reuse; 2) investment in material reprocessing technology; and 3) continuation of circular procurement practices. These suggestions should assist the progression and further success of a circular economy at the city level.

Acknowledgements

I would like to thank all respondents who contributed to this research. Additionally, my co-researchers, Joey Ten Cate and Maja Elfering-Petrovic, and my supervisor Joyeeta Gupta who provided numerous greatly appreciated suggestions and invaluable feedback. Special thanks to Sarah Campbell for your invaluable advice, and Elske van den Hoogen for your support and patience during this period.

Table of Contents

1 Introduction

1.1 Research purpose

This research examines the limitations and barriers that have arisen during the transition to and implementation of a circular economy (CE) at the scale of the city, building on insights from the CE strategy in the city of Amsterdam. In doing so it aims to document how urban spaces are facilitating the transition to CE and the spatial-sectoral challenges that have arisen during this process. If CE can effectively contribute to a more sustainable urban environment, it is essential to examine where material loops can be closed, at which scale specific circular activities are feasible and the particular challenges that are inhibiting its adoption. This chapter outlines the global challenges of resource overuse and scarcity (see 1.2), research gaps (see 1.3), research questions and intention (see 1.4) and the structure of the thesis (see. 1.5).

1.2 Problem statement

The world is rapidly approaching the 'point of no return' in preventing the unprecedented damages of climate change, which is accelerating due to human activity (Voor et al., 2013: 5). At the global level, research suggests current environmental trends, such as excessive land-use, water and soil pollution, biodiversity loss and resource depletion, have already jeopardized the Earth's regenerative carrying capacity (WWF, 2016; Rockström et al., 2009). The incessant demand and consumption of raw materials is contributing to this ecological degradation, whilst rapidly decreasing their availability, with estimates projecting a 50% supply gap in key materials (such as iron, ore, zinc, bauxite, copper and aluminium) by 2030 due to increased extraction (see Figure 1.1) (Gupta, 2014a).

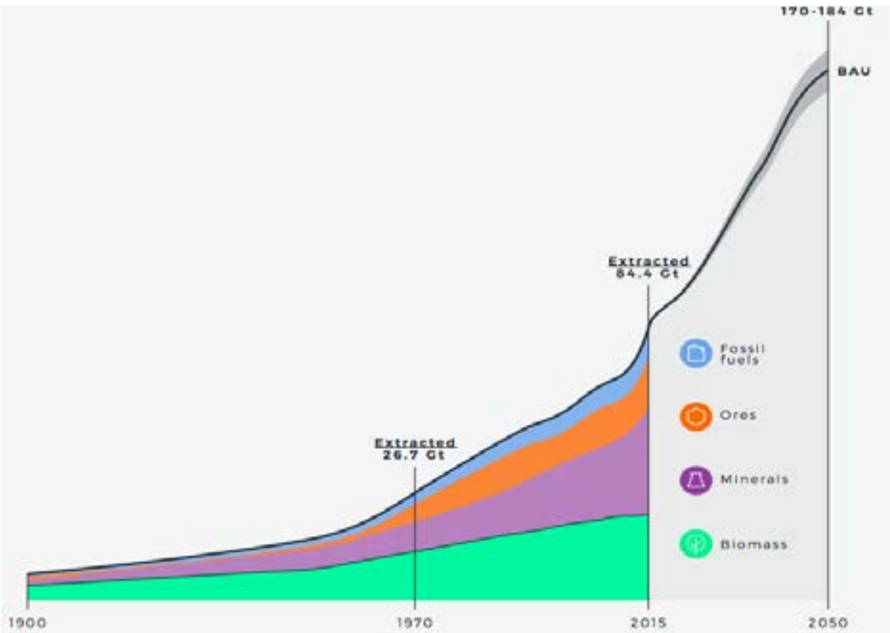


Figure 1.1 History of and forecasts for material extraction
Source: Circle Economy, 2018.

This proliferation of resource consumption has been intricately tied to the present linear economic model, which has dominated production processes for the past 150 years (Franco, 2017). This model is characterised as ‘take-make-waste’, where virgin resources are extracted, produced, consumed and ultimately discarded, damaging the ecosystem through the initial extraction process and eventual waste discharge (Lazarevic and Valve, 2017). Its design is predicated on the assumption of limitless growth, which disregards how it intrinsically undermines the natural resource base, damages ecosystems and transgresses the planetary boundaries (Franco, 2017; Rockström et al., 2009; O’Connor, 1997).

At the local level, urban environments overwhelmingly exhibit linear flows and inefficient use of resources, and represent considerable hotspots of consumption and waste generation (Ness and Xing, 2017; Grimm et al., 2008; Rees, 1992). Globally, cities are directly and indirectly responsible for 75% of annual resource use, up to 80% of energy consumption and 75% of carbon emissions (UN, 2014; UNEP, 2013). Within urban spaces, the construction and building sector is estimated to be responsible for 33% of emissions, 40% of material consumption and 40% of waste (Ness and Xing, 2017; WRI, 2016; UNEP, 2012; Levermore, 2008). Urban population concentration is expected to increase from 54% to 66% of the global population in the coming decades, and by 2030 forecasts expect roughly 3 billion people to join the middle class, representing the greatest increase in disposable income and corresponding material demand by new consumers (Franco, 2017; UN, 2014). Thus, cities are critical arenas in combatting the systemic forces of resource depletion and externalised environmental erosion, as recognised in the United Nations Development Programme’s sustainable development goals for 2030 (UNDP, 2015).

1.3 Circular economy and research gaps

CE has emerged as a potential sustainable solution to the dual challenges of resource scarcity and ecological degradation, due to its claim to overcome the present consumption/production model by decoupling economic activity from resource use by closing material and energy loops (Murray et al., 2017; Ghisellini et al., 2016; Gregson et al., 2015). CE is most popularly understood as an industrial economy that is restorative and regenerative by intention and design (Ellen MacArthur Foundation, 2013), in which, resource input and waste, emissions and energy leakage are minimised by slowing, closing and narrowing material and energy loops (Geissdoerfer et al., 2017: 759). CE initiatives have been implemented in various forms, including ‘top-down’ command and control models in China and multi-stakeholder collaborative activities in Europe (Saavedra et al., 2018; Geissdoefer et al., 2017). Given the infancy of CE discussions and initiatives, little is written on the process of implementation, in particular outlining and documenting the arising barriers and limitations in the transitions of specific CE applications (Murray et al., 2017; Lieder and Rashid, 2016). Whilst previous research has outlined the significant barriers inhibiting the implementation and transition to circularity, these have only been examined at the macro and regional level (Kirchherr et al., 2017). Concerning cities, past research has positioned them merely as features geographically proximate to circular industrial activities, or as theoretically suitable areas for closing material loops (Dong et al., 2017; Kalmykova and Rosado, 2015; Ma et al., 2014). With the exception of several case studies analysing Chinese cities, which highlighted technological innovation as a circular driver and central government reluctance to provide suitable financial support, CE discussions have rarely examined its implementation within urban, particularly European, environments (Prendeville et al., 2018; Lieder and Rashid, 2016; Su et al., 2013). Cities have often been a focus for sustainability experiments and activities, from spatial designs that emulate ecological cycles to technological innovations and smart city programmes, all concerned with the optimal use of resources and space (Jabareen, 2006). Recent research has highlighted the potential of CE as a strategic sustainable measure that cities can pursue, but little is written on CE applications within the urban built environment (Linder et al., 2017; Ness and Xing, 2017). As CE develops from the conceptual levels to specific (and concrete) measures, it is essential to examine the process and identify existing transitional limitations and barriers at different scales (Ghisellini et al., 2016). This has added significance if CE is adopted and pursued as a strategic measure to advance urban sustainability. Cities have continuously engaged with measures regarding sustainability issues, examples being the European Union (EU) Covenant of Mayors and the C40 Cities Climate Leadership Group. The launch of the Circular Cities Network by CE think-tank the Ellen MacArthur Foundation in 2016 highlights the increased focus on CE within urban environments (Ellen MacArthur Foundation, 2016). Despite this, critical academic research on implementing the CE at the city level is inconclusive, and lags behind government and business initiatives (Ghisellini et al., 2016). Thus, this research contributes to a greater practical understanding of the process of implementing CE at a specific scale, its potential to transform the present consuming nature of cities, and the limits and barriers to such strategies. It seeks to address the following gaps: 1) how CE is being implemented within cities, 2) contribution of CE strategies to urban sustainability and 3) transitional barriers and limits arising from this implementation.

1.4 Research question and intention

Based on the identified gaps in the knowledge base on the CE, the research question is:

> *What circular economy activities are currently feasible within a city whilst transitioning to a sustainable form, and what are the barriers and limits to such a transition?*
>
> The research will address the following sub-questions:
>
> 1. What is the CE in the context of a city and how does it contribute to urban sustainability?
> 2. How are cities driving the transition to CE?
> 3. What are the barriers to circularity within the city?
> 4. What are the limits to circularity within a city?

This research involves an in-depth analysis of an individual city (Amsterdam), which is currently implementing a CE as a case study. This research is one strand of a larger research project, which synthesized three literature reviews – CE, transition theory and urban sustainability – to form the conceptual framework. The framework and research methodology was jointly agreed upon and designed using the three literature strands. Each researcher then examined the same research question through different case studies, emphasizing the literature in their own way. Throughout the research proceedings, the research group had regular contact, where we supported each other and discussed the process and findings. I use content analysis of the national strategy and existing circular and sustainable city strategies, supplemented with in-depth interviews with associated stakeholders and additional literature to highlight how CE has been applied, and the existing limitations and barriers that are arising during the city's transition. Because CE is still in its infancy, comprising a 'cluster' of and discourse on activities and concepts, many diverse activities fall under its definition (Korhonen et al., 2018a: 548). For the purpose of this research, emphasis is given to institutional strategies and corresponding sector that focus on closing material loops, a feature central to CE conceptualizations and existing operationalizations (Lazarevic and Valve, 2017). To illustrate this process this study examines the construction sector/built environment within the city. The emphasis is justified because: 1) Amsterdam is prioritizing circular activities in this sector (see Chapter 4); 2) little academic research has been written on CE and the built environment (Ness and Xing, 2017); and 3) this sector represents the greatest material volumes and environmental impact (internally and externally) from the city (ABN AMBRO et al., 2017). This case study provides insights into the dynamics and challenges of transitioning to CE, as well as introducing the spatial focus to highlight the inter-scalar complexities and interrelated elements of this process.

1.5 Structure of thesis

This research is structured as follows. Chapter 2 outlines the existing knowledge base regarding CE, sustainable cities and transition theory, and sets out the conceptual framework used in this research. Chapter 3 presents the methodological steps taken, which include: 1) content analysis of specific national and city documents (see 3.5.1); 2) semi-structured interviews (see 3.5.2); and 3) final data analysis (see 3.5.3). It gives a detailed explanation of these three steps taken to collect and analyse the data, illustrating how the conclusions were derived. Chapter 4 presents the findings from Stage 1 of the research process, which describes the circular application within Amsterdam. Chapter 5 presents insights from Stages 2 and 3 and discusses transitional barriers and practical limitations, insights from the interviews and literature. Chapter 6 presents the conclusions whilst reflecting on the research process, methodology and future areas of study.

2 Theoretical framework

2.1 Introduction

This chapter reviews the relevant literature for this study's theoretical foundation and outlines the intended conceptual framework used to examine CE at the city level. It focuses on three strands of literature: 1) CE (see 2.2); 2) urban sustainability (see 2.3); and 3) transition theory (see 2.4), to understand the current knowledge base and draw more holistic insights onto the problem statement and research question. The concepts are used in a composite and complementary fashion to understand CE within cities as a transitional process towards urban sustainability, whilst addressing the current knowledge gaps (see Chapter 1, 1.3). This section draws inspiration from the literature base compiled for the broader research project (see Chapter 1, 1.4). First, this chapter examines CE (see 2.2), it then discusses urban sustainability and the conceptual compatibility with CE principles (see 2.3), before outlining the transition process (see 2.4), the intended conceptual framework (see 2.5) and research intentions (see 2.6).

2.2 The circular economy

2.2.1 Origins and goals

The origins of CE can be traced to various sources that include general systems theory, environmental economics and industrial ecology. Industrial ecology's significant contribution to CE is the study of human-induced material and energy flows, gauging ways to minimize their environmental impact through the closing of material and energy loops, an element that has become central in both CE's conceptualization and implementation (Lazarevic and Valve, 2017).

CE is an antonym of the linear economy, in both its design and symbiotic interaction with the environment (Murray et al., 2017: 371). Where the linear or open-loop model operates on the basic assumption of continuous resource extraction, inefficient use and eventual waste dumping, a circular or closed loop model seeks to redesign the economic system, where waste and materials are perpetually reincorporated back into the cycle, substituting the need for virgin material input (Jurgilevich et al., 2016). CE is therefore imagined as an industrial economy that resembles a living organism or replica of a natural ecosystem, which operates within the environmental and ecological limits of the planet (Dong et al., 2017; Bonciu, 2014). Consequently, CE is presented as a mechanism for reducing material consumption and discharge into ecosystems, with the ultimate goal of decoupling economic growth from resource consumption and ecosystem depletion by keeping resources, energy and materials in perpetual cycles of (re)use (see Appendix A) (Murray et al., 2017; Ghisellini et al., 2016; Jurgilevich et al., 2016; Gregson et al., 2015). This feature differentiates CE from 'linear' or 'reusing' economies, which, although are able to reduce economic impacts through redesigning and remanufacturing industrial procedures, is still predicated on an ever-increasing demand for natural resources (Dutch Government, 2016). Thus, CE is not simply a concept, but a practical framework for creating a more sustainable model of production and consumption compared to a linear economy (see Table 2.1) (Bocken et al. 2017; Jurgilevich et al., 2016).

Table 2.1 Linear vs. circular economy

	Linear economy	**Circular economy**
Principles	Take-make-dispose	Reduce-reuse-recycle
Conceptual vision	Material efficiency	Replica of the natural ecosystem
Underlying assumptions	Continuous resource extraction and waste dumping	Perpetual cycle of materials in a continuous closed loop.
Systems boundaries	Short term use	Long term/multiple cycles
References: Murray et al., 2017; Jurgilevich et al., 2016; Ellen MacArthur Foundation, 2013		

2.2.2 Core principles and related applications/concepts

The CE is underpinned by three core principles and two sub-principles: reduce, reuse and recycle (3Rs), and redesign and remanufacture. These principles are the practical and operational framework for reducing virgin extraction and waste dumping. The reduce principle aims to drastically lower the input of primary energy, raw materials and waste by improving consumption and production processes (Ghisellini et al., 2016). The reuse principle indicates a process or operation whereby products, components or various elements are reused or recovered in their existing form, instead of being wasted. This specifically excludes the use of waste materials in a different form (Kirchherr et al., 2017). The advantage is that virgin extraction and subsequent labour and energy costs are eliminated if the item retains its inherent value. The recycle principle refers to the recovery of former waste materials that are repurposed into products, either in an original or modified form (Ghisellini et al., 2016). The order of these principles represents the hierarchy of their importance in reducing material consumption, with recycling commonly recognized as the least sustainable solution (Ghisellini et al., 2016). The two sub-principles – redesign and remanufacture – are evident within these core principles as processes that can extend the use of products and materials (Saavedra et al., 2018).

The overarching structure, goals and principles of CE have been operationalized and imagined through various associated concepts:

1) **Cradle-to-cradle** (C2C) seeks to create a more positive environmental footprint by (re)designing eco-effective solutions, where constituent parts and waste are brought back into the cycle. The core idea is to create 'nature-like' industrial systems by designing products so that materials can flow into two metabolisms: biological and technical (Braungart et al., 2007).
2) Connected to C2C is **reverse supply chain management**, informed by CE principles. Product design, logistical operations and end-of-life management actions are taken to maximize value creation of a product, through high-value recovery and reuse. Such activities operate either in open

loops (materials recovered by a third party) or closed-loop (products returned to the original manufacturer for recovery or reuse) (Genovese et al., 2017).

3) The **performance economy**: goods and materials are rented or leased instead of sold, operating under a 'shared business models' format. The consumer is no longer responsible for an item's disposal, whilst the manufacturer retains ownership and is therefore responsible for creating durable products, creating the highest possible use-value, for the longest time (Lazarevic and Valve, 2017; Stahel, 2016). Successful examples of such use-based or product service system business models have been the leasing of washing machines and has been dubbed the service economy (Saavedra et al., 2018; Gnoni et al., 2017). Thus, an element of CE is its connection to dematerialization (Saavedra et al., 2018).
4) CE necessitates **collaboration** and **knowledge exchange** between actors through sharing, lending, renting, gifting or end-of-pipe exchanges between businesses and a promotion of information and material transparency (Ellen MacArthur Foundation, 2013).
5) Promoting responsible consumer behaviour and purchasing practices through the use of **eco/green labelling** (Ghisellini et al. 2016). These represent practical examples of how various scholars, businesses and groups have attempted to realize CE (see Table 2.2).

Table 2.2 The circular economy overview

The circular economy			
	Description		*References*
Definition	An industrial system that is restorative and regenerative by design.		Ellen MacArthur Foundation, 2013
Goals	Decouple economic growth from resource consumption and ecosystem depletion by keeping resources, energy and materials in a perpetual cycle of use.		Gregson et al., 2015; Ghisellini et al., 2016; Murray et al., 2017
Principles			
Reduce	Lower the input of primary energy, raw materials and waste through improving the consumption and production processes.	Most important	Ghisellini et al., 2016
Reuse	A process where products, components or various elements are used again instead of being wasted.	Moderately important	Ghisellini et al., 2016
Recycle	Recovery of former waste materials that are repurposed into products, either in original or modified form.	Least important	Ghisellini et al., 2016
Redesign	Redesign products to assist disassembly and increase their longevity. Redesign also extends to the industrial process to minimise energy and waste discharge,	Sub-principle	Murray et al., 2017
Remanufacture	Remanufacture materials and products that would otherwise be discarded.	Sub-principle	Saavedra et al., 2018
Associated concepts			
Cradle-to-cradle	Through product (re)design parts and wastes are brought back into the cycle.		Braungart et al., 2007
Reverse supply chain management	Product design, logistical operations and end-of-life management are taken to maximise product value, through recovery and reuse. Operate within open or closed loop framework.		Genovese et al., 2017

Performance economy/ service economy/ product service systems	Manufacturer retains ownership of products and leases them to users/consumers.	Stahel, 2016; Lazarevic and Valve, 2017; Gnoni et al., 2017; Saavedra et al., 2018
Collaboration/ knowledge exchange	Platform sharing among businesses to utilise end-of-life waste/materials.	Ellen MacArthur Foundation, 2013
Green labelling	Promoting responsible consumption and consumer practices	Ghisellini et al., 2016

2.2.3 City level operationalization

The applications of CE and corresponding analysis have predominantly focused on industrial sectors, such as manufacturing, meaning its application and examination within cities has been limited (see Chapter 6, 6.2) (Ness and Xing, 2017). A previous literature review (Ghisellini et al., 2016) demonstrates that whilst the notion of 'eco-towns', which aim to redesign urban environments according to more ecological concepts, have taken off across the globe, research on cities attempting to be 'circular' is missing. In China, CE activities at the city level have followed an industrial symbiosis format, highlighting how the exchange of waste produce from different industrial processes can lead to mutual ecological and social benefits (Dong et al., 2017). At the European level CE principles have been viewed as a method to improve municipal waste management or as a practical means of closing material loops through analysing the urban metabolism of cities (Ribić et al., 2017; Kennedy et al., 2011). Since 2015, the EU has begun applying pressure on member states to move towards a CE, seeking a greater commitment from European countries, regions, stakeholders and cities (European Commission, 2015a).

2.2.4 Limits and challenges

Whilst CE has attracted a lot of attention regarding its potential to reconcile economic activity with ecological limits, eleven prominent critiques have arisen.

1) CE explicitly lacks discussions of its social benefits – how CE activities definitively lead to greater social, gender and racial equality, and intergenerational wellbeing remain unanswered. These are crucial if CE is to be pioneered as a sustainable development initiative, highlighting that it is not tantamount to sustainable development at present (Murray et al., 2017).
2) Perpetually (re)cycling material stocks may not reduce virgin resource demand (Fellner et al. 2017). Analysis of a theoretical economy, based on all waste becoming utilized secondary materials, showed that a significant demand for primary materials still exists, highlighting the present impossibility of purely functioning on recyclables (Fellner et al., 2017; Bocken et al., 2017).
3) Closing loops to prevent primary extraction is undermined by the 'rebound effect', where efficiency gains cause an increase in production levels to the extent they cancel any previous

benefits (Zink and Geyer, 2017). This critique has been evidenced in increased economic production in China due to energy efficiency increases (Wang et al., 2010).

4) Little is known about how consumers will change into their role as 'users', how this role can be created and if it can function (Lazarevic and Valve, 2017).
5) Turning waste or low-value material into resources is exceptionally difficult and is inhibited by economic and logistical problems (Gregson et al., 2015).
6) Based on an assessment of C2C businesses in the textile industry, Franco (2017) demonstrated the inherent difficulties in overcoming the linear mindset and its competitive advantage.
7) Many circular activities do not produce positive environmental outcomes.
8) Thermodynamic limit: impossible to recover all material components, some are inevitably lost through degradation (Korhonen et al., 2018b);
9) Spatial and temporal boundary limitations: given the globalized nature of the world economy, CE has not adequately considered its spatial parameters (Korhonen et al., 2018b);
10) Path dependency and lock-in to existing production/consumption patterns: CE can also lead to increased virgin resource extraction, failing to reconcile economic activity with ecological limits. Therefore, it can be characterized as an 'alternative growth' discourse, not alternative to growth (Ghisellini et al., 2016: 6);
11) Intra-organizational vs. inter-organization strategies, management and governance: Material flows and consumer influences do not respect administrative or man-made boundaries, which raises the question about the level or scale on which scale CE activities and practices should be governed (Korhonen et al., 2018b).

2.3 Urban environments and sustainability

The notion of sustainability at the city level is not a new phenomenon and has been envisioned and pursued in three prominent ways since the 1980s. Such initiatives have examined the interaction between urban landscapes and their proximate and supportive ecosystems, gauging ways to reduce friction between them (McDonnell and Picket, 1990). The concept of eco-cities (see Chapter 1, 1.3) has focused on redesigning towns and their urban industrial activities following biomimicry principles (Ghisellini et al., 2016). Examples, from Japan to the US, have pursued industrial symbiosis designs or zero waste plans, which have met success in reducing net water and energy consumption (Ghisellini et al. 2016). Alternatively, 'smart cities' are concerned with data gathering to evaluate and optimally use resources through specific innovative technologies as a means to contribute to urban sustainability (Prendeville et al., 2018). Last, 'compact cities', are fundamentally high-density, urban environments, with optimally used space and high levels of connectivity through urban transport systems (Jabareen, 2006; Dantzig et al., 1974). Through compactness the transportation time of energy, water, materials, products and people is minimized (Elkin et al., 1991). Core intentions of compact cities include: a) increased life quality; b) increased social cohesion, diversity and cultural development; c) reduced energy and materials consumption; leading to d) a reduction of emissions and resources; and e) sustainable land-use that protects rural landscapes beyond the city (Jabareen, 2006; Hillman, 1996; Newman and Kenworthy, 1989). Thus, realizing this sustainable form has led cities to focus on specific targets, including: 1) an emphasis on green energy (van der Ryn and Calthorpe, 1986); 2) reduced per-capita consumption and ecological footprint (Rees and Wackernagel, 1996); 3) sustainable land-use (Jabereen, 2006); and 4) compactness of urban density and reduced distance between citizens and the resources that sustain them (Jabareen, 2006; Dumreicher et al., 2000; Elkin et al., 1991; Dantzig and Saaty, 1974;). CE intentions and practices correspond to four of the prominent intentions of sustainable cities (Figure 2.1). Whilst CE has placed limited emphasis on the social issues associated with sustainability, it clearly has overlapping ambitions (Murray et al., 2017). Despite this, little has been written on how specific CE strategies contribute to sustainable urban environments.

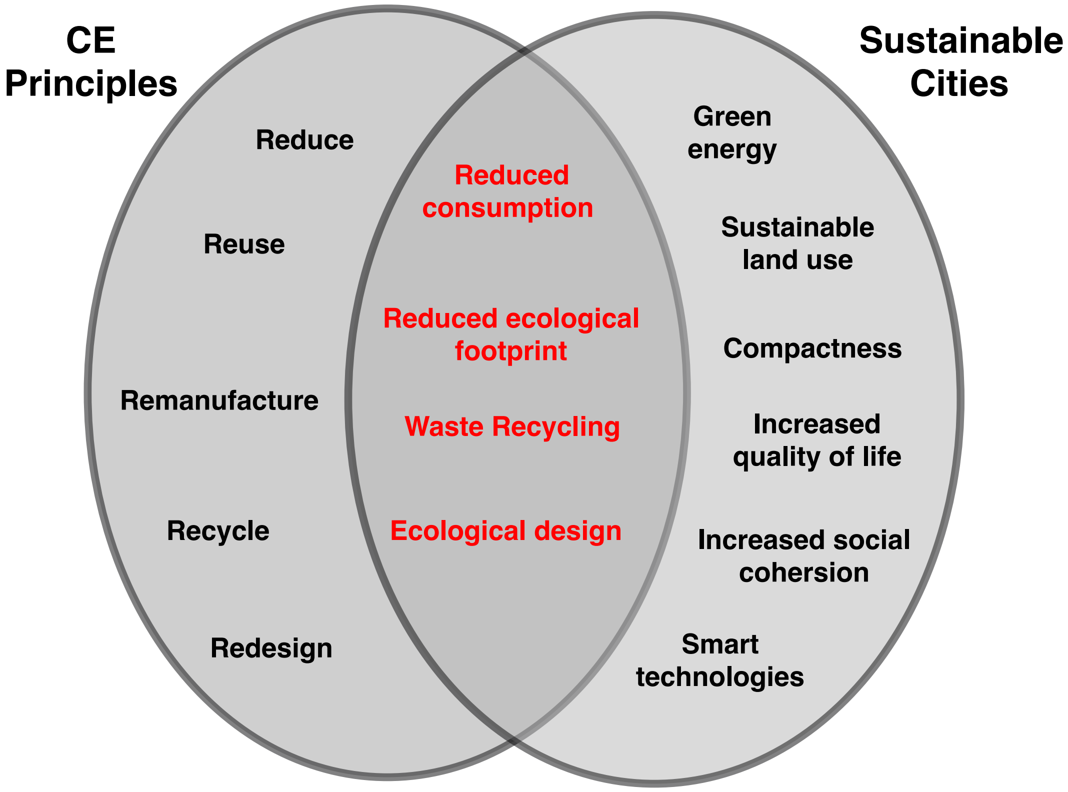


Figure 2.1 Potential CE contributions to sustainable cities

Within the United Nations, four distinct pillars have been identified as the foundations of sustainable cities, which include social development, economic management, environmental management and urban governance (UN DPAD, 2013). Therefore, how CE initiatives are contributing to these specific goals remains unexplored, beyond the conceptual dimensions to actual instances of circular implementation.

2.4 Transition

2.4.1 Transitions theory: phases and drivers

To examine the systemic changes of various phenomenon, the concept of transition theory has developed as a theoretical and analytical tool for understanding these processes (Rotmans et al., 2001). Transitions can be multi-dimensional or occur across multiple locations, and represent the process of change over time in areas such as the economy, institutions, technology, culture and beliefs (Turok and Seeliger, 2013; Geels, 2011; Rotmans et al., 2001). A transition is nominally conceptualized as four distinct phases (Figure 2.2): 1) *pre-development phase,* the existing systemic form or status quo; 2) *take-off phase,* where the process of change is initiated; 3) *breakthrough or acceleration phase,* where systemic change manifests through socio-cultural, economic, ecological and institutional bodies; and 4) *stabilization phase,* when the speed of societal change is reduced and stabilization and a new status quo are achieved (Rotmans et al., 2001).

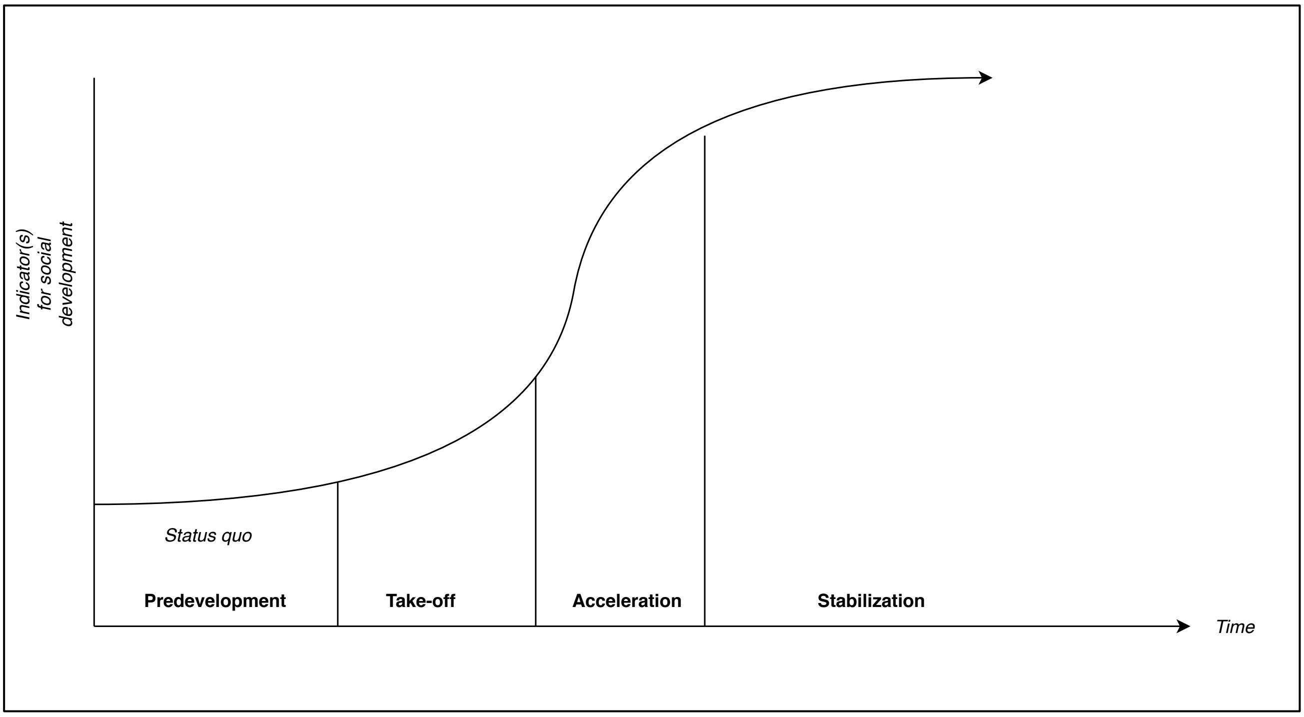


Figure 2.2 Transition phases
Source: own creation (based on Rotmans et.al, 2001)

The process of a transition is driven by three types of forces: 1) *formation forces,* which relate to the prospect of socio/technical/institutional innovation; 2) *supportive forces,* which either strengthen or weaken transitional trends; and 3) *triggers,* which disturb or shock the existing system into a process of change (Frantzeskaki and de Haan, 2009: 597). These forces manifest by 'top-down' change, through instruments such as legislation, infrastructure development, knowledge sharing, capacity building, suasive measures and financial support (de Haan and Rotmans, 2011). Correspondingly, 'bottom-up' change occurs when new emergent constellations, i.e. non-governmental organizations (NGOs), social movements or business initiatives etc., are scaled up through external influences to wider social systems (de Haan and Rotmans, 2011). However, few transitions are this binary, and often comprise a synthesis of both these mechanisms for change. Thus, CE 'drivers' should be understood as factors that enable and encourage transition during implementation (de Jesus and Mendonça, 2018: 77).

2.4.2 Transition management

Whilst transitions can occur in either a spontaneous or planned manner, understanding how they can be successfully managed is highly relevant to policy-makers. The non-linearity, multi-dimensional nature and complexity of transitions indicate that every aspect cannot be fundamentally controlled or governed (Geels, 2011). However, a transition's specific direction and trajectory can be influenced and managed through various mechanisms (Kemp and Loorbach, 2003). Transitional management – as a strategic approach – combines long-term thinking with short-term policies, linking together multiple stakeholders and multi-level aspects of transitions (Rotmans et al., 2001). Initial actions and discussions are flexible following an experimental philosophy of learning-by-doing and doing-by-learning, which prevent early undesirable lock-ins and enables the establishment of systemic innovation and improvement (Rotmans et al., 2001). Governance models that facilitate a transition often have four elements: 1) strategic activities, which are amenable to and set out long-term visions; 2) tactical activities, which link specific strategies to long-term visions; 3) operational activities, which focus on linking various everyday activities to long-term visions; and 4) reflexive activities including monitoring, assessment and evaluation of policies and practices that enable a strategic revision and adjustment. Thus, transitions are constantly assessed and adjusted in the process, allowing greater flexibility for change (Kemp and Loorbach, 2003).

2.4.3 Transitional barriers to circularity

The transition towards circularity from linearity and the present status quo is argued to require a paradigmatic shift in systems thinking (Urbinati et al., 2017). The literature suggests that there are four barriers to transition (de Jesus and Mendonça, 2018: 78; Kirchherr et al., 2017), two of which are described as *hard* (technological and market/financial) and two as *soft* (institutional/regulatory and cultural). Examples of hard barriers include a) technological: difficulty of circular design; lack of proven technologies for implementing CE; challenge of up-cycling and delivering high-quality remanufactured products (also see 2.2.4), and b) market/financial: low virgin material prices and high upfront investment costs mean circular companies products are typically more expensive. Examples of soft barriers include a) institutional/regulatory: obstructing laws and regulations; and lack of global consensus from policymakers, and b) cultural: consumer interests and habits are interrelated with a linear mindset; business culture is difficult to shift, especially to thinking long-term about resource use and impact; the niche and novel nature of CE makes it currently a minor focus for companies. Thus, the technical/financial or regulatory/cultural bottlenecks that obstruct accelerated transition towards CE represent the barriers (de Jesus and Mendonça, 2018: 77; Kirchherr et al. 2017). These are broad categories, necessitating greater elaboration regarding contextual and space specific CE activities. Previous research on CE barriers at the regional level indicated that cultural and regulatory barriers were those inhibiting the transition, whilst technological issues were of low importance (Kirchherr et al., 2017). If the transition to urban sustainability through CE is to be accelerated, analysing existing processes is imperative in order to identify the barriers inherent at certain scales and within specific strategies.

2.5 Conceptual framework

Based on the above literature review, the following conceptual framework has been adopted (see Figure 2.3) to answer the proposed research question (see Chapter 1, 1.4). This framework is used as a heuristic lens to examine how CE is being applied at the city level, and the barriers and limits of this strategy as experienced by respective stakeholders. The idealized vision of urban sustainability includes all CE principles (see Figure 2.3). However, the transition to this vision will not happen immediately. Thus, where each of these principles materializes in the transition is unknown and warrants examination (see Figure 5.5).

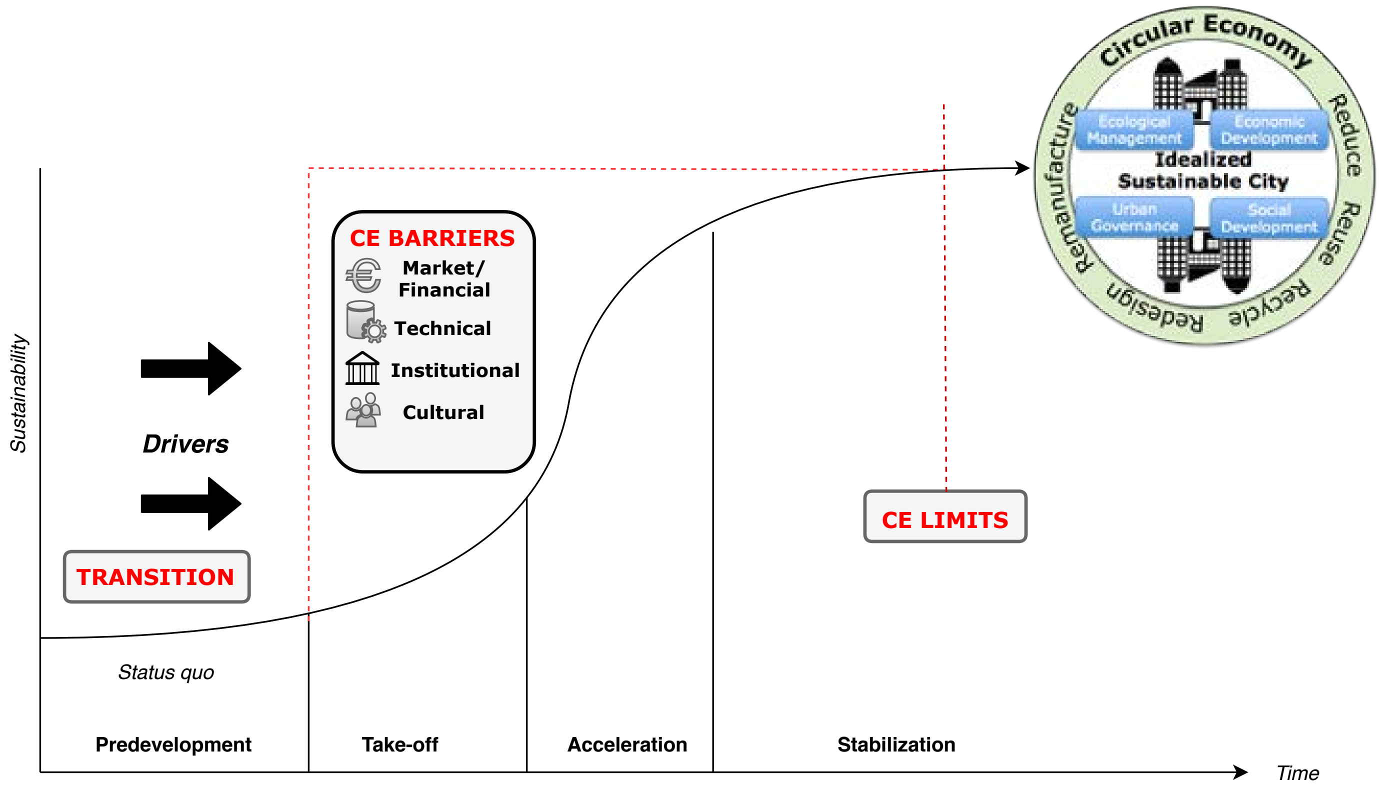


Figure 2.3 Conceptual framework

Source: own creation, co-designed with research team.

CE is understood as a restorative and regenerative economy that creates closed cycles of material loops, underpinned by the three core principles reduce, reuse and recycle. The application of CE corresponds to the strategic focus at the city level, with the elements being: 1) CE principles (3Rs) deployed in the strategy; 2) sectoral/material focus; and 3) drivers, including stakeholders, instruments (legislation, infrastructure development, knowledge sharing, capacity building, suasive measures and financial support) being deployed.

In this respect, the study automatically uses a 'top-down' institutionalized lens for its starting point. However, given the enormity and breadth of CE activities and initiatives, this is important for both the feasibility and focus of the study. 'Bottom-up' activities and views are still considered but in the context of the institutionalized approach, for instance, the corresponding materials, sectors and stakeholders affected (see Chapter 4). An idealized sustainable urban city comprises of four elements as outlined by the United Nations: 1) social development; 2) economic management; 3) environmental management; and 4) urban governance (UN DPAD, 2013). These have been applied through various practical measures including compactness, smart cities and eco-cities and associated elements (see Figure 2.1). The 'barriers' are specific issues that obstruct the implementation and acceleration of this strategy at this scale, and are classified in four categories: 1) technological; 2) market; 3) regulatory/institutional; and 4) cultural (see 2.4.3). These are issues that have arisen that prevent the strategic implementation and adoption of CE and are therefore indicative of the strategy at the city and sectoral level (de Jesus and Mendonça, 2018: 77; Kirchherr et al. 2017). Given that the goal of CE is to create a completely closed loop of material cycles that reduce input and reuses waste (see 2.2.1), limits are therefore the strategic, spatial and material issues that practically inhibit the complete closure of material loops at this scale (see 2.2.4).

2.6 Research intention

The proposed conceptual framework outlines the theoretical parameters of this research, with the purpose of answering the research question as outlined in Chapter 1 (1.4). The examination and composite use of CE, urban sustainability and transition theory illustrate their theoretical elements (see 2.5), which are used as the methodological units of analysis (see Chapter 3, 3.5). This review allows the examination of the circular application at the scale of the city (see Chapter 4) and the barriers and limits of this transition (see Chapter 5). Thus, this research addresses the gaps in knowledge that were further identified in Chapter 1 (see 1.3), whilst providing generalizable findings, useful for cities seeking to implement and transition to CE (see Chapter 6, 6.1).

3 Methodology

3.1 Introduction

The following chapter presents the methodological approach and systematic process taken in this research (Figure 3.1). This process was designed with the other researchers but was individually written. This chapter outlines how the literature review was done (see 3.2), the case study research approach taken (see 3.3.), the case study site selection and justification (see 3.4), data gathering and analysis (see 3.5) and research scope and limits (see 3.6).

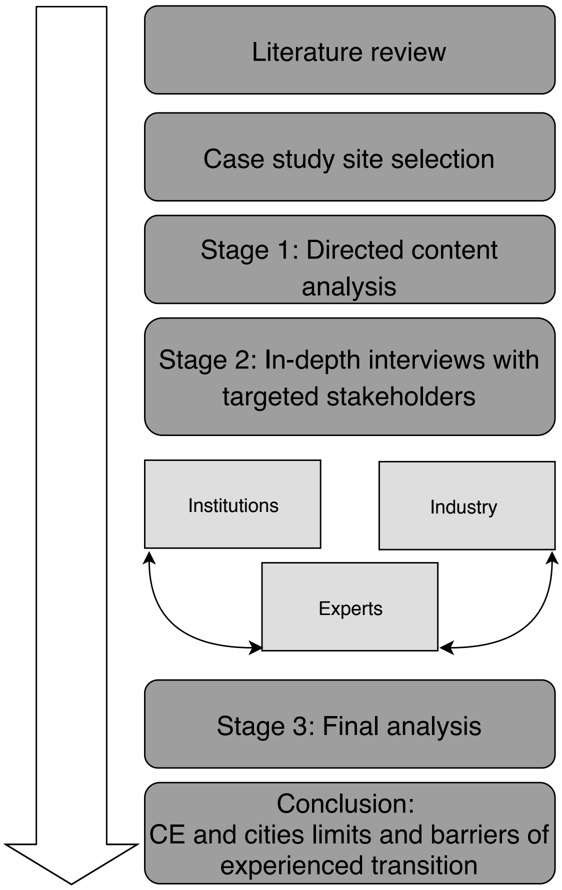


Figure 3.1 Summary of the research process

3.2 Literature review

Each researcher critically examined the existing knowledge base of three concepts: CE, transition theory and sustainable cities. I examined the knowledge base on CE, which included over 40 articles dating from 2007. Researchers drew on each other's work for greater conceptual scope and understanding (see Chapter 2). The location and examination of the literature was conducted as follows. Each researcher searched the Web of Science database to identify the most frequently cited articles (Appendix B for example). Having reviewed these articles, targeted searches were undertaken for further material. A synthesis of the literature on these three topics established the knowledge gaps (see Chapter 1, 1.3), whilst providing a broad knowledge base to construct the conceptual framework (see Chapter 2, 2.5).

3.3 Case study approach

To explore the proposed research questions, informed by the conceptual framework, I pursued an inductive-driven research design, suitable for studying a novel phenomenon and drawing generalizable inferences (Boeije, 2010). Using a case-study approach supports this qualitative research design as it entails a detailed and intensive analysis of a single case, comprising in-depth descriptions of a bounded system associated with a specific location (Bryman, 2012; Gerring, 2011). Since my focus is the implementation of CE at the city level, a qualitative approach is suitable to document the impressions and perceptions of this phenomenon in its real-life context (Bryman, 2012; Boeije, 2010; Yin, 2009). Utilising one case study will lead inevitably to criticisms of its lack of generalizable and robust conclusions in comparison to a multiple case-study approach (Eisenhardt and Graebner, 2007). However, a well-established and executed case study – with intensive data examination and saturation – can show a particular process exists, whilst also providing detailed insights beyond its own particular parameters (Bryman, 2012; Small, 2009). Because CE is still a novel phenomenon in the early stages of implementation, instances of CE initiatives, actors and organizations, specifically institutionalised CE strategies and assessments of it, are relatively unknown (Lieder and Rashid, 2016; Ghisellini et al., 2016: 12). Accordingly, an exploratory piece of research is suitable for the specific research questions and overarching design.

3.4 Case study site selection

To understand more about the present application of CE at a city level and the existing challenges associated with this transition, each researcher selected a specific city as a case study. The selection criteria were: 1) cases should be located in developed regions and be affluent based on assertions that cities with such characteristics are hotspots of material consumption and waste generation (Grimm et al., 2008; Rees and Wackernagel, 1996); 2) The city must have a specific CE strategy; and 3) a circular strategy should also exist at the national level. This third reason allowed the inter-scalar aspect of CE activities to be examined, but also to accurately contextualise the city strategy.

This research uses the municipality of Amsterdam, the capital of the Netherlands, as the area for study (see Figure 3.2). It corresponds to the selection criteria as follows: 1) as an OECD country, which annually produces 44% of global municipal waste, the Netherlands ranks seventh on the Human Development Index, which measures health, education and income of all nations (HDR, 2015; World Bank, 2012). With a population of over 800,000, Amsterdam is located in the Randstad, the predominant location for the country's industry and service sector, and has an annual household income of over €33,000 (WPR, 2018; CBS, 2014); 2) Since 2015 the municipality has initiated its vision for a CE within the city, 'Circular Amsterdam: A vision and action agenda for the city and metropolitan area' (Circle Economy et al., 2015); 3)

The Dutch Government has similarly proposed a national circular strategy, aiming to be circular by 2050 (Dutch Government, 2016). Additional caveats and reasons for this selection are given in scope and limits (see 3.6). Focusing on one city and its institutionalised strategy keeps the research focused, reducing extraneous findings, and more clearly outlining the limits and extent to which the findings can be generalised (Boeije, 2010).

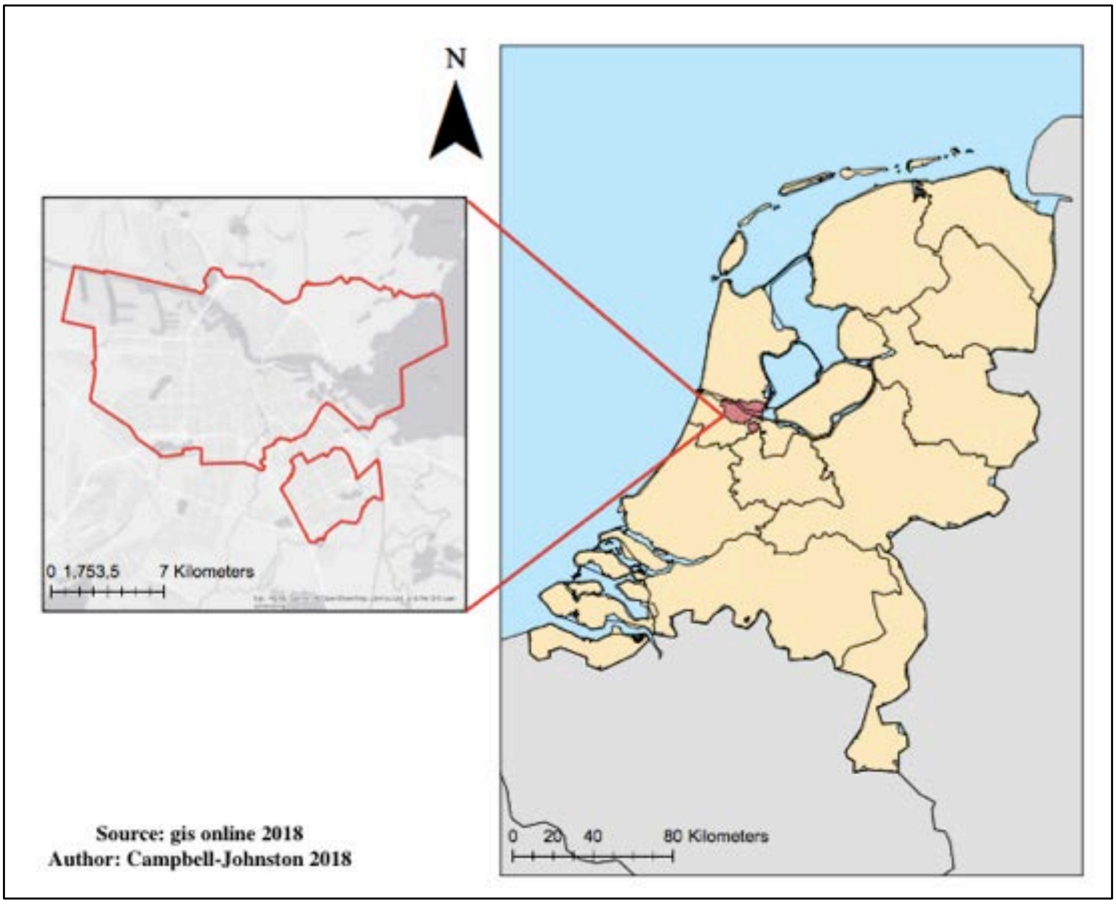


Figure 3.2 Case study site, the municipality of Amsterdam, the Netherlands

3.5 Data gathering and analysis

The process of data collection and analysis was undertaken in three stages: 1) directed content analysis of national circular strategy and Amsterdam circular strategy, supplemented and contextualized with additional literature (see 3.5.1); 2) targeted in-depth qualitative interviews with key stakeholders (see Appendix C) based on insights from the content analysis (see 3.5.2); and 3) an analysis of the interview data, supplemented with additional academic and grey literature (see 3.5.3).

3.5.1 Stage 1: Directed content analysis

Stage 1 of the research gathering and analysis was a directed content analysis of the national circular strategy, ‘A circle economy in the Netherlands by 2050’ (Dutch Government, 2016) and the city-specific strategy, ‘Circular Amsterdam: A vision and action agenda for the city and metropolitan area’ (Circle

Economy et al., 2015). This was supplemented with additional literature. A directed content analysis is based on pre-existing theory and knowledge that aims to identify the key concepts and themes from a chosen document (Hsieh and Shannon, 2005). The purpose of this analysis was to map: 1) how CE is being applied and implemented at the city level in relation to the national level; 2) the specific CE approach of the city; 3) institutional mechanisms (drivers) utilised; 4) material and sectoral focus; 5) associated stakeholders; and 6) theoretical contributions to the sustainable form of the city. This would answer the first part of the research question, whilst also giving focus and direction for the remainder of the research. The documents were reviewed and then coded in terms of the following units of analysis: 1) material/sectoral focus and targets; 2) CE Principles (3Rs); 3) drivers/instruments (top-down) – infrastructure development, knowledge sharing, capacity building, formal instruments, etc. (see Chapter 2, 2.5); and 4) associated actors (stakeholders).

3.5.2 Stage 2: Qualitative interview

Stage 2 of the data gathering process comprised qualitative in-depth semi-structured interviews with targeted stakeholders. Qualitative interviews allow for in-depth experiences and descriptions of the investigated phenomenon to be explored. The methodological merit of semi-structured interviews is that they allow for the topics to be examined in a purposeful yet flexible way (Bryman, 2012). Based on the outcome of Stage 1 (see Chapter 4), I selected the construction sector to contextualize and illustrate the strategic barriers and limitations of this transition (see Chapter 5). Based on this purposive sampling selection (Bryman, 2012: 545), I identified three groups of informant for discussion: institutional, experts and sectoral. Institutional informants are individuals formally employed within the municipality in either an administrative, research or advisory capacity, which is responsible for the implementation of the strategy. Expert informants refer to individuals or organizations (consultancy, NGO, academic) working in the field of CE, the construction sector or both. These informants had an understanding of the city strategy or the topic under examination. Sectoral informants are individuals employed in different aspects of the industry: consultancy, design, building construction, logistics, refurbishment or demolition.

Informants were identified by consulting the Amsterdam circular strategy, followed by targeted web searches, who were then contacted by email, LinkedIn or phone call. All individuals and companies selected had an understanding of CE within cities and/or the construction sector. To reach thematic saturation whilst avoiding impression management and personal biases from interviewees (Eisenhardt and Graebner, 2007), I attempted to interview multiple individuals associated with different aspects of the construction sector.

The units of analysis (see Table 3.1) for the semi-structured interviews are classified into two sets: 1) institutional, where topics included the specific limitations of the existing CE strategy, and the barriers to implementing CE at the city level in the chosen sector; and 2) sectoral: which focused on the specific limitations of the existing CE strategy, and the barriers to circular construction and becoming circular at the city level. These differing perspectives were supplemented with and corroborated by expert interviews using the above units of analysis. The units of analysis that structured these interviews were based on the conceptual framework as outlined in Chapter 2 (2.5).

Table 3.1 Research stages and units of analysis

<table>
<tr><td colspan="2">Stage 1: Directed content analysis</td></tr>
<tr><td>Document</td><td>Units of analysis for coding (primary)</td></tr>
<tr><td>Primary
• Circular Amsterdam: A vision and action agenda for the city and metropolitan area. (Circle Economy et al., 2015).
• A circle economy in the Netherlands by 2050. (Dutch Government, 2016)
Supplementary literature
• Towards the Amsterdam circle economy (City of Amsterdam, 2013).
• Transitioning Amsterdam to a Circular City Vision and Ambition. Amsterdam. (Metabolic et al., 2015).
• Amsterdam Sustainability Agenda (City of Amsterdam, 2015).
• A Future Proof Built Environment. (ABN AMBRO et al., 2017).
• National Transitional strategy (Dutch Government, 2018)
• Circular Amsterdam: Evaluatie en handelingsperspectieven. (Circle Economy et al., 2018).</td><td>1) Material/sectoral focus and targets/goals.
2) CE principles
3) Transition drivers/instruments utilised
4) Associated actors (stakeholders)</td></tr>
<tr><td colspan="2">Stage 2: In-depth interviews with targeted stakeholders</td></tr>
<tr><td>Informant (type)</td><td>Units of analysis</td></tr>
<tr><td>Institutional – Municipality representatives</td><td>Limits of and barriers to implementing (city and sector specific)</td></tr>
<tr><td>Industry – Construction industry representatives</td><td>Limits of and barriers to becoming circular (city and sector specific)</td></tr>
<tr><td>Expert – Experts in the construction industry and CE in general.</td><td>Corroboration and reflection on above units.</td></tr>
<tr><td colspan="2">Note: All units of analysis are based on the literature review (see Chapter 2)</td></tr>
</table>

A total of 25 semi-structured interviews were conducted between February and April 2018. Interviews followed a thematic guideline for accuracy and continuity purposes (see Appendix D) and typically lasted between 30 minutes to an hour (Bryman, 2012). Interviews were conducted in person at an agreed location (usually the informant's place of work), via telephone or Skype. Interviews were recorded, transcribed verbatim following a standard transcription format, and sent to the respondent's for clarification when necessary. Whilst conducting interviews, I kept a research log where I reflected on the research process and tried to start understanding the information. Interviewees were anonymised, with minimal reference to their place of work. In text references to and quotes from interviewees are given by a number (see Appendix C), which corresponds to their group: expert, industry and institutional. Numbers 1 – 5 are respondents who worked for the municipality, with the exception of respondent 3 who is employed by an organization that is independent of the municipality, but is closely associated with it. Numbers 6 – 14 represents industry figures, including company representatives involved in building design, logistics/coordination, construction/building, refurbishment and demolition. Numbers 15 – 25 represents experts, including academics, sustainability and CE consultants. Several of these experts and industry figures had also collaborated in developing the Amsterdam CE strategy, thus providing an alternative perspective to that of institutional figures. This sample provided a diverse and robust group from which to answer the research question.

3.5.3 Stage 3: Final analysis

The interview analysis was undertaken in two stages. First, I segmented all the transcribed documents into the three groups (institutional, expert and industry) for organizational purposes in the qualitative analysis software Atlas.ti (Boeije, 2010: 77). Second, I reviewed each text line-by-line, constantly comparing between interview and case study literature (triangulation), whilst highlighting sections and elements under code names following an inductive open coding process (Bryman, 2012: 543). These codes were reread and several were merged together for clarity purposes whilst others were dropped for their lack of relevance. Next, I reviewed the codes again, using an axial/selective process of grouping codes together to form more concrete categories that were indicative of the case study and sectoral focus i.e. barriers (market, regulatory etc.) (Bernard and Ryan, 2010: 62; Charmaz, 2006: 57–8). The limits were identified through triangulating the interview responses and established barriers with the content analysis. This process of revision and constant comparison between the data was needed to ensure theoretical saturation and concluded when no new codes could be derived from the text (Bryman, 2012: 542). The thematic categories, quotes and insights from this second stage are used to highlight the particular barriers and limitations of the Amsterdam strategy at the city and sectoral level (see Chapter 5). The write-up of these findings were peer-reviewed by the co-researchers to enhance their validity.

3.6 Research scope and limits

This research examines the implementation of CE by the municipality of Amsterdam using content analysis and in-depth stakeholder interviews. The research only considers institutional actions and one correspondingly affected material stream (construction). It does not focus on other city level activities that are also classified as 'circular', such as C2C (see Table 2.2). A 2017 evaluation of circularity within Amsterdam indicated that the construction sector was the most responsive and active within the city, which meant a greater likelihood of understanding the implementation process and corresponding barriers and limits (Circle Economy et al., 2018). Consequently, this research is limited by the following: 1) generalizability, because only one European city and its institutional activities are the subject of analysis. Consequently, the research is more indicative of the multi-stakeholder and sectoral CE activities that prevalent in Europe, indicating that insights for non-OECD and countries pursuing alternative CE models are limited. 2) Examining the cities strategy and the construction sector will exclude the other circular activities within the city, an example being the service economy (Stahel, 2016). 3) The qualitative focus and interpretive approach means it is not possible to make a metabolic assessment of material flows within the city and how circular strategies affect them. Therefore, discussing whether material flow loops can be closed is based on a synthesis of interview perspectives and interpretive reflection, not a material flow analysis. 4) For the purpose of the study, the construction sector is the primary strategic focus of the study (see Chapter 4). Thus, this study does not consider the energy implications of material use, only its continued usability, and the feasibility of such circular actions within the city.

Language was a personal researcher limitation: I am not a Dutch speaker, therefore, interviews were conducted in English. Whilst this was not a major issue, there were some problems, particularly around nuance. In one instance, I had to ask a research colleague to conduct and interview in Dutch with a construction company because English was not suitable.

4 Circular implementation within Amsterdam

4.1 Introduction

This chapter describes how CE is being implemented at the city level, through presenting the findings of stage 1 of the methodological approach (see Chapter 3, 3.5.1). As CE moves beyond conceptual to practical implementation, understanding how such processes are being directed is essential. This chapter answers the question how is CE being implemented within cities? This informs two of the sub-questions: What is CE in the context of a city and how does it contribute to urban sustainability? How is circular transition directed at the city level? This describes the details of the case study, whilst also providing context for transitional barriers and limitations identified through the interviews (see Chapter 5).

First, a description of the different CE strategies is provided (see 4.2), including the national (see 4.2.1), the city level (see 4.2.2), and the city's sustainable strategy (see 4.2.3). Then, the chapter contextualizes the city's circular implementation within the national strategy, whilst also reflecting on CE's sustainability contributions (see 4.3), before drawing conclusions (see 4.4).

4.2 Circular application

4.2.1 National focus.

Discussions regarding the CE within the Netherlands began in 2011, with national recommendations for implementing being outlined in 2015, and conceptualized as a formal programme in 2016 following a decree by the European Commission (Circle Economy et al., 2018; European Commission, 2015a). This programme was presented to the Dutch Government in January 2017, with policy suggestions outlined in April 2017 for the direction of raw material use and five transition agendas for key value-chains outlined in January 2018 (Circle Economy et al., 2018).

Nationally, CE is presented as a strategic measure to contribute to five global sustainability goals: 1) promote continuing, inclusive and sustainable economic growth; 2) sustainable industrialisation and innovation; 3) make cities and human settlements inclusive, safe, resilient and sustainable; 4) conserve and make sustainable use of oceans, seas and maritime resources; and 5) make production and consumption sustainable. The strategy seeks to move from the present 'linear' economy to the 'idealized' CE, via a 'reusing' economy (see Figure 4.1). The conceptual difference between the 'reusing' and 'circular' economic models is the latter's complete elimination of residual waste streams, which are reincorporated back into the economic cycle in a perpetual fashion. The overarching strategic aim is to ensure the country' long-term resource security through: 1) using raw materials more efficiently and in a high-quality manner; 2) replacing fossil-based materials with 'sustainably produced renewable and generally available materials'; and 3) developing new production methods that utilize materials more effectively (Dutch Government, 2016: 15). The programme has set one target: a 50% reduction in the use of primary raw materials (mineral, fossil and metals) by 2030, with the intention of becoming 'fully circular' by 2050 (Dutch Government, 2016: 5). However, the strategy forewarns that it will not be possible to achieve a closed material loop because of the globalized economy.

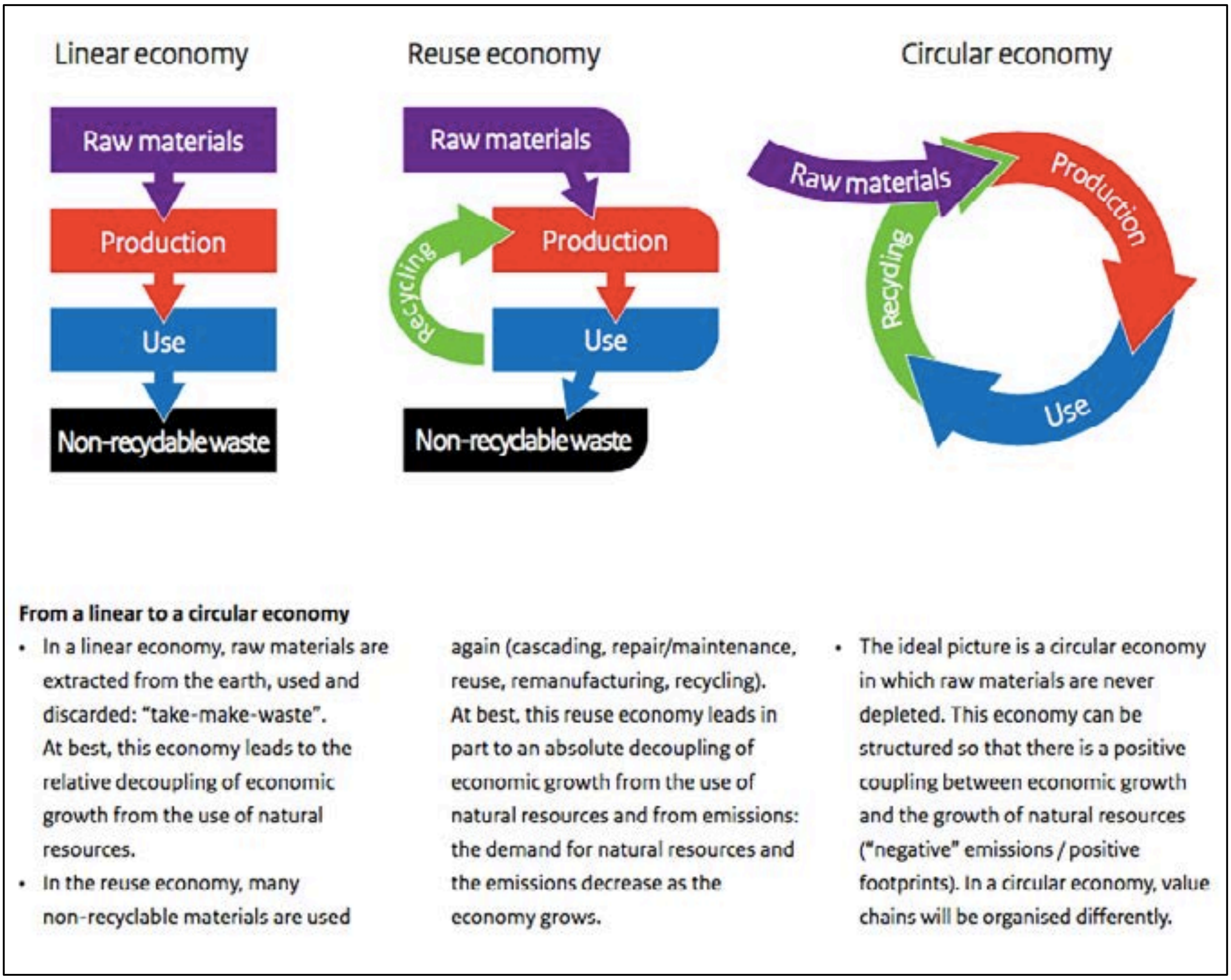


Figure 4.1 From linear to a circular economy
Source: Dutch Government, 2016: 15.

CE in the Netherlands is pursued through three areas: scale, specific material chains and stakeholders. The strategy states that CE measures will be developed locally and nationally, but emphasises 'pioneering cities' as places where projects are initiated (Dutch Government, 2016: 18). However, it does not specify which cities will pioneer and why cities are the most appropriate scale for implementation. Five priority chains are signified as of importance for the Dutch economy: 1) biomass and food, which states that all biomass must be reused in some capacity. This includes the incineration of organic waste as a sustainable practice; 2) plastics, which aims to introduce bio-based plastics and increase recycling, but does not specify recycling targets and timetables; 3) manufacturing industry, which aims to make 50% of manufacturing companies aware of future supply risks, but does not outline the instruments and timetable; 4) construction sector, which aims to optimize material throughput and reduce carbon emissions, but does not give a baseline of material reduction; and 5) consumer goods, which aims to promote reuse and sharing activities amongst citizens, but does not present the driving mechanisms.

To transition from the present to the idealized CE, the government intends to make five targeted interventions including regulation, market initiatives and knowledge sharing measures, to move economic and social activities towards a more circular and sustainable form. Examples of regulation changes include shifting from treating the effects of waste to utilizing waste, and changing the definition of certain wastes so they can be legally used. Market interventions include increased taxation of landfilling and incineration and financing circular projects through institutions such as the Netherlands Investment Agency and BMB Bank, whilst knowledge development includes learning programmes and knowledge exchanges.

The Netherlands strategy for becoming circular by 2050 is a 70-page document, which focuses on: a) its circular vision; b) its core materials streams; and c) intended instruments. However, five issues are prevalent: 1) the strategy has rhetorical goals, but no clear/legally binding targets, timetable and funding; 2) the instruments used are broad descriptions, but few specifics are given; 3) the 2030 target of 50% reduction in primary resource use is ambitious. However, no baseline or reference point is given for this specific target, which begs the question of a reduction of 50% primary material in relation to what and when? 4) A direct link between the proposed instruments and the sectoral and strategic targets is not presented; and 5) does use of waste materials actually substitute for prior material inputs, or does it merely add to previous inputs? The latter point gives credence to the assertion that CE is simply an alternative growth narrative, which does not address the fundamental issue of input and use (Ghisellini et al., 2016: 6).

4.2.2 Circular Amsterdam

Within the municipality of Amsterdam, circularity discussions began in 2013, with a formal policy adopted into the city's sustainability agenda in 2015 (see 4.2.3). This process was pursued through a circular scan of Amsterdam's main material and energy flows in combination with employment levels across the administrative area. This scan was followed by an experimental phase titled 'learning by doing' in 2016, additional publications on the potential for circular land use in 2017 and an evaluation in 2018 (Circle Economy et al., 2018; Rotmans et al., 2001). The strategy claims to make the city the forefront of circularity by reducing the city's material consumption, ecological impact and greenhouse gas emissions, whilst realizing economic growth and stimulating employment (Circle Economy et al., 2015; City of Amsterdam, 2013). The intentions are to create closed loops of various elements, with idealized visions presented for the food, phosphate, waste, water, electricity and heat cycles, seeking to shift from global to local cycles (City of Amsterdam, 2013).

This roadmap to circularity seeks collaboration between local business, companies and citizens to focus on two key material flows, organics and construction. For organics, the primary aim is facilitating organic waste separation from household waste, then utilizing it in experimental processes for bio-based products, or eventually incinerate it for local energy, with a target of 65% separation set for 2020. This action is presented as improving the city's existing waste infrastructure and follows the 2008 European Waste Directive on the stages of material (re)use (Circle Economy et al., 2018). Within the construction sector – which account for 40% of the total municipal waste stream and is the city's most ecologically impactful sector – the strategy focuses on the entire value chain from the smart design of buildings, better dismantling and separation, high-value recycling, and creating local material banks (Circle Economy et al., 2015: 26). These are facilitated through the adoption of technologies – such as 3D printing – and logistical coordination between stakeholders using online platforms (Circle Economy et al., 2015). Through this, the city aims to retain materials for building stock to assist the planned building of 70,000 more homes in the municipal area and 250,000 in the region by 2040 (Circle Economy et al., 2015).

The strategy sets out a spatial vision for an idealized CE within the targeted sectors to facilitate these ambitions. These visions describe the potential for CE activities within the city's boundaries for each element in the value chain. The future spatial design envisions CE within the broader Metropolitan region, as an area for storing and reprocessing materials (Circle Economy et al., 2015).

The strategy indicates the instruments available to the city to drive these processes, including market mechanisms (e.g. tax incentives for adopting circular business practices), and regulatory powers affecting the construction sector (e.g. zoning laws, procurement practices and demolition tendering contracts). Additional proposed drivers include: 1) infrastructure development for waste collection and refinery hubs; 2) capacity building amongst stakeholders, including workshops and training sessions; 3) knowledge exchange and development through platforms for material and product exchange; and 4) suasive measures, including using the municipality as a platform to showcase and encourage circularity.

A total of 73 experimental projects, existing and new operated during the period 2015 to 2018, which were supported by the city's sustainability fund. The primary objective was examining if the city's long-term sustainability pillars (see 4.2.3) could be adapted to, whilst learning about circularity at the city level. Experimental examples include designated legislation free zones, which allow local partners to experiment with waste collection and material recovery in new development areas, or the self-sufficient community called 'De Ceuvel', with homes from reclaimed materials and decentralized energy production (Prendeville et al., 2018; Metabolic et al., 2015). The city's review of these projects indicated that the greatest sectoral activity was within the construction sector (due to the emphasis on zoning legislation), whilst networking, information gathering and knowledge development was the most common activity undertaken across all sectors and stakeholders (Circle Economy et al., 2018). The critical argument highlights that circularity, in these early innovative projects, was both feasible and profitable, and therefore advocates the greater adoption of its practices and principles (Circle Economy et al., 2018; see Chapter 5, 5.2.2 Cultural). The report characterizes Amsterdam at the innovation/take-off stage in the transition to circularity, which indicates a combined use of *supportive* and *formation* forces to foster this process (see Chapter 2, 2.4.1; Circle Economy et al., 2018; Frantzeskaki and de Haan, 2009: 597; Rotmans et al., 2001).

4.2.3 Sustainable Amsterdam

The municipality has set five areas to advance its sustainability agenda from 2015: renewable energy, clean air, a CE, climate resilient city, and sustainable municipal actions (City of Amsterdam, 2015). Each area contains specific sub-focuses and targets including: 1) the growth of locally generated sustainable energy by 92,000 homes by 2020 through bio-incineration, wind energy, reduced energy consumption (per capita); 2) expansion of electric cars, low emissions zoning, and tax levies on polluting vehicles aiming to increase the cleanliness of transport; 3) increased recycling and repairing at local level, encouragement of innovation into circular activities to recover and retain natural capital with an intention to focus on construction and household waste by 2020; 4) climate resilience through mapping flood susceptible areas and developing urban greening tactics to increase water absorption; 5) procurement policies for sustainable focus particularly aimed at public use of IT, lighting, office spaces and vehicles. This extends to office waste separation and concrete sourcing and recycling as measures to reduce Carbon dioxide (CO_2).

Table 4.1 National and city circular strategies compared

Dutch National and city strategies compared		
Units of analysis	**National level**	**City level (Amsterdam)**
Circular economy contribution	Circular economy proposed contribution to sustainable development goals: 1) Promote continuing, inclusive and sustainable economic growth; 2) Sustainable industrialisation and innovation; 3) Make cities and human settlements inclusive, safe, resilient and sustainable; 4) Conserve and make sustainable use of oceans, seas and maritime resources and 5) Make sustainable production and consumption.	Part of cities sustainability policy.
Aims	By 2050 reduce primary use of raw materials (minerals, fossil and metals) by 50%. Decouple economic growth from material use and preservation of natural capital.	To be the 'front-runner' for circularity: reducing greenhouse gas emissions and material consumption.
Stakeholders (description)	Multi-scale, businesses and pioneering cities.	Business, citizen and government.
Sectors and intentions	*Biomass and food* All biomass must be reused in some capacity. *Construction* By 2050 50% of building stock to be retained after demolition for reuse. *Manufacturing* Make 50% of businesses aware of future material supply risks. Develop circular business models and urban mining knowledge. *Plastics* Introduce bio-based plastics, change designs. Increase recycling for reuse through changing designs and discouraging use of non-recyclable plastics. *Consumer sector* Promote behavioural knowledge and responsibility, promote sharing, reuse and repair among residents, more effective waste collection and return systems.	*Organics/biomass* Separation of organics for reuse – 65% by 2020. Bio-based refinery for energy generation. *Construction* Smart design of buildings, dismantling and separation of materials for reuse, high-value reuse of materials and resource bank for future projects.
Drivers/ instruments/ interventions	*Regulatory* Fostering legislation and regulations; e.g. change definition of waste. Establishing assessment framework for recycled/non-recycled materials. Promoting adoption of circular product design at EU level. *Market* Intelligent market incentives to move markets towards CE. Tax schemes that give investment into environmentally friendly assets. Increased tax on waste incineration. Financing; investments in circular products. Support private sector initiatives. Netherlands Investment Agency, BNG Bank and Ministry of Economic Affairs. Supporting circular businesses through lending. *Knowledge* Knowledge and innovation; draw and develop knowledge banks. Top focus bio-based economy programme and circular economy. Collaboration between multiple stakeholders – learning process. International cooperation: for circularity to be reached it must happen at the global level.	*Regulatory* Ease legislation – for bio-based refinery experimentation (organics). Zoning laws, circular permits for demolition and circular procurement (construction). *Market* Taxing grey waste to force separation (organics). Tax rebate for companies using circular principles (construction), lift real-estate taxes and create secondary market through municipal procurement. *Knowledge exchange* Establishing knowledge hubs for product exchange (construction) Facilitating information on waste streams for companies (construction) *Capacity building* Encourage experimentation amongst stakeholders (construction). Workshops/information sessions on circularity. *Suasive* Use Municipality as a platform to promote circularity and circular projects. *Infrastructure development* Renovating waste collectors and rebuilding waste hubs (organics).

4.3 Contextualizing the circular economy

4.3.1 National to city level implementation

The implementation of CE within Amsterdam represents an extension of the national aims, whilst also contributing to the city's specific sustainability pillars. Whilst the national strategy sets a broader overarching focus – citing five strategic sectors compared to two within the city – its policy specifications to drive and manage the circular transition are unclear. Instead, the national strategy emphasises its role as facilitator, whilst cities are responsible for actions. The city strategy is formulated in the national document, but sets its own direction (construction and organics) and targets, using the instruments available to it, including: public procurement, zoning laws, tendering practices etc. (see Table 4.1). The implementation of CE within the city broadly emphasises practices to reuse and recycle two of the city's largest material and waste streams, through redesigning certain processes to create positive material feedback loops within the city and wider metropolitan boundaries. This selection is based on the ecological impact and damage caused by these material flows, and seeks to mitigate their end-of-life impact (Circle Economy et al., 2015). Comparing the city and national documents (see Table 4.1), two key questions are raised: 1) can the city pursue smart design and circular construction projects independent of the national legal standards? (see Chapter 5, 5.3.2 intuitional/regulatory); and 2) how much power and scope does the city have to enact these actions? (see Chapter 5, 5.3.1 funding and scope). Thus, in the context of the city and its strategy, CE must be characterized as a systemic effort of internalizing throughput and making positive feedback loops by preserving material stocks within the city's spatial parameters (Saavedra et al., 2018; Franco, 2017).

4.3.2 Contribution to urban sustainability

For the city, CE is presented as a specific sustainability pillar, but also a strategic process in its own right. This indicates that CE is used in a dual fashion as a *means* of reaching sustainability in the proposed areas, but also a *goal* in itself, with CE and urban sustainability viewed as interchangeable.

Whilst this strategy is indicative of the context of this case study, a more abstract indication of CE's sustainable development contributions to urban environments can be made through a reflexive comparison between the city policy design (see 4.2.2) and elements of urban sustainability (see Figure 2.1). Core contributions for CE refer to the intention to reduce the relative consumption of core materials, which reduces the city's ecological footprint – relative to the previous 'linear' model – through the effective management, retention and use of waste materials. Through technological innovation and systematic change, the intention is to reuse and recycle waste streams to contributing to reducing the ecological impact and increasing economic opportunities, by realizing a CE based on positive feedback loops and preserved material capital within city boundaries. Concentrating on the key CE principles reuse and recycle, and the sub principle redesign, the city aims to reduce the ecological footprint and recycle waste, and stimulate the use of new (smart) technologies.

4.4 Conclusion

In conclusion, this chapter used content analysis to examine the intended CE implementation within cities. The national strategy emphasizes cities as the scale to drive circular actions and is prioritizing five material streams with one overarching target: a 50% material reduction by 2030. This target and circular ambitions in these materials chains intend to be driven through: a) regulatory (e.g. changing waste definitions); b) market (e.g. tax incentives for circular practices); and c) knowledge exchange (e.g. collaborations between sectors/stakeholders) (see Table 4.1). However, the strategies effectiveness is diminished due to its vagueness of the document regarding instruments, the lack of clear targets and legal commitments, and specific funding allocation (see 4.2.1). Comparatively, the city of Amsterdam is prioritising two material streams: organics and constriction. Within the city, of the five material chains outlined at the national level only the construction sector is at the innovation/take-off stage, organics is under exploration, whilst the other three are not yet considered. The transition at the city level intends to drive CE through: regulation (e.g. circular zoning laws), market stimulation (e.g. procurement policies), knowledge exploration (e.g. collaborative knowledge hubs), capacity building (e.g. workshops/training), suasive (e.g. public announcements) and infrastructure development (e.g. renovating waste hubs) connected to these sectors (see Table 4.1). The city aims to be at the forefront of CE but has only set one definitive target, 65% organic waste separation by 2020. Based on the policy design, the circular strategy has the potential to contribute to urban sustainability through: reduced ecological footprint, waste recycling, and smart technologies. Thus, at the city level CE can be characterized as a strategic intention to reuse and recycle material throughput, in order to create positive/closed feedback loops within its spatial and administrative parameters. This chapter has identified how CE shall be implemented within the city. However, the findings from this content analysis do not give insight into the specific challenges that have arisen from this strategic process. A fundamental question from the policy comparison is whether the city scale is the most appropriate to pursue circular actions (see Chapter 6, 6.1). Now Amsterdam has started implementing the aforementioned strategy, it is important to understand the barriers and limits as experienced by respective stakeholders at this scale. (see Chapter 1, 1.4) Through using the construction sector (a city and national focus), the following chapter examines the barriers and limitations that have arisen during this take-off phase in the circular transition.

5 Barriers and limits

5.1 Introduction

Realizing a CE requires a paradigm shift across all socio-cultural, economic and ecological interactions (de Jesus and Mendonça, 2018). However, no attempt has been made to begin systematically documenting the specific transitional barriers and limitations that arise during its implementation at the scale of the city (see Chapter 1, 1.3). Chapter 4 explored how CE is being applied as a transitional programme towards urban sustainability, and demonstrated that this initial process is focusing on two key material chains: organics and construction. Having set the context, this chapter examines the following question: what are the barriers and limits to circularity within the city? The following subsections present the key themes that emerged from the interviews and final stage of data analysis (see Chapter 3, 3.5.2–3), demonstrating the barriers and limitations to this particular CE implementation, focusing on the construction sector to illustrate the inter-scalar/sectoral complexities and perspectives.

This chapter is structured as follows. First, it presents the barriers identified to implementing this circular strategy at the city level within the construction sector (see 5.2). It uses the barriers as outlined in the theoretical framework (see Chapter 2, 2.4.3) to contextualize the interview data within the case study (see Chapter 4) and the conceptual depiction of the circular transition (see Chapter 2, 2.5). Next, it triangulates the barriers, literature and interview insights against the content analysis, to outline the practical and strategic limitations, inherent within this strategy at this scale (see 5.3), before drawing conclusions (see 5.4).

5.2 Barriers

This subsection presents the key themes from the interviews that illustrate the barriers to implementing CE, as experienced in different aspects of the construction sector. Understanding the particular issues that emerge within sectors at certain scales can provide insight and guidance to accelerate the transition to CE, whilst avoiding potential lock-ins from ineffective and problematic actions (Korhonen et al., 2018b; Rotmans et al., 2001). To provide structure this section outlines the barriers (market/financial, cultural, institutional/regulatory and technological) for the different aspects of the construction sector, from smart design (see 5.2.1), construction (see 5.2.2) and demolition (see 5.2.3). Each subsection provides an in-depth description of the CE actions connected to that stage, the justification given by respondents for it, and insights on the most salient barriers as emerged from the final analysis (see Chapter 3, 3.5.3).

5.2.1 Smart design

Design in circular construction is critical for achieving CE goals because buildings can be reconfigured for multiple cycles and purposes, which can accommodate different work and living practices (Lieder and

Rashid, 2016; Circle Economy et al., 2015). Respondents mentioned three actions which contributed to circular construction: 1) modular and flexible designs; 2) material passports; and 3) designing the on-site/reuse of materials. A modular home is built indoors or off-site, often in a factory. As such, they are not permanent structures but have the capacity to be disassembled and moved between locations, and therefore have a lower impact than conventional construction processes (Shattuck, 2017). Flexible homes are designed for multiple purposes over the course of their lifecycle, meaning they can house various users and operations within them. This reduces the necessity for new buildings and large-scale refurbishment (Circle Economy et al., 2015). Respondent 22, a sustainability consultant, described a current flexible project to design an office that could be converted to become housing and a school in 20 years. This foresight reduces the building's long-term impact, because of the lower material costs needed to convert it (22). Material passports dive right down to the material and systems level of buildings by documenting the materials used in a development. This knowledge documentation allows future users to easily update or replace items, or harvest them more effectively for reuse/upcycling during demolition (see 5.3.2) (Zijlstra, 2017; BAMB, 2012). Thus, by knowing what a building contains, material repurposing is more effective and waste is reduced (22). On-site reuse relates to designing buildings using existing materials to act as building stock.

Design is important in circular construction, because, as respondent 23 noted, "you have to start at the start looking at design, businesses model in the middle and how to tackle the end. But if you don't do the first two you're going to keep having to do the last bit. Where actually we don't want […] the end of pipe solutions anymore." The lifecycle of materials in the construction/buildings process has a delayed effect, with input becoming waste years later, due to it being locked-in to existing structures. Thus, rethinking the process of design and inputs reduces waste problems and low-quality materials in the future. Therefore, (smart) design was presented as the most important step in circular construction (6, 21 and 23). In this phase, significant market/financial, cultural and technological barriers were identified in trying to implement these actions.

Market/Financial

> There is nothing new about this, and of course, they are going to try and resist it because of course, it's going to be more expensive and take some of their profit margins (21).

In the design phase, cost is a significant market barrier associated with pursuing these actions. One respondent, an architect, noted, the municipality was pushing circular projects, yet, without the budget and funds developers would "stick to what they know" (6) and would not bother to incorporate these ambitions. The upfront costs in adopting these ideas would be borne by the investors and developers, who were perceived as begrudging participants – unwilling to adapt – because it would hit their profit margins (9, 21 and 22). This reluctance was explained by uncertainties around circular buildings and their functionality (13; see 5.2.1, Technological). Amsterdam's 2018 circular progress report asserted that the construction sector was the most responsive sector within the city (Circle Economy et al., 2018). This reflected a sentiment from respondents 20 and 21 that the economic attractiveness of Amsterdam would necessitate companies adapting their development practices in order to capture the profits from its inflated housing market. Rental prices and the cost of buying a house have reached a peak in Amsterdam not seen since the financial crisis, and it is unclear whether the adoption and cost of applying CE will add to the cost of renting and buying (Financial Times, 2017).

Cultural

In the design process, two prominent cultural barriers emerged that were interconnected and influencing the developers' reluctance to incorporate circular design: client-driven and lack of circular mentality.

Client-driven

> It really depends on the type of project, the type of client, what kind of circularity principles you apply (6).

The financial costs of pursuing circular building practices were borne out by the investors and developers, which meant they decided the extent circular practices were incorporated within building designs. The Amsterdam strategy includes a circular requirement within tendering and procurement practices. However, these requirements are limited to buildings on land in the public domain, and not applied to the vast majority of scheduled new builds. As respondent 6 noted, the types of circular principles, from modular design to material passports, were presently driven by client preferences (6; also 9 and 10). Often, the desire for a sustainable or circular project was outweighed by the desire to create attractive projects and buildings, with respondent 9 arguing that the demand for sustainability versus aesthetics was 30% compared with 70%. Thus, at present, the CE part of development was still niche and without mandated legal standards were not attractive enough for large-scale designers to incorporate them in everyday practices.

Lack of circular mentality

> Lots of developers are like "sure this idea of a material passport is fine" […] the problem is they're not truly thinking in a circular fashion. They're thinking what we can do as an input but not thinking the output end. So, one of the big barriers with this is when you come to take materials out, and building these buildings with design for disassembly principles, and a lot of developers are not interested in doing that. Because their argument is well we're going to develop this building, but we're not going to own it (22).

Designing in a circular fashion requires thinking carefully about the entire material lifecycle, from material inputs, the building's functionality, and the materials and space post-demolition. This process requires detailed planning and foresight in order to break the linear relationship with materials over their entire lifecycle (Franco, 2017). The above quote illustrates the challenge of breaking this model, of thinking about the future uses of materials, which have no relevance for current business operations. Thus, a major barrier to the success of the CE is accounting for the future benefits that today's actions can bring (6). For instance, it is difficult to require businesses – which operate on more immediate financial reward – to undertake the work to ensure future benefits from circular practices when they won't necessarily reap the financial benefits. Despite the assertion that the initial stage of implementation had demonstrated the feasibility and profitability of circular design (Circle Economy et al., 2018), those developers was reluctant to incorporate them into the design phase. This highlights this partial ineffectiveness of the municipality's capacity buildings and suasive tools (see Chapter 4, 4.4).

Institutional/Regulatory

The ambition, at the city and metropolitan region, is to develop respectively 70,000 and 250,000 extra homes by 2040 (see Chapter 4, 4.2.2). The requirement for these developments to adopt circular practices is pursued by the municipality through its zoning and tendering processes for developers and contractors (see Table 4.1). However, these instruments have limited scope. "We are able now to put circular criteria in every tender, we can in fact, but the other thing in is transformation areas, and the large part of new to build [new build] houses are going to be built in transformation areas, where we don't own the land anymore and we have to convince, one-on-one the developers that they really should make a different way" (1). As this quote reveals, the direct scope of the strategy is limited to public land. Consequently, the instrumental reach and influence of the municipality beyond this is only possible through suasive measures, i.e. convincing developers. This institutional barrier illustrates the limited scope and capacity for accelerating the adoption of these CE principles in all construction projects, because the municipality is dependent on convincing often reluctant developers (see 5.2.1, Cultural) to adopt such practices. Thus, the municipality's suasive tools have the broadest scope to influence developers, but cannot compel them to do so.

Technological

Knowledge is also an obstacle, the lack of knowledge of what is a circular building exactly (1).

Whilst the previous sections illustrate examples of CE in the design phase (see 5.2.1), the barriers for those pursuing them can be attributed to the technological uncertainty around CE. This was particularly evident in designing projects to include secondary and repurposed materials. Respondent 6 described a redevelopment project that aimed to reuse/recycle 98% of the existing materials on-site, creating a short loop between demolition and new construction. However, whilst this was the intention at the design phase, whether it could be achieved was unknown. Such sentiment reflects broader assertions from respondents that some of the technology, such as on-site refurbishment of materials, was unproven. "A problem with a lot of these new technologies they're unproven, so they're [industry figures] a little concerned" (22). This factor was not effectively accounted for in the city's strategy (see Chapter 4, 4.2.2). The doubt about the feasibility of these circular intentions from a practical and technological point of view is closely interrelated with the cultural and market barriers, which is inhibiting the greater adoption of these practices. Such issues were not accounted for in the strategic roadmap for Amsterdam, where smart technologies were presented as an effective accelerating force to break the present lock-in.

The barriers for smart circular design are visualized in Figure 5.1

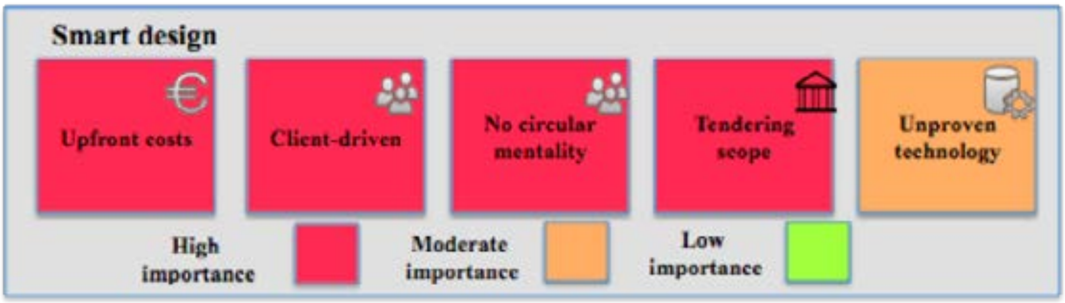


Figure 5.1 Smart design barriers (visual representation, see Appendix E for explanation/classification)

5.2.2 Construction

The previous section outlined the emerging city/sectoral barriers in the design phase of construction. Whilst building design was crucial in addressing future waste/material issues, current construction and refurbishing processes would also remain an on-going challenge. Presently, 90% of Amsterdam's construction and demolition waste stream is recycled, the majority beyond the city parameters in low-value applications such as rubble for road foundations (Circle Economy et al., 2015). With the intention to reduce material use by 50% by 2030 and utilize waste in a high-value manner – only 3% of current demolition waste corresponds to this – changing materials practices is becoming increasingly significant (AMBN AMBRO et al., 2017). Two actions to drive this surfaced during interviews: secondary materials (re)use and bio-based material substitution. On a strategic level, the municipality of Amsterdam uses its procurement power to stimulate the adoption of these practices within projects. As established, the intention of the CE strategy is to localize the flows of certain materials, ideally creating a closed loop from existing waste streams to act as inputs (see Chapter 4, 4.3.1). Therefore, the reuse and recycling of secondary materials and use of non-finite resources represent the key means to create circularity within the construction sector. The following sections examine the barriers to these intentions.

Market/Financial

Three significant market/financial barriers emerged that inhibited the adoption and progression of CE within the construction phase that reduced its effective capacity: material competition, developed secondary market and scaling up projects.

Material competition

It's an open economy (1).

The attempt to close these material loops – using repurposed and sustainably sourced materials to support circularity – is challenged by the linear open market. Secondary materials and circular practices have to compete with similar materials on the open market, which can be sourced at the cheapest rate. The competitiveness of CE activities in relation to the broader economy is an underlying market feature intertwined with the process of construction. The cost of secondary materials in relation to primary materials was a recurring point made by respondents (1, 12, 22 and 22). This is due to the additional costs associated with repurposing and separating materials (see 5.2.3, Market/Financial) in comparison to new products that can be cheaply imported. Presently, the cheap costs of materials in the linear systems means secondary materials are not preferred (Franco, 2017). Thus, closing material loops at the city level mean reused materials must be competitive with ones sourced outside its boundaries. As respondent 12, who worked in refurbishment, argued, although the price differential between primary and secondary material was narrowing, secondary materials remained roughly 20% more expensive than primary ones (12). Therefore, if the price was the only feature valued in the construction projects, then such materials could not yet compete and would not be used. The circular drivers and instrumental scope at the city level (see Chapter 4, Table 4.1) only relate to material flows within its boundaries. However, owing to market dynamics there is not an automatic incentive for companies, who operate on different supply and value chains, to match their linear activities to the circular intentions of the city. Again, this illustrates the limited instrumental scope at the city level. The regulatory capacity to offset this challenge cannot be taken by cities, which suggests they are fundamentally limited to suasive measures to encourage the adoption of these practices by companies operating within their boundaries.

Developed secondary market

> There is not a mature market for secondary materials (1).

To stimulate the growth of a secondary materials market, the municipality is using its procurement policies to stimulate local demand (Circle Economy et al., 2015; see Chapter 4, 4.2.2). As respondent 1 outlined, a mature market for such materials is not fully developed. The difficulty this brings is ensuring the supply and demand of secondary and biomaterials meets the required amount in the city (4 and 6). However, without an established market, which is also competitive, the capacity for local contractors to use such materials is reduced, resulting in a continued reliance on primary or other materials sourced from the open market.

Scaling up projects/material volumes

> The first thing that comes to mind is people always talk about scaling up. So we have a pilot we learn something and we adapt it so it becomes more successful on a bigger scale – never seen it happen. I have never seen it happen (4).

CE is often viewed as a niche phenomenon that is not often a company's main focus (Kirchherr et al., 2017). In attempting to cultivate CE at the city level, 73 pilot projects were examined to establish if CE was profitable and feasible (Circle Economy et al., 2018). However, to accelerate the transition to CE requires pilot processes, such as the use of secondary material inputs, to operate on a large scale. "With all parties, there is some kind of risk-averse and questions that are good, like can you guarantee the volumes and quality of your resources" (9). Hence, guaranteeing the quantities of secondary materials from the city level arose as a continuing problem. As respondent 6 argued the city is growing and the input is bigger than the output, so meeting demand via secondary materials, especially ones from the city, would be difficult. "Start doing a 100 apartments or more […] you find it difficult to find second-hand materials that fit this scale" (6). Therefore, simply ensuring the quantities required to meet demand was an issue in the construction process. Annual house building outweighs house demolition nationally, a feature evident in Amsterdam, which has an increasing demand for new houses (ABN AMBRO et al., 2017). The reuse of all national demolition waste would only provide enough material for 30% of currently planned new builds (Circle Economy et al., 2017). Thus, in the hypothetical situation that all construction and demolition waste can be reused in a high quality manner, it won't meet the demand for materials needed to fulfil the present housing quotas. This challenges a core principle at the heart of CE that material substitution can prevent new material input (Jurgilevich et al., 2016). Because of the current and increasing demand, operating on a closed cycle of materials, without new inputs, is not feasible at the city and national level.

Cultural

Three cultural barriers emerged concerning the adoption of these CE practices within the physical process of construction: lock-in of existing practices, trust between partners and client driven nature of the construction sector. Client driven insights reiterate the same issue discussed in the design section (see 5.2.1, Cultural), and is not repeated here.

Lock-in

A lock-in relates to an inability to change procedures and practices due to cultural, financial and technological structures supporting existing practices and procedures. Often this refers to the difficulty in reversing decisions due to the high costs involved (Gupta, 2014b: 3). The cultural lock-in within Amsterdam refers to the difficulty of implementing and adopting new practices within the construction sector. Respondent 5 described the industry as a machine, which goes in one direction at a rapid pace. Consequently, introducing new practices and techniques was challenging (9). Often, this was described as contractors and builders being unwilling to experiment or deviate from existing practices (5, 9 and 10). This was explained due to present building methods being tried and tested in comparison with new approaches, suggesting an inherent conservatism in the sector (10). To overcome this, respondent 10 argued that CE needed to prove "that secondary raw material based construction products are reliable and sustainable and just as good as new products". However, even with pilot projects, interviewees stated that adopting new practices and materials would take time.

Trust

> You also need to look at the city and the parties available in your city [...] Try to make new chains because you find companies are just working [with] one they already work with before, but don't know about the potential of using local parties. That's again why I put this idea of trust, about building trust (6)

Implementing CE within the city implies the localization of material cycles to create closed loops of materials at this scale (see Chapter 4, 4.2.2). Construction material chains often operate across various administrative boundaries, from local to global. Respondents argued that the spatial component to CE meant businesses and individuals shortening their material supply chains to using resources at the city/regional level (7, 10, 22 and 25). However, changing particular supply and procedural practices that incorporated material elements, such as secondary materials, require a level of trust between partners. In seeking to facilitate this, the municipality utilized an online/knowledge exchange platform, where businesses could exchange products and services at the city scale (Circle Economy et al., 2015). As respondent 11, who worked on the online platform, stated, "The biggest challenge we have is the social challenge" (11) referring to the adoption of CE practices and collaboration between bodies. Alternating supply chains to orientate around a city represent a challenge to circularity at this scale, raising the question of whether city level bodies will automatically reimagine their supply chains to accommodate CE strategies. Thus, trust between stakeholders and actors was presented as a significant issue that CE actors had to contend with, which has not been considered in previous CE visions (Ellen MacArthur Foundation, 2013). Whilst capacity building and knowledge exchange were strategically emphasised as a success with the 2018 Amsterdam report (see Chapter 4, 4.2.2; Circle Economy et al., 2018), their success was not guaranteed.

Institutional/Regulatory

Through acting as a public platform, the municipality was increasing interest in CE (9, 11, 14, 24 and 25). However, those working within and with the municipality discussed the challenge of ensuring CE was not simply another department (24), but a unifying and coherent theme connecting all aspects of the municipality (5, 15, 22 and 23).

> It's really complicated, because if you look at the whole apparatus that the municipality is, people who work and such, in terms of labour pool and how the teams are organized, that organization needs to change, to allow for circular procurement, because you have budget allocation, the various teams have budget, but then circular procurement is about extending responsibility of what has been procured. However, why would the purchasing team have to

spend all of their budget on that when that should come from another budget because we only have so many euros to spend (23).

Despite CE being a strategic goal for the municipality (see Chapter 4, 4.2.3) ensuring responsibility and the leadership for it remained a challenge. For example, respondent 5, who worked for the municipality, stated that the department of public works – responsible for the maintenance of public spaces – would only use materials from their predetermined catalogue, and were not open to using secondary materials from the city. Thus, managing and changing daily habits and practices remained an on-going issue in advancing CE within the city, illustrating the management and collaborative challenges of this transition (Rotmans et al., 2001).

The construction barriers are visualized in Figure 5.2

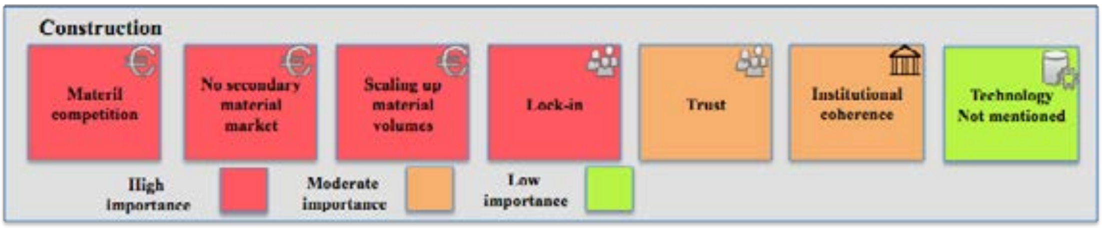


Figure 5.2 Construction barriers (visual representation, see Appendix E for explanation/classification)

5.2.3 Demolition

The previous sections outlined the prominent barriers that emerged during the implementation of CE practices during the design and construction phases. The conceptual vision of CE is the minimization of end-of-pipe solutions, through systematically adopting CE principles, which aims to eliminate all residual waste streams through incorporating them back into the production cycle (see Chapter 2, 2.2.2; Gregson et al., 2015). Eliminating residual waste streams represents a significant aspect of CE conceptualization and implementation, as seen in the EU's adoption of CE in order to achieve its zero waste ambitions (Ghisellini et al., 2016; European Commission, 2014). A core component is using waste materials to replace primary inputs, thus reducing virgin material extraction whilst maintaining economic activity (Ghisellini et al., 2016). Circular demolition is based on maximizing the use of end-of-pipe materials, in their highest value or original form, from demolitions processes through reusing and recycling as much as possible.

Nationally 97% of construction and demolition waste is recycled in the Netherlands, usually in a low-grade form, with only 3% being used in similar processes (European Commission, 2015b; ABN AMBRO et al., 2015). Three actions to cultivate a greater (re)use of construction waste were pursued in the city: 1) urban mining; 2) high-value demolition; and 3) waste separation and retrieving materials. Urban mining is based on harvesting high-value systems or components from demolition (New Horizon, 2018). Material passports (see 5.2.1) can contribute to its success, where a greater knowledge of systems allows for effective and high-value extraction. High-value demolition and waste separation are processes to ensure the highest volume and quality of material salvation during deconstruction. This subsection examines the end-of-pipe barriers to implementing these actions.

Market/Financial

The market/financial barriers for end-of-pipe solutions are closely intersected with the process of construction (see 5.2.2). Specifically, this refers to the challenge of ensuring a certain supply of secondary/reused materials for construction projects. Because the demand for supplies is known to outstrip the availability of materials recovered from demolition, the demand for secondary materials is reduced because of the lack of reliable and consistent supply (see 5.2.2, Market/Financial). An additional challenge inhibiting material reuse is the added labour costs in separating useable construction waste. The increased time and subsequent labour costs required to physically separate, clean and repurpose construction waste, instead of discarding or incinerating it, reduce its competitiveness in relation to imported primary materials (12). The continuing low cost of primary material has reduced the development and expansion of secondary processing for reuse, and confirms previous research that indicated the same issue at the regional level (Kirchherr et al., 2017). The demand for and ecological impact of raw material supply is often externalized to peripheral countries with lower environmental and labour standards (Newell, 2012: 65). Thus, whilst at the global level, materials remain cheap the incentive to reuse and prevent the externalization of these environmental impacts at the city level is limited.

Cultural

Two prominent cultural barriers emerged regarding demolition for reuse: 1) mind shift in actors and 2) trust between actors. Point 2 (trust) reiterates the issues discussed concerning construction (see 5.2.2, Cultural), and therefore are not repeated.

> One of the issues we found […] companies produce waste, they don't see their waste as a resource so they don't have any quality management, they just see it as waste you have to dump somewhere (9).

The shift to a city level CE necessitates cooperation between local actors and the use of local resources (see 5.2.2, Cultural). However, the availability and desire to use them often hinges on the quality and quantity of materials available (see 5.2.2, Market/Financial and 5.2.3, Technological). As respondent 9's quote illustrates encouraging construction sector actors to consider the continued value of materials post-demolition is an enduring issue. Respondent 22 joked that in the demolition phase such companies just destroy without thinking of the longevity and alternative uses of these materials. Thus, for many respondents adapting to CE necessitated a mind shift in how materials could be most effectively and continually used. This underlines the prevalence of the linear mindset within the existing demolition structures that simply discard materials (Franco, 2017). In part, this is attributed to the cheapness of primary materials, the high costs associated with repurposing secondary materials, and the take-make-discard society that drives it, which removes an incentive to embrace this material mind shift (Lazarevic and Valve, 2017; O'Connor, 1997).

Institutional/Regulatory

> Then the legislation […] it's difficult if something is garbage you cannot use it as a new material, you're not allowed (11).

Institutional barriers were not particularly salient during the interviews. This is perhaps due to the legislative flexibility being deployed as part of the city's CE strategy (see Chapter 4, Table 4.1). However, respondents made reference to the national and regional legal standards on waste. These prevent the reuse of materials once they have been given that legal distinction (Deloitte, 2015). A simple recommendation to remedy this would propose the relaxation of such legal standards. However, as respondent 3 argued, "knowing exactly the quality of what you take out is the most challenging, and still conforming the regulations […] still, stopping it because you cannot guarantee safety in some cases" (3). The reuse of construction and demolition waste is hindered by the strict building standards for materials. There are various durability requirements for different materials (wood, metal, concrete), which are informed by EU standards (Dutch Government, 2012). Thus, reusing and harvesting current, often low-grade materials (see 5.2.3, Technological), is challenging because they must conform to the same standards as primary materials, which are specifically produced to meet the standards and are often cheaper. Whilst one respondent argued that urban mining was profitable (1), it was hindered by the labour costs (see 5.2.3, Market/Financial) and available knowledge of materials (see 5.2.3, Technological), which also made repurposing secondary materials challenging.

Technological

In the demolition stage, three technological barriers arose: knowledge of materials, the quality of materials available and technological limits of material reuse.

Knowledge of materials

> [The] most challenging is to know what is there (3).

This barrier referred to the challenge of having a holistic understanding of the materials streams and material components within the city's administrative boundaries. Urban mining for reuse is most effective when extrapolating from knowledge sources, such as material passports (New Horizon, 2018). Knowledge of the material components of the city remained a barrier for demolition projects, which fed into practical challenges of design (see 5.2.1) and construction (see 5.2.2).

> What is often a really big hurdle for them is that they don't know much about material stream that are going into the city […] and what happens to them as they come out of the city. They do have a lot of data on it, in different offices, they probably have knowledge about it, but all of that knowledge is extremely scattered and no one have a complete overview of […] the metabolism of the city (21).

Despite having conducted a material scan of the material flows and a report on urban mining in 2016, which described the materials stocks within various buildings and infrastructure, several respondents' acknowledged the difficulty of acquiring a holistic understanding the city's complete material elements (3, 21, 22 and 24; van der Voet et al., 2016). Thus, having a complete understanding and knowledge of the material elements within the city was essential in determining how elements could be (re)used. As the above quote infers, the material knowledge of the city is often dispersed between various departments, necessitating close cooperation between them. The lack of this knowledge base lowers the potential for construction projects via secondary streams and more importantly guaranteeing the quantities needed for such projects (see 5.2.2, Market/Financial).

Material quality

As demonstrated above, a significant challenge in the acceleration of CE was lock-in of existing practices and conservatism within the construction sector to changing such practices (see 5.2.2, Cultural). This can in part be explained by the difficulty of meeting regulatory requirements of repurposed materials (see 5.2.3, Technological). Exacerbating this situation was the low-grade quality of materials being harvested from existing structures. Whilst 97% of the Netherlands construction and demolition waste is recycled annually (European Commission, 2015b), the majority is in low-grade applications such as road foundations or backfilling. Turning low-grade materials into high-grade/value items is incredibly difficult (Gregson et al., 2015). Respondents stated that the quality of materials harvested from the city in the coming years would be low grade, which would have to comply with national and regional durability and quality standards that are regularly amended (6 and 11; Dutch Government, 2012). Thus, whether CE can operate on such low-quality materials is questionable, especially if they have to adhere to the requisite material safety standards set at the national and EU level (Dutch Government, 2012). Should zero waste goals be pursued if the construction waste can only go into low-value applications and not substitute new material inputs (see below)?

Technological limits

> The big part of construction waste is concrete, as the technology is right now is not being directly recycled. Typically you can put up to 20% of reused concrete into a new build of concrete, then what's done in the Netherlands is you can put old broken up concrete on the roads as a foundation […] But that's not really recycling that's downsizing […] think about it,

when you send 20% old concrete, you still need 80% virgin concrete, which isn't really solving the problem (21).

Concrete accounts for 25% of total energy use in the Dutch demolition sector and is estimated to be responsible for 35% of the total climate impact of the entire construction sector. Within concrete, cement – the binding agent for concrete mixtures – represents 95% of the total carbon impact (ABN AMBRO et al., 2015). Legally, new concrete can contain up to 30% of recycled material and up to 50% with client approval, yet neither is mandatory. This extends to an estimated 70% to 80% of the concrete currently being used within the Netherlands (14). Despite the technological capacity, only 2% of old concrete is reused in new mixes, the rest being used in backfilling (ABN AMBRO et al., 2015; European Commission, 2015b; 14). Thus, whilst there was the technological capacity for 100% of concrete to be reused, owing to the technological limits (and regulatory), 30% to 50% could be substituted into new mixes. Therefore, whilst CE intends to reduce material input by reusing waste streams, the technological capacity within concrete prevents this. This finding contradicts previous CE research that argues technology is an accelerator and minor barrier to CE (Kirchherr et al., 2017). Furthermore, the findings illustrate the limits of material repurposing and challenge the notion of a perpetual cycle of material use completely preventing new material inputs.

The demolition barriers are visualized in Figure 5.3

Figure 5.3 Demolition barriers (visual representation, see Appendix E for explanation/classification)

5.2.4 Barriers summary

This section examined the construction sector to identify barriers to implementing CE at the city level (see Table 5.1). These barriers and their impact on the construction process, as identified in the interviews, are visualized in Figure 5.4 (see Appendix E). Within this transitional process, cultural barriers emerged as the most prevalent that inhibits the acceleration to and greater adoption of CE, which confirms previous research on the barriers to CE (Kirchherr et al., 2017). An example is a hesitancy to adopt CE practices within the construction sector. These cultural barriers were interconnected with others such as competitiveness and technological capacity, which made this initial step in the transition a cautious one, indicating the challenges of closing material loops in a globalized economy. Previous research has emphasised technological innovation as an effective tool to accelerate the transition to CE (Kirchherr et al., 2017). However, the perception that many of these technologies are unproven, and that through their adoption a completely closed cycle of materials can be created disputes this assertion. Ecological modernization and technological innovation are often presented as the means to negate environmental challenges (Newell, 2012). However, these findings highlight the practical challenges of implementing and adopting technological practices to transition to circularity.

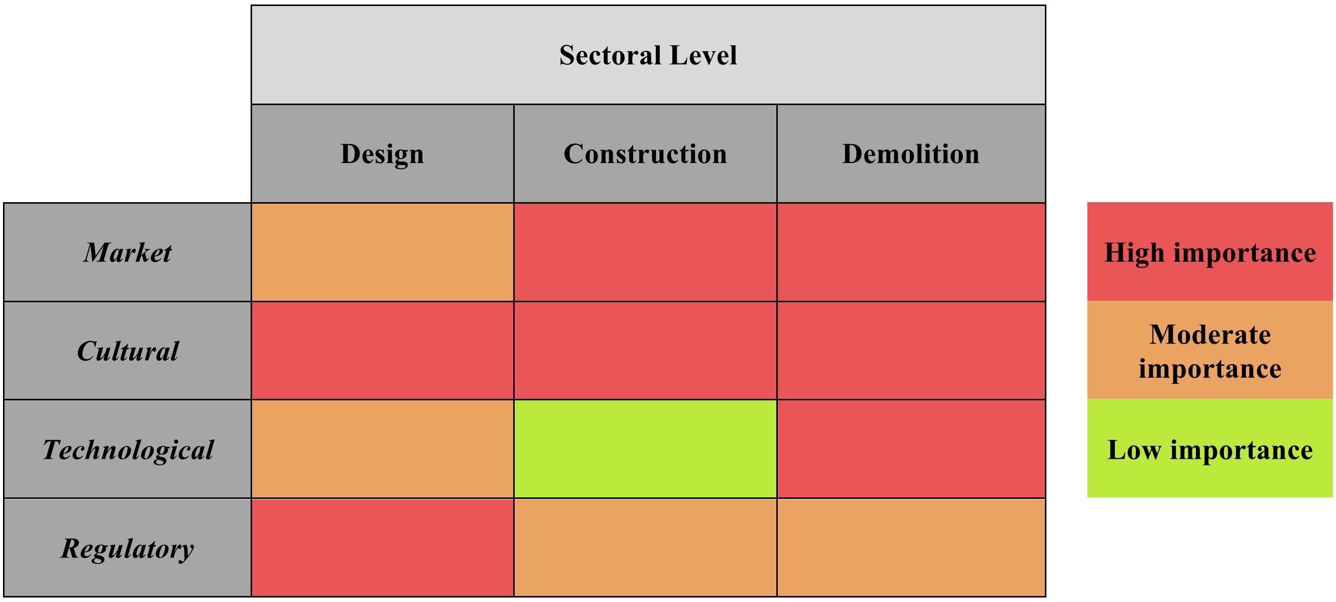


Figure 5.4 Construction barriers (visual representation and synthesis of Figures 5.1,2 and 3: see Appendix E).

Table 5.1 Barriers to implementing circular economy within the construction sector

Construction phase	CE actions	Barriers	Suggestions (*See Chapter 6)*
Smart design	Modular and flexible design Material passports On-site reuse	*Financial/Market* • High upfront costs for companies to adopt practices *Cultural* • Circular practices are driven by client preferences • Developers not thinking in a circular manner *Institutional/Regulatory* • Circular construction only in public areas, municipality has to influence developers. (1) *Technological* • Proof that circular designs work/lack of knowledge of what it is/hesitancy • Don't know how much material can be reused on sight (experimental stage)	1. Devolution of Crisis - en herstelwet legislation to cities.
Construction and refurbishment	Inputs from secondary and bio-based sources	*Financial/Market* • Secondary materials more expensive than primary/open market competition. (2) • No mature market for secondary materials (2) • Difficult to get supply and demand right for secondary materials – ensuring consistency of supply. • Scaling up projects/volume of materials (3) *Cultural* • Circular practices driven by client preferences • Construction industry hesitancy to adopt new practices/lock-in of existing practices. • No proof that secondary materials work. • No trust between partners. *Institutional/Regulatory* • Communication between municipal departments	2. Assist market progression by increased taxation on primary/subsidy of secondary. 3. Mandated requirements for material salvation at city level.
Demolition and reuse	High-value demolition Waste separation/ retrieving materials Urban mining	*Financial/Market* • Low market for secondary materials. (2) • High labour costs in separation (2) *Cultural* • Knowledge of and use for city level materials • Trust between actors • Willingness to consider waste as resources *Institutional/Regulatory* • Legal definition of waste preventing reuse (national/regional legislation) *Technological* • Low-quality of materials/companies not thinking about waste practices. • Concrete repurposing limit, 30% to 50%. (4)	4. Target for 100% concrete reuse from demolition, mandate 30% in new mixes.

5.3 Limits

The previous section established the barriers to the initial stage of circular implementation. This section answers the question: what are the limits to implementing CE at this scale? Using the barriers (see 5.2), interviews and academic literature to reflect on the theoretical aspects of CE (see Chapter 2, 2.2) and the circular strategy as outlined in the content analysis (see Chapter 4), this section considers the strategic and limitations to closing material loops and realizing a CE within cities (Lazarevic and Valve, 2017). First, this section considers the strategic limitations experienced at the city level (see 5.3.1), then it discusses the material limitations (see 5.3.2) before concluding (see 5.3.3).

5.3.1 Strategic limits

Two strategic limits emerged for implementing CE at the city level CE focus, and funding and scope.

Circular economy focus

Reflecting on the Amsterdam strategy (see Chapter 4, 4.2.2) reiterates its focus is primarily on recycling materials (organic and construction), with elements of reuse within the construction sector. This fits various interpretations of CE as a means of creating positive feedback loops, which facilitate an alternative and more efficient growth strategy (Franco, 2017; Ghisellini et al., 2016: 6). Therefore, CE at the city level can refer to a systematic focus on processing materials, so that they can be reincorporated back into the city as valuable material stock. This end-of-pipe focus points to the challenge of realizing a closed loop economy within a spatially bounded and administrative area, especially cities, which are highly dependent on large material volumes to meet their demands (Korhonen et al., 2018b; Grimm et al., 2008; Rees, 1992). The municipality's idealized vision of CE envisions a closed material cycle between the city and its broader metropolitan area (see Chapter 4, 4.2.2). However, at the city level, due to these spatial parameters, the focus relates to the reprocessing of waste/end-of-pipe solutions. Whilst this represents a change from the linear model of the city (see Chapter 1, 1.2) it fails to address material inputs, or focus on material reduction; 'reduce' is the most significant CE principle. Given that there is a thermodynamic and practical limit to material reuse and durability (see Chapter 2, 2.2.4), greater emphasis needs to be placed on redesigning systems and materials for reuse. This implementation suggests that cities can effectively implement strategies aimed at reuse, recycling and input substitution, but are not affecting the total reduction of materials through closing material loops. Thus, at the city level cities can only create a 'reusing' economy, not a decoupled and fully closed one because it is still dependent on new and increased material input. This mirrors other European literature that describes CE being used as a mechanism for municipal waste improvement, whilst also highlighting the differences between the idealistic depiction of CE and its practical realization at a particular scale (Ribić et al., 2017; Gregson et al., 2015).

Funding and scope

The national strategy emphasises the role of the cities and regions in realizing circularity. Several respondents, working in the municipality or closely with it, felt there was little governmental support. Whilst nationally cities are showcased as vehicles for achieving circularity, this was not the experience at the local level, as reflected in the lack of any new money or devolved powers to the city. "The national government doesn't have, or has not allocated new money to the city level […] there is an increasing emphasis on city, and city level and regional level to realise all these goals, on the other hand, there is a slow and too slow change in legislation and funding and the right funding and we have to bring that in balance" (1). This reveals an inter-scalar dimension to the responsibility for or suitability of the strategic implementation of CE. On a practical level, CE's focus and action at the city level are concentrated on end-of-pipe reprocessing (see 5.3.1, Market/Financial), yet the national drive to transition to a full CE is fixated on this smaller spatial unit, but without designating specific funding. This lack of funding likely restricts the scope of CE to end-of-pipe solutions without addressing material reduction.

Moreover, the strategic/instrumental scope reveals the limited capabilities at this scale. As previously established (see 5.2.1, Institutional/Regulatory), a highly significant barrier for the municipality was influencing developers on non-public land. On a practical and strategic level, the increased adoption and acceleration towards circularity within the building sector is inhibited due to the number of formal instruments the municipality has. This institutional barrier is insurmountable unless the city's legislative instruments have greater scope. One municipal worker argued that the city needed new legislation to accelerate the market's adoption of CE. "We can overrule the developer and say ok for the whole city we have more stringent norms" (1). The instrumental/regulatory scope at the city level (see Table 4.1) inhibited the strategic capabilities of the municipality to affect CE across the entire construction process. This means that without more 'stringent norms' (1) or new devolved instruments, the practical drive to realize CE at the city scale, beyond small pilots and procurement practices in public land, is limited to suasive measures. Because there is a fundamental limit to material reuse (see Chapter 2, 2.2.4), design is the most important stage in circular construction (see Chapter 5, 5.2.1), meaning greater emphasis needs to be placed on this stage. However, the cities limited instrumental reach inhibits the effectiveness of promoting the most important circular action. This highlights a significant spatial/sectoral tension in CE implementation. Specifically, cities – owing to their legislative and administrative scope – cannot compel companies operating within their limits to alter their supply chains. Such chains may operate from the local to global level, meaning CE at the city level is bound by the intentions of those operating within them.

5.3.2 Material and sectoral limits

On a material basis, the Netherlands claim that 97% of construction and demolition waste is recycled. However, the majority is used in low-value applications with only 3% of it reused in its original form (European Commission, 2015b; ABN AMBRO et al., 2015). Respondents reiterated the challenge of indefinitely reusing construction materials, which inevitably degrade (see Chapter 2, 2.2.4). Such a point underlines the dichotomy between CE conceptualization and practicality, whilst underscoring the notion that all materials inevitably degrade and cannot be used in a perpetual cycle (Korhonen et al., 2018b; Gregson et al., 2015).

Whilst the Amsterdam strategy aims to considerably increase the (re)use of existing materials, it is presently limited by its technological capacity to reuse concrete. Concrete represents the largest material waste stream (city and national) from construction and demolition processes, with only 2% presently being reused in new mixes (ABN AMBRO et al., 2015). Whilst respondents stated that 100% of concrete could be reused in new mixes through various processing techniques, it could only substitute a maximum of 30% of the volume of new mixes, and 50% with client approval. This material substitution does not reduce the carbon impact of cement, estimated at 95% of the carbon content within concrete (ABN AMBRO et al., 2015). As respondents acknowledged, low-grade construction waste would continue as a material waste stream within urban environments due to the existing infrastructure (see 5.2.3, Technological). Whilst an increase from 2% to 30% in its reuse is definitely a marked improvement, this still necessitates that ≥70% of all future concrete inputs are primary materials with high CO_2 levels due to cement. This does not account for the additional energy costs of repurposing old cement, which is not strategically accounted for. This represents a CE dilemma of whether all materials should be reused, even if this requires a continued commitment to virgin materials to substitute it. Even though waste streams can be brought back into the cycle and create a completely closed loop, as the concrete example illustrates, this is based on the continued requirement for large volumes of new material inputs to meet the city's housing aims. This social commitment constrains the CE intentions for material (re)use, reinforcing the notion that the present economy cannot completely function on recyclables given the present demand (Fellner et al., 2017; Bocken et al., 2017).

5.3.3 Limits summary

This section presented the limitations of this strategy at this scale. Previous research has argued CE has not considered the spatial and administrative parameters of its focus (Korhonen et al., 2018b). An analysis of a spatially bounded application reveals the feasibility and practical limitations of CE processes. The spatial aspect of CE has limited its practical focus, with activities predominantly emphasizing end-of-pipe solutions and reprocessing of material waste volumes. Crucially, at this stage of implementation, the regulatory and instrumental drivers available at the city level inhibit its scope and practical application. Finally, whilst CE has been championed as a model for technological innovation (Kirchherr et al., 2017), at the strategic level analysis indicates the practical limitations to material reuse that exist. These refer to the capacity for material reprocessing and substitution within the production of concrete.

5.4 Conclusion

In conclusion, the findings from the interviews and final analysis illustrate the barriers and limitations that arose in the innovation/take-off phase of the circular transition, as visualized in Figure 5.5. A summary of these findings highlights the most important barriers (see 5.2.4) and the strategic and material limits to this transitional process (see 5.3.3). Critical barriers include: a) market quality for secondary materials, b) knowledge of materials within city boundaries, c) public tendering scope, and d) hesitancy and reluctance to adopting the circular mindset. The city level application is limited in its capacity to create a closed material cycle and CE due to: a) limited focus on end-of-pipe actions (reuse and recycle), b) instrumental scope for new circular developments limited to public land, and c) technological capacity to substitute new input with output limited to 30% to 50% in the case of concrete. These findings highlight the practical difficulties and dynamic challenges at the intersection between sectoral and city processes, illustrating the fundamental challenges in transforming a city's linear flow of materials. Whilst previous research documented the CE barriers at the regional level and the administrative and material challenges in adopting CE (Korhonen et al., 2018b; Kirchherr et al., 2017), this research situates and contextualizes these issues in a specific and detailed case study, which indicate the practical and short-term complications to transitioning to a CE at the city scale.

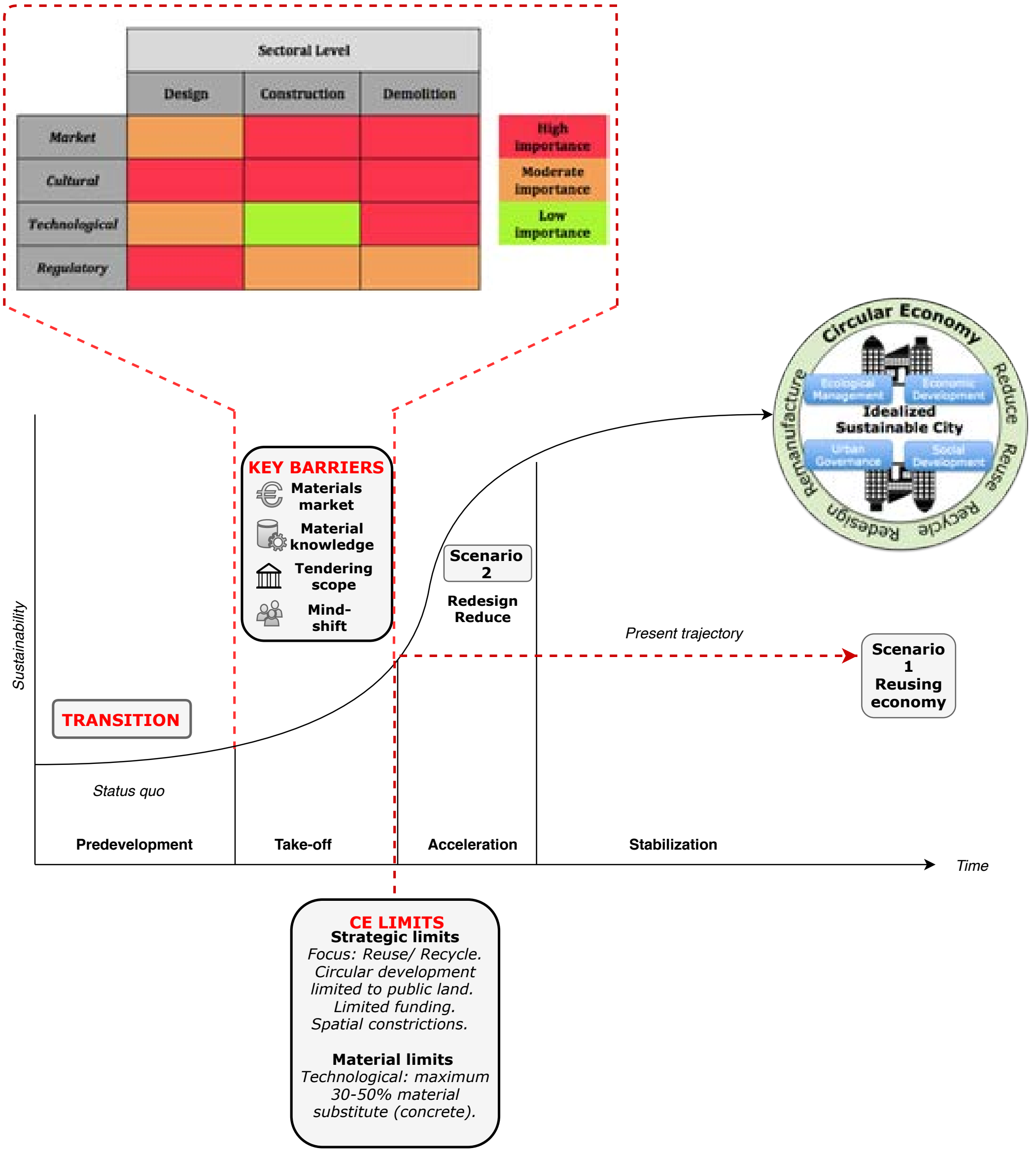


Figure 5.5 Barriers and limits of experienced transition (construction sector)

6 Conclusions

6.1 Conclusions and suggestions

In conclusion, this paper examined CE at the city level, exploring what circular activities are feasible, and the barriers and limits in the transition to a sustainable urban form. The purpose was to examine how urban spaces are directing this process, where material loops can be closed, and the scale that specific activities are feasible using the construction sector and the city of Amsterdam as a case study (see Chapter 1, 1.3). Cities overwhelmingly exhibit linear flows of materials and are hotspots of global consumption and waste, with the construction sector the biggest culprit of such trends (Ness and Xing, 2017; UNEP, 2012; Levermore, 2008; Grimm et al., 2008; Rees, 1992). The conclusions from this case study provide insight into the difficulties of circular transitions and practical implementation.

The content analysis of key documents (see Chapter 4) showed the variance between the national and city circular designs. The national strategy has set one overarching target, a 50% material reduction by 2050, whilst prioritising five material chains, and emphasising cities as the area for action. Whilst it indicates the intended instrumental drivers (e.g. changing waste definitions, see Table 4.1), the strategy is vague, has no baseline for measuring material reduction, includes incineration as a sustainable energy source and sets no legally binding targets or funding. At the city level, Amsterdam is experimenting with two of these material streams, organics and construction, for which only the construction sector is at the innovation/take-off stage of the transition (Rotmans et al., 2001). The construction strategy proposes the reuse and recycling of materials to create positive feedback loops and material stocks, resembling a trend within ecological economics and CE of internalizing and closing previously externalised and open linear material cycles (Franco 2017; Lazarevic and Valve, 2017). However, the overarching strategy has set only one definitive target, 65% collection of organic waste by 2020. The city intends to drive circularity through various measures including: regulation (e.g. circular zoning laws), market stimulation (e.g. procurement policies), knowledge exploration (e.g. collaborative knowledge hubs), capacity building (e.g. workshops/training), suasive (e.g. public announcements) and infrastructure development (e.g. renovating waste hubs) connected to these sectors (see Table 4.1). The design has the potential to contribute to urban sustainability through reduced consumption, reduced ecological footprint, waste recycling, and smart technologies. This analysis indicates how cities are implementing CE and its contribution to urban sustainability, gaps that were identified in Chapter 1 (1.3).

The findings from the interviews (see Chapter 5) revealed the barriers and limits in the initial stage of the transition for the construction sector. Significant barriers include: a) market quality for secondary materials;

b) knowledge of usable materials within city boundaries; c) public tendering scope; and d) hesitancy and reluctance to adopt the circular mindset (see Table 5.1). Whilst previous research concluded that technology is a minor barrier to the adoption of CE (Kirchherr et al., 2017), this paper shows that in practical instances of implementation, technological capacity and knowledge are distinct factors that greatly inhibit the progress of circular actions. However, such technologies and knowledge cannot overcome the high material demands of cities and the challenge of material durability. The city level application is limited in its capacity to create a closed material cycle and circular economy due to: a) limited focus on end-of-pipe measures (reuse and recycle), when the inevitable degradation of materials necessities prioritizing material reduction and systems redesign; b) instrumental scope for new circular development is limited to public land, which means the potential for circular (re)design is low; and c) technological/material capacity to substitute new input with output limited to 30% to 50%, as evidenced through the material reprocessing limits of concrete and cement. Whilst the city can drive circular development through its available instruments and encourage greater cooperation between city level stakeholders, its administrative scale inhibits the scope, possibilities and ultimately the potential for a full CE. Focusing on circular and smart design can reduce waste generation in the future. However, the current circular construction processes are still locked into using low-quality and low-value materials from the current built environment's material stock. This stock can substitute the demand for new materials to some extent. However, given the large demand for housing from the city and region, these processes cannot create a completely closed material loop that prevents an ever-increasing material demand. These characteristics illustrate the sharp distinction between the theoretical conceptualizations of CE and the realities of practical implementation, which cannot stop material inputs through using waste material substitution (Gregson et al., 2015; Fellner et al., 2017).

These findings highlight the dynamic and inter-scalar challenges of breaking the linear flow of materials within cities. The administrative scale inhibits the feasibility and scope of circularity, confirming assertions that scale is an innate complication for circular designs (Korhonen et al., 2018b). This reaffirms previous research that the present economy cannot function of recyclables, due to the high material demand, and the impossibility of perpetually recycling materials owing to their inevitable degradation (Korhonen et al., 2018b; Fellner et al., 2017; Gregson et al., 2015). The city's idealized vision imagines localized cycles of materials within its administrative region (see Chapter 4, 4.2.2). However, this idealized vision is underpinned by the assumption that the city is going to expand due to its financial attractiveness (see Chapter 5, 5.2.1 Market/Financial). Therefore, the circular vision is intertwined with the ever-increasing expansion of the city, where the localization of material cycles (construction) substitute the material input (see Chapter 5, Chapter 5, 5.3.2). This reiterates assertions that the application of CE is merely an alternative and more efficient growth story, not an alternative to growth (Ghisellini et al., 2016: 6). Thus, the conceptual ideal of CE drastically differs from current instances of practical implementation.

Based on these findings, this research presents two circular transitional scenarios (see Figure 5.5). Scenario 1 continues the present trajectory of this CE application. Its focus on end-of-pipe measures and partial material substitution means it cannot fully decouple from increased material inputs. Consequently, from a conceptual standpoint, it can only be defined as a reusing economy owing to its current focus and limitations. However, the city's emphasis on modularity and flexible design are important circular steps, but because these measures are limited to public land this diminishes the city's circular capabilities. Scenario 2 contends that pursuing the CE principles reduce and (systems) redesign will accelerate the transition to circularity. However, because of the city level limitations, this necessitates greater value-chain collaboration and breaking past the present barriers. Achieving this requires action and collaboration at the national level to facilitate management, drivers and funding for this process, suggesting greater governance involvement at the national level (Korhonen et al, 2018b). However, the Dutch national strategy presently emphasises the city level as the space to pursue CE (see Chapter 4). As scenario 1 illustrates this will only result in a reusing economy. Thus, this research demonstrates the need for greater involvement, and collaboration at the national level, to provide *triggers* and more *supportive forces* to assist acceleration of CE at the city level (Frantzeskaki and de Haan, 2009: 597).

For CE to accelerate from its present phase, the present construction barriers need to be overcome. This paper makes the following suggestions. At the national level, this paper suggests: 1) to compel the circular development on all land, experiment with devolving the 'crisis en herstelwet/crisis and recovery law' (Dutch Government, 2010) to the city level. This act can accelerate and demand specific practices in new development, for example, more stringent or circular norms (Dutch Government, 2010), which must be used to shift the market more promptly towards circular development in projects that have already been approved. The devolution of this legislation must only allow circular developments and not general infrastructural projects. 2) Increased taxation on primary materials and subsidies for the use of secondary material to stimulate greater demand and use with primary ones. This will accelerate the market adoption that has already started as a result of the city's procurement policies. 3) National legal requirement for 100% of concrete from demolition to be recycled, and, depending on availability, all new concrete mixes to contain a minimum of 30% reused/recycled material. This policy should seek to raise this minimum to 50% whilst maintaining quality control. 4) Set a budget and funding for CE. At the municipal level, this paper suggests that: 1) municipal targets be set for the reuse and retention of construction/demolition materials. The building regulations require the separation of demolition material, but no specific targets for high-value reuse are required (Dutch Government, 2012); 2) investment and encouragement of high-value reprocessing technology for material reuse; and 3) extend circular procurement policies to stimulate the local secondary market.

6.2 Theoretical and methodological reflections

CE is a potential mechanism to transform the present production/consumption model through efficient resource use and the perpetual (re)cycling of materials and waste (Jurgilevich et al., 2016; Ghisellini et al., 2016). Viewing the implementation of CE from an administrative perspective indicates the present impossibility of creating a decoupled and completely closed cycle of materials, because of the inter-scalar nature of material flows and continued demand for new resource input from cities. CE has predominantly applied to industrial sectors, such as the manufacturing industry (Ness and Xing, 2017). This case study illustrates the prominent limitation at the city level, which gives insight into why CE applications have focused on material chains and not spatially bounded areas (see Chapter 2, 2.2.4). CE at the city level can assist in transforming a city's linear characteristic, by altering the systemic processing of waste materials to create positive feedback loops (see Chapter 2, 2.2.3). However, whether circular cities can move beyond these actions and end-of-pipe focus to critically reducing the volumes of materials, without causing a rebound effect, still need to be verified (see 6.3).

This research focused on the city level and the construction sector, meaning the analysis emphasized the material aspects of CE. Consequently, this narrow focus fails to account for the social dynamics, and issues such as social well-being, that CE discussions have generally overlooked (see Chapter 2, 2.2.4). This focus on material use within construction processes does not account for changing demographics and social preferences for housing.

Methodologically, this paper followed an inductive and exploratory research design. This process captured the inter-sectoral and scalar challenges of implementing and transitioning to CE. However, to further validate this research, a qualitative survey that includes a statistical survey of reuse, recycling and material substitution would substantiate the findings of this qualitative study. In addition, this paper worked from a common research design and methodology (see Chapter 3). This approach bore the risk of failing to show the specific expertise of each researcher. However, the use of a common research question and methodology is justified because: a) the collaborative approach and literature synthesis brought out more diverse findings; and b) the approach allows a combination of the different case study outcomes to draw more profound and generalizable conclusions.

6.3 Future research

This research has purposefully looked at one strategic implementation and material flow to examine their barriers and limits. This paper suggests three areas for future research: Amsterdam, national and theoretical. 1) The national strategy has highlighted another four key material streams plastics, manufacturing, organics and consumer goods. Future studies examining Amsterdam could consider the same research question and design, examining these material streams. 2) Future research could examine the potential for CE at the national scale and explore the specific barriers and limitations. 3) CE is deployed at the city scale to create positive feedback loops and substitute output for material input. Whilst this is not a ‘closed loop’ economy, it does support the assertion that CE uses resources more efficiently (Ghisellini et al., 2016). However, a crucial theoretical question for CE is whether these efficiency gains will cause a net increase in material use, where efficiency gains cause an increase in production levels to the extent that they cancel any previous benefits, the so-called rebound effect (Zink and Geyer, 2017). A potential research question must be: How has the implementation of CE at the city level affected the net and relative rates of material used in the construction sector? A longitudinal study of the city’s relative material use could determine whether adopting CE has accelerated the net material consumption of targeted resources.

References

ABN AMBRO and Circle Economy. (2015). *Circular construction: the foundation under a renewed sector*. Retrieved 19 April 2018 from https://www.circle-economy.com/circular-construction-the-foundation-under-a-renewed-sector/#.WthZylPRAUs.

ABN AMBRO and Circle Economy. (2017). *A future proof built environment*. *The Future of the built environment*. Retrieved 28 March 2018 from https://circle-economy.com/future-built-environment.

Bernard, H. R., and Ryan, G.W. (2010), *Analysing qualitative data*: *Systematic approaches.* London: Sage Publication.

Bocken, M. P. N., Olivetti, E. A., Cullen, J. M., Potting, J. and Lifset, R. (2017). Taking the circularity to the next level: A special issue on the circular economy. *Journal of Industrial Ecology,* 21(3): 476–482.

Boeije, H. (2010). *Analysis in qualitative research*. Los Angeles, CA: Sage Publications.

Bonciu, F. (2014). The European economy: From a linear to circular economy. *Romanian Journal of European Affairs,*14: 78.

Braungart, M., Mcdonough, W., and Bollinger, A. (2007). Cradle-to-cradle design: Creating healthy emissions strategy for eco-effective product and system design. *Journal of Cleaner Production,*15(13/14): 1337–1348.

Bryman, A. (2012). *Social research methods* (3rd ed.). Oxford: Oxford University Press.

Buildings As Material Banks. (2012). *Material passports and the circular economy*. Retrieved 10 May 2018 from http://www.bamb2020.eu/topics/materials-passports/circular/

CBS. (2014). Amsterdam Income Data, 2010–2014. Retrieved 26 April 2018 from https://www.ois.amsterdam.nl/popup/1223.

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis*. London: Sage Publications.

Circle Economy, Fabric, TNO, and Gemeentre Amsterdam. (2015). *Circular Amsterdam: A vision and action agenda for the city and metropolitan area*. *Circle Economy*. Retrieved 5 April 2018, from https://www.circle-economy.com/report/developing-a-roadmap-for-the-first-circular-city-amsterdam/

Circle Economy, Copper8 and Gemeente Amsterdam. (2018). *Circular Amsterdam: Evaluatie en handelingsperspectieven*. Retrieved 12 April 2018 from https://www.amsterdam.nl/wonen-leefomgeving/duurzaam-amsterdam/publicaties-duurzaam/amsterdam-circulair-1/.

Circle Economy. (2018). *The Circularity Gap Report: An analysis of the circular state of the world economy*. Retrieved 8 February from https://www.circularity-gap.world/.

City of Amsterdam. (2013). *Towards the Amsterdam Circular Economy*. Retrieved 5 May 2018 from https://www.amsterdam.nl/wonen-leefomgeving/duurzaam-amsterdam/

City of Amsterdam. (2015). *Sustainable Amsterdam. Agenda for renewable energy, clean air, a* *circular economy and climate resilient city*. Retrieved 28 March 2018 from https://www.amsterdam.nl/bestuur-organisatie/organisatie/ruimte-economie/ruimte-duurzaamheid/making-amsterdam/sustainability/.

Dantzig, G.B., and Saaty, T.L. (1974). Compact city: A plan for a livable urban environment. *Operations Research,* 22(2): 446–448.

de Haan, J., and Rotmans, J. (2011). Patterns in transitions: Understanding complex chains of change. *Technological Forecasting and Social Change,* 78(1): 90–102.

de Jesus, A., and Mendonça, S. (2018). Lost in translation? Drivers and barriers in the Eco-innovation road to the circular economy. *Ecological Economics,*145: 75–89.

Deloitte. (2015). *Screening template for construction and demolition waste in the Netherlands.* Retrieved 11 May 2018 from http://ec.europa.eu/environment/waste/studies/deliverables/CDW_The%20Netherlands_Factsheet_Final.pdf.

Dong, S., Wang, Z., Li, Y., Li, F., Li, Z., Chen, F., and Cheng, H. (2017). Assessment of comprehensive effects and optimization of a circular economy system of coal power and cement in Kongtong district, Pinging City, Gansu Province, China. *Sustainability,* 9(5): 787.

Dumreicher, H., Levine, R.S., and Yanarella, E.J. (2000). The appropriate scale for "low energy": Theory and practice at the Westbahnhof. In K. Steemers and Y. Simos (eds.), *Architecture, city, environment. Proceedings of PLEA* (pp.359–63). London: James and James.

Dutch Government. (2010).*Crisis – en herstelwet.* Retrieved 25 April 2018 from https://www.rijksoverheid.nl/onderwerpen/omgevingswet/crisis-en-herstelwet.

Dutch Government. (2012). *Bouwbesluit.* Retrieved 17 May 2018 from https://rijksoverheid.bouwbesluit.com/Inhoud/docs/wet/bb2012/hfd8.

Dutch Government, Ministry of Infrastructure and Environment and Ministry of Economic Affairs. (2016). *A Circular Economy in the Netherlands by 2050*. Retrieved 18 April 2018 from https://www.government.nl/documents/policy-notes/2016/09/14/a-circular-economy-in-the-netherlands-by-2050.

Dutch Government. (2018). *Transitieagenda's: op weg naar een circulaire economie*. Retrieved 18 April 2018 from https://www.circulaireeconomienederland.nl/transitieagendas/default.aspx.

Eisenhardt, K.M., and Graebner, M.E. (2007). Theory building from cases: opportunities and challenges. *The Academy of Management Journal,* 50(1): 25–32.

Elkin, T., McLaren, D., and Hillman, M. (1991). *Reviving the city: Towards sustainable urban development.* London: Friends of the Earth with Policy Studies Institute.

Ellen Macarthur Foundation. (2013).*Towards the circular economy: Economic and business rationale for an accelerated transition*. Retrieved 2 April 2018 from https://www.ellenmacarthurfoundation.org/publications/towards-the-circular-economy-vol-1-an-economic-and-business-rationale-for-an-accelerated-transition.

Ellen MacArthur Foundation. (2016). *The Ellen MacArthur Foundation launches Circular Cities Work*. Retrieved 19 March 2018 from https://www.ellenmacarthurfoundation.org/news/circular-cities-network.

European Commission. (2014). *Towards a circular cconomy: A zero waste programme for Europe*. Retrieved 11 May 2018 from http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52014DC0398R%2801%29.

European Commission. (2015a). *Closing the loop. An EU action plan for the Circular Economy*. Retrieved 10 April 2018 from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52015DC0614.

European Commission. (2015b). *Resource efficient use of mixedwWaste*. Retrieved 16 April 2018 from http://ec.europa.eu/environment/waste/studies/mixed_waste.htm.

Fellner, J., Lederer, J., Scharff, C., and Laner, D. (2017). Present potentials and limitations of a circular economy with respect to primary raw demand. *Journal of Industrial Ecology*, 21(3): 494–496.

Financial Times. (2017). Amsterdam returns Dutch house prices to 2008 high. Retrieved 10 May 2018 from https://www.ft.com/content/79dca9b4-c3b7-11e7-b30e-a7c1c7c13aab.

Franco, M. A. (2017). Circular economy at the micro level: A dynamic view of incumbents' struggles and challenges in the textile industry. *Journal of Cleaner Production,* 168: 833–845.

Frantzeskaki, N., and de Haan, H. (2009). Transitions: Two steps from theory to policy. *Futures,* 41(9): 593–606.

Geels, F. W. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions,* 1(1): 24–40.

Geissdoerfer, M., Savaget, P., Bocken, N. M, and Hultink, E. J. (2017). The circular economy - A new sustainability paradigm? *Journal of Cleaner Production,* 143: 757–768.

Genovese, A., Acquaye, A. A., Figueroa, A. and Lenny Koh, S.C. (2017). Sustainable supply chain management and the transition towards a circular economy: Evidence and some applications. *Omega,* 66: 344–357.

Gerring, J. (2011). The case study: What it is and what it does. In R. E. Goodin (eds.), *The Oxford Handbook of Political Science*. Oxford: Oxford University Press.

Ghisellini, P., Cialani, C., and Ulgiato, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production,* 114:11–32.

Gnoni, M. G., Mossa, G., Mumble, G., Tornese, F., and Verriello, R. (2017). Supporting circular economy through use-based business models: The washing machine case. *Procedia CIRP,* 64: 49–54.

Gregson, N., Crang, M., Fuller, S., and Holmes, H. (2015). Interrogating the circular economy: The moral economy of resource recovery in the EU. *Economy and Society,* 44(2): 218–243.

Grimm, N.B., Faeth, S.H., Golubiewski, N.E., Redman, C.L., Wu, J., Bai, X., and Briggs, J.M., (2008). Global change and the ecology of cities. *Science,* 319: 756–761.

Gupta, J. (2014a). Sharing our Earth, Inaugural address as Professor of Environment and Development in the Global South. *University of Amsterdam*, 5 June 2014. Received 30 May from https://cgd.leeds.ac.uk/events/sharing-our-earth-in-the-anthropocene/.

Gupta, J. (2014b) *The history of global climate change governance*. Cambridge: Cambridge University Press.

Hillman, M. (1996). In favour of the compact city. In Mike Jenks, Elizabeth Burton and Katie Williams, *The compact city: A sustainable urban form*? (pp.36–44). London: E and FN Spon.

Hsieh, H. F., and Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research,* 15(9): 1277–1288.

Human Development Reports (HDR). (2015). *Human development indicators, Netherlands*. Retrieved 10 April 2018 from http://hdr.undp.org/en/countries/profiles/NLD.

Jabareen, Y.R. (2006). Sustainable urban forms: Their typologies, models, and concepts. *Journal of Planning Education and Research,* 26: 38–52.

Jurgilevich, A., Birge, T., Kentala-Lehtonen, J., Korhonen-Kurki, K., Pietikainen, J., Saikku, L., and Schosler, H. (2016). Transition towards circular economy in the food system. *Sustainability,* 8(1): 69.

Kalmykova, Y., and Rosado, L. (2015). Urban metabolism as a framework for circular economy design in cities. *Proceedings of the World Resources Forum 2015.*

Kemp, R., and Loorbach, D. (2003). Governance for sustainability through transition management. *Open meeting of human dimensions of global environmental change research community, Montreal, Canada,* 16–18. Retrieved 27 February 2018 from http://sedac.ciesin.columbia.edu/openmtg/docs/kemp.pdf.

Kennedy, C., Pincetl, S., and Bunje, P. (2011). The study of urban metabolism and its application to urban planning and design. *Environmental Pollution,* 159: 1965–1973.

Kirchherr, J.W., Hekkert, M.P., Bour, R., Huijbrechtse-Truijens, A., Kostense-Smit, E., and Muller, J. (2017). Breaking the barriers to the circular economy. Retrieved 10 April 2018 from https://www.kidv.nl/7554/breaking-the-barriers-to-the-circular-economy.html.

Korhonen, J., Nuur, C., Feldmann, A., and Birkie, S. E. (2018a). Circular economy as an essentially contested concept. *Journal of Cleaner Production,* 175: 544–552.

Korhonen, J., Honkasalo, A., and Seppala, J. (2018b). Circular Economy: The concept and its limitations. *Ecological Economics,* 143: 37–46.

Lazarevic, D., and Valve, H. (2017). Narrating expectation for the circular economy: Towards a common and contested European transition. *Energy Research and Social Science,* 31: 60–69.

Levermore, G. (2008). A review of the IPCC assessment report four, part 1: The IPCC process and greenhouse gas emissions trends from buildings worldwide. *Building Services Engineering Research,* 29(4): 349–361.

Lieder, M., and Rashid, A. (2016). Towards circular economy implementation: A comprehensive review in context of manufacturing industry. *Journal of Cleaner Production,* 115: 36–51.

Linder, P. Mooij, C., and Rogers, H. (2017). Circular cities: A strategic approach towards a sustainable society? Blekinge Institute of Technology Karlskrona, Sweden. Retrieved 28 March 2018 from http://bth.diva-portal.org/smash/record.jsf?pid=diva2%3A1108675&dswid=8058.

Ma, S., Wen, Z., Chen, J., and Wen, Z. (2014). Mode of circular economy in China's iron and steel industry: A case study in Wu-an city. *Journal of Cleaner Production,* 64: 505–512.

McDonnell, M.J., and Pickett, S.T.A. (1990). *Humans as components of ecosystems: The ecology of subtle human effects and populated areas.* New York: Springer-Verlag.

Metabolic, Studioninedots, DELVA Landscape Architects. (2015). *Transitioning Amsterdam to a circular city vision and ambition.* Retrieved 5 April 2018 from https://www.metabolic.nl/our-work-2/publications/.

Murray, A., Skene, K., and Haynes, K. (2017). The circular economy: An interdisciplinary exploration of the concept and application in a global context. *Business Ethics,* 140(3): 369–380.

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

New Horizon. (2018). *From dismantling to high-quality end separation*. Retrieved 19 April 2018 from http://newhorizon.nl/waarom-new-horizon/.

Newell, P. (2012). *Globalization and the environment, capitalism, ecology and power.* Cambridge: Polity Press.

Newman, P.W.G., and Kenworthy, J.R. (1989). Gasoline consumption and cities: A comparison of U.S. cities with a global survey. *Journal of the American Planning Association,* 55(1): 24–37.

O'Connor J. (1997). *Natural causes: Essays in ecological Marxism*. New York: Guilford.

Prendeville, S., Cherim, E., and Bocken, N. (2018). Circular cities: Mapping six cities in transition. *Environmental innovation,* 26: 171–194.

Rees, W. E., and Wackernagel, M. (1996). Urban ecological footprints: Why cities cannot be sustainable and why they are a key to sustainability. *Environmental Impact Assess Rev,* 16, 223–248.

Rees, W.E. (1992). Ecological footprints and appropriated carrying capacity: What urban economics leaves out. *Environment and Urbanization,* 4(2): 121–130.

Ribić, B., Voća, N., and Ilakovac, B. (2017). Concept of sustainable waste management in the city of Zagreb: Towards the implementation of circular economy approach. *Journal of Air and Waste Management Association*, 62(2): 241–259.

Rockström, J., Steffen, W., Noone, K., Persson, A., Chapin, F.S., Lambin, E.F., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H.J., Nykvist, B., de Wit, C.A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P. and Foley, J.A. (2009). A safe operating space for humanity. *Nature,* 461(2): 472–475.

Rotmans, J., Kemp, R., and van Asselt, M. (2001). More evolution than revolution: Transition management in public policy. *Foresight,* 3(1):15–31.

Saavedra, Y. M. B., Iritani, D. R., Pavan, A. L. R., and Ometto, A. R. (2018). Theoretical contribution of industrial ecology to circular economy. *Journal of Cleaner Production,* 170: 1514–1522.

Shattuck, L. (2017). *What is a modular home?* Retrieved 10 May 2018 from https://www.bankrate.com/finance/real-estate/what-is-modular-home.aspx.

Small, M.L. (2009). How many cases do I need? On science and the logic of case selection in field based research. *Ethnography,* 10(1): 5–38.

Stahel, W.R. (2016). The circular economy. *Nature News,* 531(7595): 435.

Su, B., Heshmati, A., Geng, Y., and Yu, X. (2013). A review of the circular economy in China: Moving from rhetoric to implementation. *Journal of Cleaner Production,* 42: 215–227.

Turok, I., and Seeliger, L. (2013). Towards sustainable cities: Extending resilience with insights from vulnerability and transition theory. *Sustainability,* 5(5): 2108–2128.

United Nations Development Policy and Analysis Division. (2013). *Sustainable cities*. Retrieved 28 March 2018 from https://search.un.org/results.php?tpl=desaandfq=url%3A%28%22http%3A%2F%2Fwww.un.org%2Fdevelopment%2Fdesa%2Fdpad%2F%22%29and_ga=GA1.2.923683624.1505390715and__utma=114554307.923683624.1505390715.1510145696.1519990658.4and__utmz=114554307.1519990658.4.3.utmcsr%3Dgoogle%7Cutmccn%3D%28organic%29%7Cutmcmd%3Dorganic%7Cutmctr%3D%28not+provided%29and_gid=GA1.2.1731019327.1522224295and_gat=1and_gat_UA-60287747-2=1andquery=sustainable+citiesandrows=10#!.

United Nations Development Programme. (2015). *Sustainable Development Goals*. Retrieved 10 April 2018 from http://www.undp.org/content/undp/en/home/sustainable-development-goals.html.

United Nations Environment Programme, (2013). *City-Level Decoupling: Urban resource flows and the governance of infrastructure transitions: A Report of the Working Group on Cities of the International Resource Panel*. Retrieved 10 April 2018 from https://www.wrforum.org/uneppublicationspdf/city-level-decoupling-urban-resource-flows-and-the-governance-of-infrastructure-transitions/.

United Nations Environment Programme. (2012). *Sustainable, resources efficient cities – Making it happen.* Paris: UNEP. Retrieved 30 May 2018 from https://sustainabledevelopment.un.org/index.php?page=view&type=400&nr=1124&menu=35.

United Nations. (2014). World urbanization prospects. *United Nations, Economic and Social Affairs.*

Urbinati, A., Chiaroni, D., and Chiesa, V. (2017). Towards a new taxonomy of circular economy business models. *Journal of Cleaner Production,* 168: 168–487.

van der Ryn, S., and Calthorpe, P. (1986). *Sustainable communities: A new design synthesis for cities, suburbs and towns*. London: Random House.

van der Voet, E., Huele, R., Koutamanis, A., van Reijn, B., van Bueren, E., Spiering, J., Demeyer, T., Roemers, G., and Blok, M. (2016). Prospecting the urban mine of Amsterdam. Retrieved 19 April 2018 from https://amsterdamsmartcity.com/projects/puma-prospecting-the-urban-mines-of-amsterdam.

Voor, R., Myllyvita, L., and Ayliffe, B. (2013). Point of no return: The massive climate threats we must avoid. Greenpeace International. Retrieved 10 April 2018 from http://www.greenpeace.org/archive-international/en/publications/Campaign-reports/Climate-Reports/Point-of-No-Return/.

Wang, L., and Li, H. M. (2010). Decomposition analysis on dematerialization for the further development of circular economy. *Bioinformatics and Biomedical Engineering (ICBBE), June 2010 4th International Conference on (IEEE), 1–4.*

World Bank. (2012). *What a waste: A global review of solid waste management*. Retrieved 26 March 2018 from https://openknowledge.worldbank.org/handle/10986/17388.

World Population Review. (2018). *Amsterdam population 2018*. Retrieved 26 March 2018 from http://worldpopulationreview.com/world-cities/amsterdam-population/.

World Resources Institute. (2016). *Accelerating building efficiency: Eight actions for urban leaders.* Retrieved 30 May 2018 from http://publications.wri.org/buildingefficiency/.

World Wildlife Fund. (2016). *Ecological Footprint.* Retrieved 10 April 2018 from http://wwf.panda.org/about_our_earth/all_publications/ecological_footprint2/.

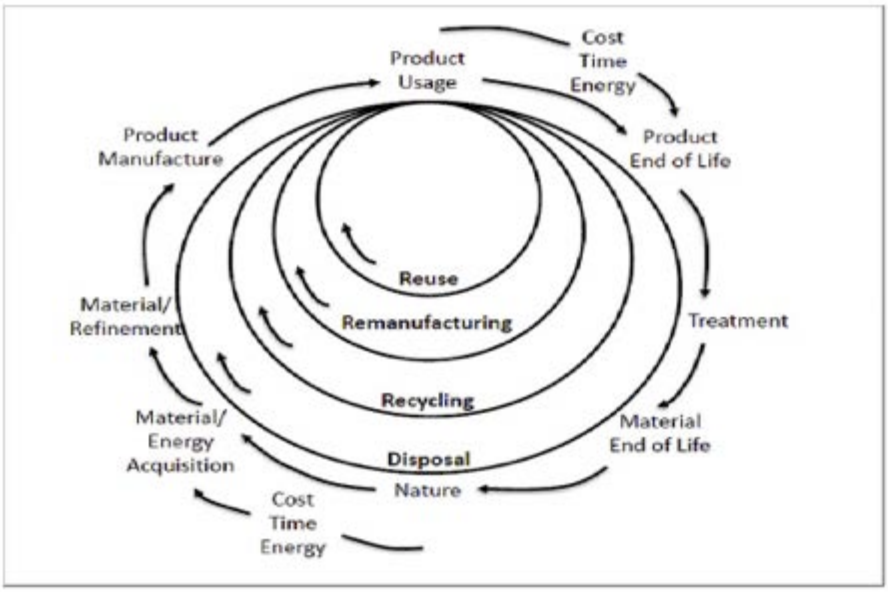
Yin, R. K. (1994). *Case study research: Design and methods* (2nd ed.). Newbury Park, CA: Sage.

Zijlstra, E. (2017). Material passport as the next step in the circle economy. Retrieved 19 April 2018 from https://materia.nl/article/material-passport-next-step-circular-economy/.

Zink, T., and Geyer, R. (2017). The circular economy rebound. *Journal of Industrial Ecology,* 21(3): 593–602.

Appendices

A: Visualization of CE



Source: Korhonen et al., 2018b: 39

B: Most cited articles on circular economy

Geissdoerfer, M., Savaget, P., Bocken, N. M, and Hultink, E. J. (2017). The circular economy - A new sustainability paradigm? *Journal of Cleaner Production,* 143: 757–768.

Geng, Y., Fum J., Sarkis, J., and Xue, B. (2012). Towards a national circular economy indicator system in China: An evaluation and critical analysis. *Journal of Cleaner Production,* 23: 216–224.

Genovese, A., Acquaye, A. A., Figueroa, A. and Lenny Koh, S.C. (2017). Sustainable supply chain management and the transition towards a circular economy: Evidence and some applications. *Omega,* 66: 344–357.

Ghisellini, P., Cialani, C., and Ulgiato, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production,* 114: 11–32.

Gregson, N., Crang, M., Fuller, S., and Holmes, H. (2015). Interrogating the circular economy: The moral economy of resource recovery in the EU. *Economy and Society,* 44(2): 218–243.

Hobson, K. (2016). Closing the loop of squaring the circle? Locating generative spaces for the circular economy. *Progress in Human Geography,* 40(1): 88–104.

Lieder, M., and Rashid, A. (2016). Towards circular economy implementation: A comprehensive review in context of manufacturing industry. *Journal of Cleaner Production,* 115: 36–51.

Murray, A., Skene, K., and Haynes, K. (2017). The circular economy: An interdisciplinary exploration of the concept and application in a global context. *Business Ethics,* 140(3): 369–380.

Smol, M., Kulcycka, J., Henclik, A., Gorazda, K., and Wzorek, Z. (2015). The possible use of sewage sludge ash (SSA) in the construction industry as a way towards a circular economy. *Journal of Cleaner Production,* 95: 45–54.

Su, B., Heshmati, A., Geng, Y., and Yu, X. (2013). A review of the circular economy in China: Moving from rhetoric to implementation. *Journal of Cleaner Production,* 42: 215–227.

Tukker, A. (2015). Product services for a resource-efficient and circular economy: a review. *Journal of Cleaner Production,* 97: 76–91.

C: List of respondents

Informant group	**In text reference number**	**Occupation/organization**	**Interview date**	**Interview type**	**Meeting location**
Institutional	1	Municipality of Amsterdam	12/4/18	Face-to-face	Respondent's location
Institutional	2	Municipality of Amsterdam	11/4/18	Face-to-face	Respondent's location
Institutional	3	Amsterdam Institute of Advanced Metropolitan Solutions	29/3/18	Face-to-face	Respondent's location
Institutional	4	Municipality of Amsterdam	24/4/18	Face-to-face	Respondent's location

Institutional	5	Municipality of Amsterdam	24/4/18	Face-to-face	Respondent's location
Industry	6	Designer/architect	30/3/18	Face-to-face	Respondent's location
Industry	7	Sustainability Coordinator	12/3/18	Skype	
Industry	8	Construction coordinator	5/4/18	Phone call	
Industry	9	Brick manufacturer	5/4/18	Phone call	
Industry	10	Construction consultant	28/3/18	Face-to-face	Neutral location
Industry	11	Material sharing platform	6/10/18	Phone call	
Industry	12	Construction contractor	4/4/18	Face-to-face	Respondent's location
Industry	13	Construction consultant	11/4/18	Face-to-face	Respondent's location
Industry	14	Demolition company	2/5/18	Phone call	
Expert	15	Academic	13/2/18	Face-to-face	Respondent's location
Expert	16	Academic	20/3/18	Face-to-face	Respondent's location
Expert	17	Academic	19/3/18	Face-to-face	Respondent's location
Expert	18	Academic	28/3/18	Face-to-face	Respondent's location
Expert	19	Academic	4/4/18	Phone call	
Expert	20	Sustainability consultant	25/4/18	Face-to-face	Neutral location
Expert	21	Sustainability consultant	21/3/18	Phone call	
Expert	22	Sustainability consultant	21/3/18	Face-to-face	Neutral location
Expert	23	Sustainability consultant	23/4/18	Face-to-face	Neutral location
Expert	24	Sustainability consultant	6/3/18	Phone call	
Expert	25	Sustainable development coordinator	11/4/18	Phone call	

D: Interview format

Institutional

My research, request to record/ offer of transcription and executive summary.

Initiating interview questions.

Can you introduce yourself, your role with the company, and describe your involvement with the circular economy.

Application

Can you briefly describe how the city has implemented CE. Why have you chosen to focus on the organics and construction chains? What was/is the primary purpose of the strategy? What instruments do you have available? How does this effect/ limit what you can/cant do?

Barriers

What do you see as the noticeable regulatory/ cultural/ market / technological barriers to implementing this strategy at the city level?
What challenges have you experienced directing this at a municipal level?
What do you think are the likely regulatory/ cultural/ market / technological barriers within the construction industry?

Limits

The national strategy aims reuse 50% of materials by 2030 – how will you attempt to do this?
The national strategy aims that 97% of construction waste is recycled – what is the difference will your strategy? How much do you estimate you can reuse?

The city strategy aims to build 70,000 new homes – given the national and city strategy, will you be able to comply with this? How much of the used material can you expect to come from the city?
Will your strategy reduce the input of new construction material? – Estimation for how much?
Will it eliminate construction waste? Will all waste be retained in the city? What targets have you set?

Has the national government allocated additional funding/ instruments for cities to become circular? How does this affect what you can/cant do?

Reflection

Personal reflection on the difficulties of implementing CE at the city level?
Municipal election expectations for CE.

Industry

My research, request to record/ offer of transcription and executive summary.

Initiating interview questions.

Can you introduce yourself, your role with the company, and describe your involvement with the circular economy.

Application

What is your understanding of CE? How has the city of Amsterdam been pursuing it? What is its purpose? How does it effect you?

Barriers

What are the barriers you experienced/ see (design/ construction/ demolition) in following this strategy?
What are the challenges in (design/ construction /demolition) of utilizing secondary materials?
Challenges in becoming circular at the city level?
What difficulties have you experienced working/ not working with the municipality?

Limits

National strategy aims for 50% reuse of construction material by 2030 – is this feasible for you? Can you do this utilizing the resources within the city? National government claims 97% of construction/ demolition waste is recycled – how much secondary material do you use/ do you use/ intend to use?

Reflection

Personal reflection on the difficulties of implementing CE at the city level?
Municipal election expectations for CE.

Expert:
My research, request to record/ offer of transcription and executive summary.

Initiating interview questions.

Can you introduce yourself, your role with the company, and describe your involvement with the circular economy.

Application

How is CE being applied at the city level? Why have they focused on the organics and construction flows? How do you think the national strategy influenced this focus? What is the purpose of this strategy?

Barriers

What do you see as the noticeable regulatory/ cultural/ market / technological barriers to implementing this strategy? What are the inherent challenges of becoming circular at the scale of the city? What do you think are the likely regulatory/ cultural/ market / technological barriers of complying with this strategy with the construction sector?

Limits

Will the strategy reduce material input? How much can they reuse/ recycling? Can they create a completely closed loop at the city level?
National government claims 97% of construction/ demolition waste is recycled, how will this strategy be different? What are the targets they have set?

Reflection

Any further reflections on CE within the city? What do you assume will happen after the local elections?

E: Explanation for the severity of barriers

The barriers to this circular transition in the construction sector and their relative importance are visualized in Figure 5.1 (smart design), Figure 5.2 (construction), and Figure 5.3 (demolition). These Figures are all combined in a composite fashion to illustrate the sectoral barriers to transitioning to CE (see Figure 5.4).

These infographics illustrate the severity of the barriers from red (high importance), orange (moderate importance), and green (low importance). This paper recommends further research on these barriers (see Chapter 6, 6.3), to statistically verify (through a survey) the severity of each barrier. The distinctions between these colours correspond to the following:

1: ‘Low importance’ was never/hardly ever mentioned by respondents. For example, technological barriers were not mentioned in the construction phase, which was interpreted to mean it was not significant at this stage.

2: ‘Moderate importance’ often arose in interviews, but occasionally required probing/follow up questions. Respondents’ did not reflect or emphasise that these barriers were highly significant during the interviews.

3. ‘High importance’ was responses that were immediately given by respondents, which were more often repeated and which were emphasised as significant. For example respondent 11 stated that no body/group/institution thought about the difficulty of the ‘social challenge’, which was interpreted as highly important/significant.

F: Email sent to potential informants

Initial message
Dear Sir/Madam/ company name,
I am contacting on behalf of a masters research group from the University of Amsterdam, examining the limits and current barriers to implementing a circular economy within a city. We want to understand, in the context of the existing strategy, what the limits to circularity are, the extent material loops can be closed and what the transitional barriers are.

Can I arrange a brief interview in the near future to discuss this topic with you?

Initial message construction
Dear Sir/Madam/company name,
I am conducting research on behalf of a masters group at the University of Amsterdam - looking at the implementation of a Circular Economy within a city, and focusing on the construction sector to explore the arising limitations and challenges.

Can I arrange a brief interview with you to discuss your work - In particular the challenges designing/ constructing/ demolishing in a circular manner, and the barriers you have faced?

G: Coding frames

Categories	Codes/components
Drivers/Instruments	Legislation Suasive Capacity building Market Taxation Subsidy Support
Market/Financial barriers	Successful business Available funding Money Upfront investment Expensive Open economy Time Labour costs Incentivizing Cost Cost of materials Developed market

	Scaling up Materials demand Taxation
Cultural barriers	Business mentality Knowledge of CE Mind shift/behavioural change Quality control People slow to adopt practices Trust Lock-in Circular mentality Client driven Social challenge Desire to change Responsibility Connectivity between stakeholders
Institutional/Regulatory barriers	Knowledge of materials Regulation Management Legislation Departmentalization Policy coherence Circular networks Policy scope Instrumental scope Operating scale
Technological barriers	Design Upcycling Knowledge Unproven technologies Quality/quantity guarantee Supply Material limits
Limits	CE focus Reuse and Recycle Idealised Reusing economy Funding Scope Instrumental scope Material limits Material cycle Sectoral limits

H: Political context

In the course of the research, municipal elections were held in Amsterdam on 21 March 2018. The question of how the political situation could effect the direction of CE within the chosen cities did not feature in our research proposal. However, during the research, we included an additional reflexive question to all respondents asking them to comment on their expectations for CE regarding the elections.

These questions were posed both before and after the elections to all respondents. Following the elections GroenLinks, the GreenLeft party, emerged as the largest party within the city, and formed a coalition agreement as of 23 May. Respondents from all classifications speculated that a/the victory for the Greens would lead the municipality to take a more direct and interventionist approach to CE and sustainability, in comparison to the prior coalition, which favoured market solutions. The findings of this research suggest that more direct institutional involvement and action is required to accelerate the circular transition. An issue raised by many respondents was that they thought CE was simply a 'greenwashing' tool. That CE was being used to legitimize increased growth and material consumption within the city, under the pretence that it was 'green' and 'sustainable'. As these findings show, the adoption of CE merely create a more efficient use of material resources, but still depends on new material inputs to fuel demand. Thus, respondents were unsure if the political change within Amsterdam could systematically change the focus of CE.