Exploring Cognitive Lock-In within the Construction Industry

Sana Firdous

TU Delft

Graduation Thesis

Delft University of Technology

"Exploring Cognitive Lock-In within the Construction Industry"

authored by

Sana Firdous

5614511

in partial fulfilment of the requirements for the degree of

Master of Science

in

Construction Management and Engineering,
Faculty of Civil Engineering and Geosciences

March 2024

Graduation Committee

Chairperson: Dr. Daan FJ Schraven

1st Supervisor: Quirien Reijtenbagh

2nd Supervisor: Dr. Martijn Leijten

Preface

Circular Economy (CE) is a topic that ignited my curiosity well before I commenced my graduate studies at TU Delft. The opportunity to focus my thesis on circularity—a concept I hold dear—has been a deeply fulfilling aspect of my academic journey. Along this path, I have gained an unexpected yet invaluable education in Cognitive science, which has greatly enriched my personal insights and professional expertise. Throughout the numerous challenges encountered during my research, I have acquired a wealth of knowledge that has been integral to the fruition of this report.

I am incredibly grateful to my thesis committee, whose guidance has been indispensable. My sincerest thanks go to my first supervisor, Quirien, who provided me with unwavering support and motivation throughout this journey. Her readiness to aid and guide has been a source of constant reassurance. I extend my heartfelt gratitude to Daan, my chairperson, who has instilled in me the importance of academic rigor. I am ever thankful for all the detailed and constructive feedback he provided me from the very beginning of my thesis work. I am also grateful to my second supervisor, Martijn, for his insightful feedback and for consistently offering fresh perspectives that have greatly enhanced our discussions. I consider it my privilege to have collaborated with you all in my academic journey!

To my dear friends from CME: Likitha, Mrinal, Shivam and Rohith- thank you for always being there for me, even through the highest highs and the lowest lows. To my roomie, support system, pseudo-therapist, and guiding force: Deepu, I am beyond grateful to you. I am also thankful to my friends from C&C who have always provided me with laughter and comfort. Sadia and Naila, to whom I am always thankful for being my source of strength wherever I go. *Ammi* and *Abba*, I hope I have made you proud parents!

This thesis journey will remain as a significant memory in my life, and I am glad I chose to take it. Lastly, I hope you- the reader, enjoy reading the thesis as much I did while working on it!

Executive Summary

Introduction

The Dutch construction industry mainly operates on a linear economy model. However, transitioning to a circular economy (CE) is seen as essential for meeting climate change objectives and adhering to the Paris Agreement. However, the industry has been slow to adopt CE principles, primarily due to its inherent aversion to risk and resistance to change. This reluctance is further compounded by cognitive biases among stakeholders, which create a "lock-in" effect that favours traditional practices over CE innovations.

The main question this research seeks to answer is, "**How does cognitive lock-in at the regime level of the construction industry hinder the implementation of the circular economy**?"

This research aims to explore how cognitive lock-in at the regime level impedes CE implementation by examining socio-cultural barriers and the impact of cognitive biases on decision-making processes.

Methodology

The research methodology centred on stakeholders at the regime level within the Dutch construction industry, such as project managers, architects, and consultants. A semi-quantitative approach was utilized, incorporating Fuzzy Cognitive Mapping to analyse.

Literature review formed the basis for the interconnections between socio-cultural barriers and cognitive biases. This approach was validated through interviews, which also helped to empirically score the influence of cognitive biases on the persistence of linear economy practices. Through this methodology, the study aimed to provide a nuanced understanding of the barriers to adopting circular economy principles.

Results

This research explored the cognitive lock-in in the construction industry, highlighted by resistance to change, insufficient knowledge of circular economy benefits, and a preference for traditional methods over innovative approaches.

It specifically identified Availability Heuristics and Confirmation Bias as the leading factors reinforcing the industry's linear economy mindset. These biases' rating indicates the widespread concern about the industry's limited awareness and education regarding circular economy. The lack of trust and acceptance of reclaimed materials, coupled with the perception of circular economy as unrealistic, further reinforces this lock-in.

Contrarily, Anchoring Bias and the Sunk-Cost Fallacy were seen as the least influential, pointing to the growing role of client demands and the pursuit of a competitive advantage.

Moreover, Status Quo bias and Confirmation bias were found to have the most impact on the rest of the biases in this landscape of linear economy lock-in. These results gave way to formulating the mitigation measures as recommendations for practice.

Recommendations

The research emphasizes the significant impact of cognitive biases and socio-cultural barriers on the persisting linear economic model in the construction industry. To transition towards Circular Economy (CE) practices, research recommends initiatives focused on enhancing awareness, education, feedback mechanisms, and long-term visioning. Specifically, the development of training programs, the implementation of feedback and accountability systems, promoting a long-term perspective on CE benefits, and appointing Circular Economy Managers to champion CE principles are suggested. Additionally, highlighting cognitive biases in professional development, fostering collaborative networks, and leveraging technology and innovation are key strategies for overcoming the industry's resistance and fostering a circular future.

Limitations and Future Work

This research identifies a limitation in its focus on regime-level socio-cultural barriers and cognitive biases, potentially missing nuances specific to the construction industry's other levels- regime and niche. Additionally, while it examines the interplay between cognitive and socio-cultural barriers, it does not fully explore the role of technical factors, which may also influence cognitive biases. The empirical study's limited sample size restricts the generalizability of findings, suggesting that a larger, more diverse participant pool could have offered a more comprehensive understanding of cognitive lock-in phenomena.

Future research could delve deeper into socio-cultural and cognitive biases with a granular analysis and extend investigations to include technical factors impacting cognitive lock-in. Additionally, timeline based, and cross-cultural studies would enhance understanding of the evolving nature of biases and barriers against Circular Economy practices. Integrating multi-disciplinary approaches could also offer comprehensive insights into overcoming the industry's resistance to change, facilitating a more sustainable construction sector.

Contents

Table of Figures

List of Tables

List of Abbreivations

CE- Circular Economy

FCM- Fuzzy Cognitive Map

1 Introduction

1.1 Background Information

In the current landscape, the construction industry is predominantly characterised by a linear economy. Within this paradigm, resources are extracted, utilised for construction, and ultimately discarded after they reach their end of life. Although this has long since been the norm in this industry, the ecological and environmental repercussions following its implementation cannot be overlooked.

Elaborating upon these repercussions, the construction sector is responsible for a substantial portion of global emissions and resource consumption due to these linear practices. According to a report by GlobalABC (2019), the buildings and construction sector hit an all-time high and accounted for nearly 40% of global CO2 emissions. Roughly, 50 billion tonnes of raw material extracted goes into the world's built environment (Circularity Gap Reporting Initiative, 2021). A third of the world's overall waste is due to construction (Miller, 2021).

The industry's continuous process of resource depletion and discarded waste accumulation is visibly an unsustainable consumption pattern. It is hence imperative that we recognise the pressing need for the construction industry to undergo a profound transformation- a transition towards a circular economy.

The Circular Economy (CE) is an economic system which aims to eliminate waste through promoting a continual use of the resources employed. With respect to the construction industry, a circular economy would entail minimising the use of natural resources and energy in the design, construction, and demolition phases of construction (Ghufran et al., 2022). The core theme lies in extending the lifespan and functionality of every building component, and thus, the building itself. Circular systems aim to create closed loops where materials and resources are continuously cycled through different uses, minimizing waste, and reducing the need for external inputs. This would remarkably decrease the industry's dependence on virgin resources, and waste production. A circular economy in the construction industry would help reduce global impacts, conserve natural resources, enhance sustainability and create value (Nodehi & Taghvaee, 2022).

A conducive environment for transitioning towards a circular economy has been put into effect after signing the Paris Agreement of 2015. The European Union set a framework for reducing greenhouse gas emissions by at least 55% by 2030 and reaching climate neutrality by 2050 (*The European Green Deal*, 2019). Additionally, The Circular Economy Action Plan (CEAP) (*Circular Economy Action Plan*, 2020) was established as Europe's new agenda for sustainable growth. In line with the UN Sustainable Development Goals, The Netherlands now aims to achieve a fully circular economy and net-zero greenhouse gas emissions by 2050. The Dutch government's approach supports innovation through collaborative projects, R&D facilities, and adjusted regulations to drive sustainable progress (*A circular economy in the Netherlands by 2050*, 2016).

Despite this recognition for change and the formalisation of intentions, the integration of circular practices within the construction industry is yet to take place in the world. GlobalABC (2019) has stated that our current model of linear economy is steering us towards a 3°– 6℃ temperature increase. This has set us further back from achieving the Paris Agreement goal. The Dutch *Integral Circular Economy Report* (2023) recognised the lack of a substantial market demand for circular products and services while identifying that the existing circular initiatives within the country are yet to be scaled-up. Although the COVID-19 pandemic resulted in decreased emissions, this cannot be attributed to a structural phenomenon. The use of minerals and metals still needs to be reduced significantly for a sustainable future. In short, there has not been a noticeable acceleration in the transition towards a circular economy in the Netherlands.

As the planet continues to heat up at an alarming rate, the Netherlands faces a looming danger of being submerged by rising sea levels. Hence, it is high time for the construction industry to have a paradigm shift to cope with this existing challenge.

Problem Statement

The construction industry is yet to fully accept and adapt circular practices, largely attributed to the infamously rigid and risk-aversive nature of the industry. McKinsey & Company (*The next normal in construction*, 2020) reinforced this claim by stating that the market's landscape is fragmented with complex dynamics within the industry, which makes it hard and slow to achieve any intended change. Notably, the environmental impacts caused by consumption in high-income countries, like the Netherlands, are significantly higher than those in low-income countries (*Circular Economy Action Plan,* 2020). However, current trends and policies indicate that resource efficiency is not improving quickly enough to reach the government's goal of halving resource use by 2030 (de Koning & van der Voet, 2022) Thus, the responsibility for a circular transition is much higher on the Netherlands. Now that it must undergo this intended paradigm shift, its rigidity is posing a critical problem in the journey to achieve circularity. The **inertia of the construction industry** towards change thus forms the first element of the problem definition.

In response to this need for transition, several innovative circular solutions have emerged in recent years, ranging from modular construction techniques and sustainable building materials to advanced recycling processes. However, these promising innovations are struggling to find traction. Even today, there is prevailing scepticism within the construction industry regarding the practicality and feasibility of transitioning towards a CE model (Charef, et al., 2021). This **scepticism towards CE** thus forms the second element of the problem definition.

The implementation of CE in the construction industry is further hampered by the apparent **"lock-in" of the linear economy** within the construction industry. This means that the industry is stuck in a system that relies on the extraction, production, consumption, and disposal of natural resources, without considering the environmental and social impacts. This system is driven by factors such as low prices, consumer

demand, regulations, infrastructure, project culture, and habits (Ghufran et al., 2022). Breaking through this "lock-in" for these circular innovations is thus, a challenge, forming the third element of the problem definition.

Thus, the problem of implementing circular economy is multi-faceted. These facets, or elements, are depicted in Figure 1. In this representation, the interconnected nature of the elements forms the core of the problem-statement for this research. This defined problem of implementing a CE within the construction sector is thus beyond mere technological innovation.

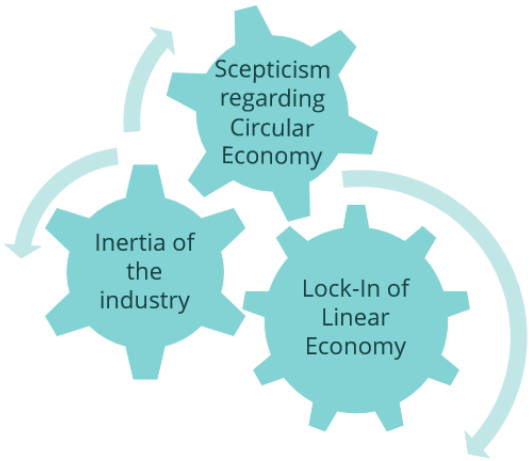

Figure 1: Multi-faceted problem.

1.2 Research Gap

While considering circular transitions, the primary focus in academic research has leaned heavily toward economic and environmental aspects. However, the concept of CE pans across the social, economic, political, and environmental sustainability domains (Daniel, 2022). This inherent complexity is further exacerbated by the involvement of numerous stakeholders in a construction project- each with their unique interests, motivations, and limitations. Since circular behaviour is not yet the new normal, creating a substantial market for circular products and services, changes in stakeholder willingness and behaviour are needed (*Integral Circular Economy Report*, 2023).

Considering this involvement of the multitude of stakeholders within a construction project, studying the sociological aspect is of importance. When faced with the challenge of adopting circular economy practices, the motivations and behaviours of these actors must be studied hand-in hand with the technological aspects. A key approach to addressing such complex challenges has been the application of socio-technical perspectives, which have proven effective in the study of sustainability transitions (Marcon Nora & Alberton, 2021).

One such application of the socio- technical perspective could be done through utilising the Multi-Level Perspective (MLP) of sustainable transitions, consisting of three levels-

Niche, Regime and Landscape (Geels, 2011). When applied to circular transitions, the Niche has demonstrated readiness with a sizable number of circular innovations. Additionally, the Dutch Landscape has been advocating for the adoption of CE practices as mentioned earlier. Intriguingly, the Regime level, which holds the most power for implementing changes, remains largely rigid and resistant to the CE agenda. This Regime is hence made the scope for the research, owing to its potential in implementing CE within the industry.

Within this Regime, the implementation of CE practices ultimately lies upon the decisions made by the involved stakeholders. Significant study (Ababio et al., 2022; Charef et al., 2021) into understanding the socio-cultural barriers hindering the implementation of CE has already delved into the stakeholder willingness and scepticism involved. However, these behaviours of the stakeholders impacting decision-making can be studied in greater detail through utilising the concept of Cognitive Biases. Considering this aspect of decision-making, Klotz (2011) has explored the impact of cognitive biases on sustainable energy decisions by the stakeholders in the construction industry. This study establishes the importance of understanding the impact that cognitive biases could have on decision-making, which is borrowed as the basis for understanding this impact on implementing CE within the industry, or, the stakeholders' decision-making regarding CE.

Cognitive biases can help explain instances, like energy use in buildings, where technical and economic factors do not fully explain the outcomes of decisions. Cognitive biases distort information in humans' thought processes and, in many cases, can enable faster decisions. However, these biases can also contribute to errors in judgment and limit our capacity to find perfectly "rational" solutions (Kahneman et al., 1991). In similar studies {Hofman, 2022; Rakitta & Wernery, 2021), various cognitive biases have been introduced and analysed for building energy decisions. However, the research of cognitive biases' impact on the sustained linear economy within the Dutch construction industry is significantly under-researched (Rakitta & Wernery, 2021). Considering the previously established scepticism for CE, which is also a departure from rational thinking and decision-making- the study of cognitive biases' impact on the persisting linear economy in the Dutch construction industry can provide valuable insights.

Thus, there is a critical need to study the potential interconnections between socio-cultural barriers and cognitive biases to effectively address and overcome the apparent lock-in of linear economy in the Dutch construction industry.

1.3 Research Questions

Main Research Question:
How does cognitive lock-in at the Regime level of the construction industry hinder the implementation of circular economy?

Sub Research Questions:
1. What are the socio-cultural barriers to implementing circular economy in literature?
2. What biases contribute towards the cognitive Lock-In of linear economy in the construction industry?
3. What is the relationship between socio-cultural barriers and cognitive biases?
4. What are the implications of cognitive biases on the cognitive lock in of linear economy in the Dutch construction industry?

1.4 Research Outline

This research is conducted through a semi-quantitative study aimed at exploring and analysing the Cognitive Lock-in of linear economy in the construction industry. The different phases of research are conducted as follows:

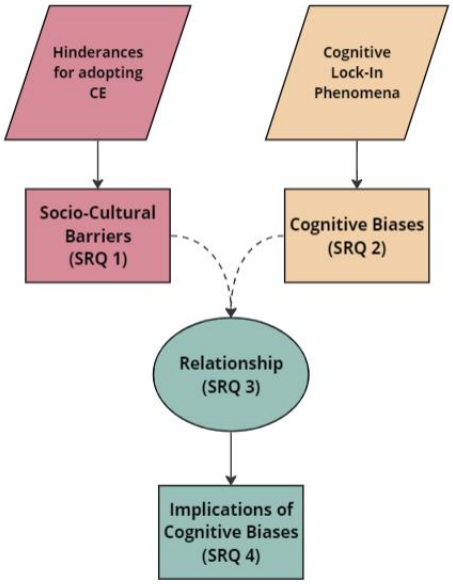

Figure 2: Research Outline

Phase 1: Literature Review

Through establishing the research background, problem statement and main research questions, the scope of the research is determined. A literature study is conducted to understand the existing research, theories and concepts involved. The socio-cultural barriers identified during this phase formulate the answer to sub-research question 1. The cognitive biases identified would form the answer to sub-research question 2.

Phase 2: Content Analysis

This phase involves the development of the Conceptual Framework, involving establishing the relationship between the identified sociocultural barriers and their relative cognitive biases from the literature study. This forms the answer to sub-research question 3.

Phase 3: Empirical Study

During this phase, empirical data is collected through semi-structured interviews. Fuzzy cognitive mapping is employed to find out the impact scores of the Cognitive biases on the lock-in of linear economy.

Phase 4: Data Analysis

Following the data obtained through the interviews, insights from theory and practice are compared to understand the implications of Cognitive Biases on the cognitive lock-in on the implementation of circular economy. This forms the answer to the sub-research question 4, which in turn provides feedback for the main research question.

In the closing phase of this research, the implications of the results obtained are studied in a broader context to gain the full picture. Recommendations and conclusions are drawn in this phase.

1.5 Research Scope

The scope of this research involves examining the impact of cognitive biases on the lock-in of the linear economy within the construction industry, specifically hindering the implementation of circular economy practices. Given that circular economy is considered a niche concept that requires acceptance and support at the regime level for widespread implementation, the research focuses on exploring the connection between socio-cultural barriers and cognitive biases primarily among regime-level stakeholders.

By focusing on regime-level stakeholders, the research aims to provide valuable insights into the socio-cultural barriers and cognitive biases that contribute to the resistance against circular economy practices within the construction industry, ultimately informing strategies for promoting more circular approaches at all levels of the industry.

Additionally, the scope of this study extends beyond the traditional boundaries of the construction industry to encompass a broader context, including infrastructure, the built environment, and the AEC industry. By expanding the focus to these interconnected domains, the exploratory nature of the research aims would provide a wiser understanding of the concept of cognitive biases and their impact.

2 Literature Review

The literature review for this research revolves around the central theme of Circular Economy. The key principles of circularity and the impending transition towards a circular future are elaborated upon. For this transition to be facilitated, the sociological aspects are further reviewed. Socio-cultural barriers impeding the Circularity Transition are comprehensively examined and summarised for clarity. Furthermore, an investigation is conducted into Cognitive Biases and their impact on this transition, while identifying and defining the relevant biases. The objective is to establish the essential insights for conducting this sociological research towards a Circular future.

This literature review adopts a narrative approach, providing a comprehensive and coherent summary of existing literature on the related topics while relying on the researcher's interpretation and synthesis of available literature. It prioritises the inclusion of literature that contributes to a comprehensive understanding of the topic, even if it varies in terms of methodologies or research designs. This approach enables a deeper exploration of the interrelationships between sociological factors, cognitive biases, and circular economy principles. The synthesis involves categorising findings, critically analysing the strengths and limitations of the existing literature and identifying common themes or patterns.

This study begins by understanding the existing situation of CE within the construction industry. A comprehensive study of the socio-cultural barriers to implementing circular economy within the construction industry is then conducted. This establishes the current state of knowledge available regarding the implementation of CE in the construction industry. In the next half, the apparent lock-in phenomenon is defined and studied in detail. Cognitive biases are then explored as contributing factors for the cognitive lock-in of linear economy. These cognitive biases are identified from various studies pertaining to the construction industry.

2.1 Circular Economy

The concept of circular economy has been called a restorative economic system that aims to maximise resource efficiency and minimise waste generation, while utilising the constituent resources to their highest possible utility, thus generating closed loops (MacArthur, 2013). The main objective of this model is to necessitate a systemic shift while focusing on both economic prosperity and environmental quality (Kirchherr et al., 2017). To achieve its intended purpose, the shift to circular economy requires fundamental changes in practices that determine the production and consumption behaviours (Hanemaaijer et al., 2023).

Although the concepts of circular economy are established, the standard definition of CE varies in the literature. The concept of Circular Economy is an evolving concept and is driven by context. The means- becoming “circular” varies when considering the highest possible utility of individual components, products, and materials, while varying in the larger context of the industry it is being utilised in (MacArthur, 2015).

However, considering the context of the Dutch construction industry, *Integral Circular Economy Report* by Hanemaaijer et al. (2023) defines the circular economy through a concept of "loops":

The "narrowing" resource loop refers to using fewer inputs in terms of energy, materials, and other resources for the manufacture and consumption of products or even buildings (Bocken, 2016). In the context of the built environment, narrowing indicates the use of fewer resources throughout the building's lifetime (Çetin et al., 2021).

Slowing" resource loops advocate a slowdown in the flow of resources by intensifying their use and extending their service life through design and operation measures (Bocken et al., 2016; Çetin et al., 2021).

The "closing" resource loop intends to reintroduce the resources back into the economic cycle when buildings reach the end of their service life (Çetin et al., 2021)

Finally, "regenerate" aims to collaborate with local communities and utilize healthy and renewable resources to create a positive impact for both humanity and nature. This principle requires a step beyond just green and sustainable building concepts and creates a continuous flow of resources that are self-sufficient (Attia, 2018; Çetin et al., 2021).

2.1.1 Circularity in Construction

While defining this shift from a linear to circular economy, it is important to identify the role of this transition for the Dutch construction industry. In contrast to the current negative impact of the linear models of construction on the environment, circular construction addresses the urgent need for flexibility, health improvements, treating real estate as a repository of raw materials, and enhancing societal benefits, which is crucial in today's context. (Zvirgzdins et al., 2019).

CE in the construction industry can be visualized into four design paradigms – adaptability, design for deconstruction, use of circular materials, and practicing resource efficiency (Densley Tingley et al., 2018). This encompasses numerous dimensions of circularity like optimum design, reduced use, material reuse, repurposing, refurbishment, recycling, structural design for deconstruction, circular supply chain, and efficient construction-demolition waste management (Norouzi et al., 2021).

Understanding the benefits of circular construction is important for this study as it forms the basis for promoting CE to the stakeholders involved. Despite the apparent advantages to implementing CE as depicted in Fig. 3, the implementation within the industry remains hampered. This hampered implementation is explored in the subsequent sections.

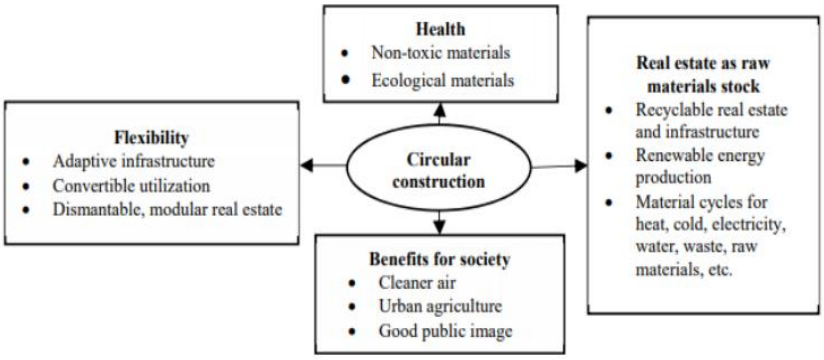

Figure 3: Advantages of circular construction implementation (Zvirgzdins et al., 2019)

2.2 Barriers Impeding Circularity Transition

In order to examine the reasons for a lack of application of circularity within the construction industry, the barriers impeding this transition have been extensively studied by researchers, as discussed in the following paragraphs. This section examines these diverse barriers that impede the adoption of circular economy, and the complexities surrounding the shift.

The shift from a linear to a circular economy in the construction industry is hindered by a number of factors, problems and norms within the industry, which research has assigned the term "barriers". These barriers assigned to Circular Economy in the construction industry frequently encircle the lack of political and legislative frameworks, and limited economic and technological advancements. While considering these technical barriers to a circularity transition, research has also identified certain barriers belonging to the sociological aspects. As a whole, the barriers from several researchers can be condensed into five main themes: definition and theory misconception, political and legislative, social and cultural, financial and economic, and technological barriers (Ababio & Lu, 2023; Flores-Colen & Silvestre, 2017; van Teeffelen et al., 2020).

Understanding these barriers is crucial as it allows for the development of effective strategies tailored to the respective barriers faced by the industry. For political and legislative barriers, implementing supportive policies and regulations can facilitate the circular economy adoption. Economically, incentivizing circular practices and investing in circular technologies can overcome financial barriers. Embracing technological advancements and fostering innovation is key to overcoming technological barriers (Mhatre et al., 2023).

Given this research into mitigating the various themes of barriers identified, it is important to note that the social and cultural theme of barriers has been given significantly less investigated. Hence, the social and cultural theme is given importance in this literature review and analysed deeper.

2.2.1 Socio-Cultural Barriers

The above-mentioned barriers cover a range of behavioural and managerial issues, including linear economy's rooted nature within the industry, attitudes and opinions on ownership and status, and silo thinking (Hart et al. 2019). CE requires conscious communication and commitment from all involved stakeholders during various phases of a construction project, which explains the emergence and implications of multiple barriers in the socio-cultural theme. This socio-cultural theme often presents itself in literature as the classification of "social and cultural" barriers (Ababio & Lu, 2023; Osei-Tutu et al., 2023). However, the term "cultural" has been used interchangeably with "behavioural" in several papers (Mhatre et al., 2023), or the overarching term "sociological" has been used (Charef et al., 2021). Notably- social, cultural, and behavioural barriers are interconnected elements that influence and reinforce each other. Social interactions and relationships contribute to the development of cultural norms, and these shared norms, in turn, shape the behaviours of individuals and organizations. For this research however, the term for this theme is deemed to be "socio-cultural barriers".

To discuss a few key socio-cultural barriers, Acharya et al. (2018) points out that the industry is typically not favourable to start-up culture given its high risk and volatile profit margins. Also, the long-standing conventional regime has not helped matters, as the widespread mentality – "this is how we have always done construction" – persists among key stakeholders in the industry. This falls under the barrier of "resistance to change", which is a direct implication of lock-in of linear economy as discussed in section 2.3 (Foxon, 2013).

Additionally, there seems to be a deficiency in interest, understanding, awareness, and involvement across the value chain, which is hindering progress in adopting circular economy practices (Kirchherr et al. 2018). The presence of markets for used or refurbished materials may not be financially viable due to insufficient material availability, inconsistent standards for secondary materials, and negative perceptions among buyers regarding their quality (Charef and Emmitt, 2020). Despite companies having pro-circular policies, their implementation may not be effective. This inefficiency is exacerbated by a lack of commitment and short-term profit-driven perspectives, further complicating the situation (Charef et al., 2021).

Given the current lack of awareness and absence of guidelines on CE, there is a certain degree of uncertainty surrounding the adoption of circular practices. Designers and engineers notably lack the necessary knowledge and data regarding material reclamation and the use of secondary materials (Charef and Emmitt, 2020).

The preference among the majority of consumers tends to lean towards the utilization of newly sourced materials instead of secondary ones. This inclination is derived from the assurance of material quality and the presence of behavioural challenges. In certain instances, subpar circular products prove to be inadequate in meeting the expectations and criteria of clients, subsequently resulting in a heightened probability of clients

rejecting reclaimed materials. Consequently, the lack of acceptance and the existence of negative perceptions regarding secondary materials impede the widespread adoption of the concept of Circular Economy (Bao & Lu, 2020).

Ababio and Lu (2023); Charef et al. (2021) Mhatre et al. (2023) and Osei-Tutu et al. (2023) conducted a scientometric and content analysis research on the barriers impeding the adoption of circular economy in the construction industry. Within this research, the theme of socio-cultural barriers was selected and further synthesized to form the Table 1 below. This table is the answer to the 1st sub-research question of this study.

Barrier	Source
Resistance to change	Ababio et al., 2022
Ingrained linear mindset	Osei-tutu et al., 2022
Construction sector inertia	Osei-tutu et al., 2022
Lack of lateral thinking	Charef et al., 2021
Negative social pressures	Ababio et al., 2022
Lack of demand in composite construction	Osei-tutu et al., 2022
Low image placed on reclaimed and recycled materials	Osei-tutu et al., 2022
Unrealistic hypothesis	Osei-tutu et al., 2022
Lacking sense of urgency: awareness and sense of urgency in society	Mhatre et al, 2023
Lack of trust and acceptance of reclaimed materials	Osei-tutu et al., 2022
Poor environmental perceptions	Ababio et al., 2022
Disbelief in the potential utility	Charef et al., 2021
Bad image of CE	Charef et al, 2021
Lack of trust in data	Osei-tutu et al., 2022
Culture of waste behaviour assumption that waste is inevitable	Osei-tutu et al., 2023
Willingness to implement CE	Mhatre et al, 2023
Lack of interest	Ababio et al., 2022
Lack of awareness	Ababio et al., 2022
Inadequate resource availability	Ababio et al., 2022
Perception of second-hand materials being sub-standard	Osei-tutu et al., 2022
Lack of empirical based literature on the barriers	Osei-tutu et al., 2022
Lack of education on CE strategies among stakeholders	Osei-tutu et al., 2022
Aesthetic trend	Osei-tutu et al., 2022
Old production and consumption practices	Ababio et al., 2022
Strong belief that waste management is more expensive	Osei-tutu et al., 2022
Lack of global vision	Charef et al., 2021
Lack of incentives	Osei-tutu et al., 2022
Market preparedness	Osei-tutu et al., 2022
Uncertainty avoidance	Mhatre et al, 2023
Hesitant company culture to engage in CE projects with higher risk profile	Mhatre et al, 2023
Want ROI quickly	Charef et al., 2021
Fear of additional construction cost	Charef et al., 2021
Lack of expertise	Ababio et al., 2022

Table 1: Synthesis of Socio-Cultural Barriers

2.3 Lock-In Phenomena

The application of circular economy thinking in construction is still in its infancy, with limited research on new business models and materials with high emissions (Adams et al., 2017). While some construction companies in Europe are integrating circular economy thinking into their strategic planning, widespread adoption and implementation are still at an early stage (Jones & Comfort, 2018). Owing to its inter-dependency on various stakeholders and the need for multi-factorial coordination,

incorporation of CE is posed by numerous deterrents (Cruz Rios et al., 2021). Given this current state, this research asserts that a "lock-in" of the linear economy persists within the industry.

Lock-in refers to a situation where an industry becomes dependent on a particular technology or system, making it difficult to transition to the alternate options available (Unruh, 2000). In the context of circular economy, "lock-in" means that the traditional or linear way of doing things is still very much stuck or fixed. By understanding what keeps an industry "locked in" to traditional methods, researchers and policymakers can develop targeted strategies to promote change. Stanca (2023) stated that this understanding of lock-in and its implications is a necessary step towards fostering innovations and technological transitions, such as the Circularity transition.

Lock-in is a consequence of barriers present to adopting new circular technologies or when there is a lack of a shift away from traditional linear models of production and consumption (Iacovidou et al., 2017). It occurs when technologies co-evolve with supporting institutions, business strategies, and user practices, leading to path dependency and bounded rationality (Foxon, 2013). Path dependency refers to a situation in which the current course of development or decision-making in a system is influenced by historical events or past choices. This establishes the “inertia” of the industry towards innovations and transitions. Further reinforcing path dependency is bounded rationality, a concept introduced by economist Herbert A. Simon (1996), suggesting that decision-makers have cognitive limitations that restrict their ability to process all available information and consider all possible alternatives when making choices (Jones, 2002). Bounded rationality is further discussed in section 2.4.

Zooming into the lock-in phenomena, this research aligns more with the study of Cognitive lock-in of linear economy in the construction industry. **Cognitive lock-in** refers to a phenomenon where individuals or organizations become entrenched in a particular mindset, limiting their ability to consider alternative approaches or adapt to new paradigms. It is characterized by a mental rigidity that hinders openness to change, innovation, or adaptation (Murray & Häubl, 2007).

Considering the previously discussed scepticism and rigidity of the industry against change, the phenomenon of Cognitive lock-in can be used to precisely describe the current situation of the construction industry. Despite circular economy being considered superior to linear economy, the existing cognitive lock-in’s influence on decision-making processes and mental habits of the involved stakeholders forms the starting point of this research. Additionally, Cognitive lock-in is closely related to cognitive biases, which are systematic patterns of deviation from rationality or sound judgment, discussed further in the sub-sequent sections.

After describing the current situation of the circularity transition in terms of Cognitive lock-in, it is important to dive deeper into the factors contributing toward this phenomenon. The subsequent sections will discuss these impediments in further detail.

2.4 Cognitive Biases

The term "bias" is interpreted in different ways in literature; mostly, it is considered an irrational belief that influences the ability to make a specific decision based on facts and evidence (Schwenk, 1986; Busenitz and Barney, 1997; Das and Teng, 1999; Simon et al., 2000). Cognitive biases, deemed to be an ever-present ingredient of strategic decision making, are cases in which human cognition reliably produces representations that are systematically distorted compared to some aspect of objective reality" (Haselton et al., 2015).

Cognitive biases refer to the systematic patterns of deviation from rationality in judgment and decision-making that affect human thought processes. Recalling bounded rationality discussed in reference to the lock-in phenomena in Section 2.3.; Bounded rationality describes how human behaviour often diverges from purely logical actions, arising primarily from three key sources: one of which is the systematic deviations from rational behaviour, so-called cognitive biases (Rakitta & Wernery, 2021). Bounded rationality contributes to decision-makers' reliance on familiar practices due to cognitive limitations, while cognitive biases reinforce these cognitive limitations. In this context of lock-in of linear economy, cognitive biases would affect the choices made by stakeholders in terms of material reuse, recycling, and regeneration. Understanding these biases is critical for overcoming barriers to circular construction practices.

Since research into the prevalence of Cognitive Biases in the construction industry with relation to the adoption of Circular Economy is scarce, the relevant cognitive biases need to be borrowed from related literature of sustainability and building energy decisions.

While analysing cognitive biases in building energy decisions of various phases of a construction project in the USA, Klotz (2011) identified the following relevant cognitive biases mentioned in the list below. It is important to note that cognitive biases are extremely context and region dependent, so the implications of these identified biases with respect to circular economy is also mentioned.

- **Status Quo Bias** (**Kahneman et al.**, **1991**)**:** The tendency to prefer the current state of affairs and resist change. Individuals with status quo bias may exhibit reluctance to deviate from existing norms or practices. Individuals may resist adopting circular practices, favouring traditional linear methods due to comfort with the existing state of affairs.
- **Anchoring Bias (Jacowitz & Kahneman, 1995):** Relying too heavily on the first piece of information encountered when making decisions. The initial information, or anchor, influences subsequent judgments, often leading to biased decision-making. Initial information or practices may strongly influence decisions, potentially limiting the exploration of diverse circular alternatives, leading to skewed decision-making.
- **Overconfidence Bias (Svenson, 1981):** The tendency to overestimate one's abilities, knowledge, or the accuracy of one's beliefs. Individuals with overconfidence bias may exhibit unwarranted confidence in their judgments or

capabilities. Actors may underestimate the resources, time, and organizational changes required for a successful transition to circular economy practices.

- **Sunk Cost Fallacy (Kahneman et al., 1991):** The irrational decision to continue an endeavour based on previously invested resources, even if the costs outweigh the benefits. Sunk cost fallacy occurs when individuals consider past investments rather than objectively evaluating current and future outcomes. The industry may prioritize short-term gains, potentially overlooking the substantial long-term benefits associated with circular economy practices.
- **Short Termism (Green et al., 1994):** The tendency to prioritize short-term gains or outcomes over long-term benefits. Individuals exhibiting short-termism may focus on immediate advantages while neglecting the potential long-term consequences of their decisions. The construction industry's tendency to prioritize immediate gains or cost savings over the long-term benefits associated with the adoption of circular economy practices.
- **Professional Bias (Linder, 1987):** The influence of one's professional background, experiences, or expertise on decision-making. Professional bias occurs when individuals rely on their specialized knowledge, potentially overlooking alternative perspectives or solutions. Professionals with deep expertise in conventional construction materials and methods may be hesitant to adopt new, circular alternatives due to their familiarity with existing practices.

In addition to these identified cognitive biases, Busenitz and Barney (1997) describe the relation between cognitive biases and heuristics. Furthermore, Rakitta and Wernery (2021) discussed the possible effects of Confirmation bias within the construction industry. These two biases are hence included in the research and described below.

- **Confirmation Bias (Nickerson, 1998):** The tendency to favour information that confirms pre-existing beliefs or attitudes while avoiding or downplaying information that contradicts them. Confirmation bias influences the interpretation of information in a way that aligns with existing views. Individuals may selectively interpret data that aligns with existing beliefs, potentially overlooking evidence supporting the benefits of circular economy practices.
- **Availability Heuristics (Kahneman et al., 1991)**: Relying on immediate examples or information readily available when making judgments. Individuals employing availability heuristics may prioritize information that is easily accessible or comes to mind quickly, potentially leading to biased decision-making. Relying on readily available information about traditional construction practices may bias decisions against exploring less familiar but potentially more sustainable circular alternatives.

In summation, the cognitive biases relevant to this research are noted in Table 2. These biases form the answer to Sub-Research question 2.

Bias	Source
Status Quo	Kahneman et al., 1991
Anchoring Bias	Jacowitz and Kahneman, 1995
Overconfidence Bias	Svenson, 1981
Confirmation Bias	Nickerson, 1998
Availability Heuristics	Kahneman et al., 1991
Sunk-Cost Fallacy	Kahneman et al., 1991
Short Termism	Green et al., 1994
Professional Bias	Linder, 1987

Table 2: List of Cognitive Biases

2.5 Key Takeaways

This literature review establishes the current state of knowledge through understanding the barriers impeding CE, while also exploring the phenomenon of cognitive lock-in alongside cognitive biases.
Socio-cultural barriers to CE implementation are evidently a highly researched topic, but do not fully explain the discussed aspects of scepticism regarding CE, and resistance to change within the construction industry.
Cognitive lock-in and cognitive biases in turn help understand these aspects better, and form another set of impediments to the CE transition.
Having understood these impediments to transition, a connection emerges between the state of lock-in, and the hampered implementation of CE in the industry. Which implies, that the socio-cultural barriers have a potential link to cognitive biases.
This potential connection is the key takeaway, which will be further defined in the subsequent chapters.
Additionally, the impact of cognitive biases on cognitive lock-in of linear economy needs to be studied further, to aid the transition towards CE.

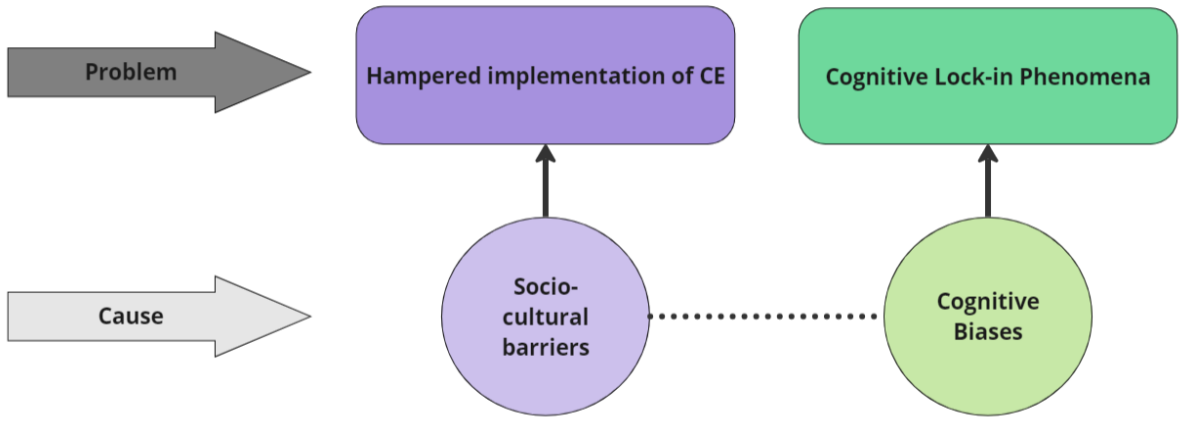

Figure 4: Key-takeaways

3 Research Methodology

This section delves into the methodology employed for this research into understanding the impact of Cognitive lock-in on the hampered implementation of CE in the construction industry. Various phases of the research are explained with respect to the selected methodology and its purpose.

3.1 Relationship between Barriers and Biases:

From the literature review, the two main outcomes of Socio-cultural barriers and Cognitive biases are connected further. Qualitative content analysis of the definitions of these two elements in literature was systematically coded using ATLAS.ti software (version 23).

Deductive coding was used for cognitive biases, based on existing definitions and understandings of these biases. This is an appropriate strategy because cognitive biases are well-documented in psychological literature, and their definitions serve as a robust foundation for identifying instances of these biases within the data. This approach ensures that your analysis is grounded in established theory, enhancing the credibility and reliability of the findings.

Simultaneously, inductive coding was applied for socio-cultural barriers, to explore these barriers as they are experienced and perceived by individuals, without imposing preconceived notions or categories. Since socio-cultural barriers can be varied, context-specific, and not as clearly defined as cognitive biases, an inductive approach is suitable for uncovering new insights and understanding the nuances of these barriers from the ground up.

Matching codes from both sets (cognitive biases and socio-cultural barriers) and establishing relationships between them was the next step. This matching process involved a comparative analysis where intersections, influences, or correlations between specific cognitive biases and socio-cultural barriers were identified. By linking these two elements, the aim is to uncover how cognitive biases might interact with socio-cultural barriers, potentially affecting individuals' perceptions, behaviors, and decision-making processes.

However, it is important to note that the interpretations and integration of codes is subjective and may vary based on different contexts and perspectives. The coded relations between the two elements are available in the Appendix. This relationship is further discussed in the subsequent chapter.

3.2 Empirical Study

Taking the above formed relationship as the conceptual framework for further research into Cognitive lock-in, semi-structured interviews are conducted for gathering data. Owing to the fairly new concept of Cognitive Biases within the construction industry, this research uses the derived relationship between socio-cultural barriers and

cognitive biases as a proxy to help the interviewees fully understand the definitions and implications of biases in the context of CE within the industry.

Since the data gathered in this phase needs to measure the impact of Cognitive biases, which in turn correspond to the sociological aspect of the stakeholder's behaviours- a semi-quantitative approach is utilised to gain statistical data to understand people's behaviours and attitudes.

Conducted in three phases, the semi-structured interview will first validate the connection between socio-cultural barriers and the assigned cognitive biases. In the next phase, cognitive mapping is conducted to assess the impact of cognitive biases on the lock-in of linear economy in the industry. This is done through using the Mental Modeler software (https://www.mentalmodeler.com) to make a Fuzzy Cognitive Map (FCM).

Fuzzy cognitive mapping is a methodology that constructs semi-quantitative models based on the understanding of interconnected variables within a given system (Jetter & Kok, 2014). Bart Kosko introduced Fuzzy Cognitive Mapping (FCM) in 1986 as a way to model expert knowledge through a "fuzzy" soft system programming technique, mirroring human decision-making processes. FCM encapsulates knowledge by identifying a system's elements, the nature (positive or negative) of interactions among these elements, and the extent of one element's impact on another, characterized through qualitative assessments like high, medium, or low influence.

FCMs are advantageous in the representation of intricate social-ecological systems as perceived by the stakeholders inhabiting and operating within the system (Voinov & Gaddis, 2017). The inherent characteristics of FCMs facilitate the involvement of stakeholders in building the map individually. FCMs possess a notable degree of adaptability, allowing the incorporation of various domains of the system which would otherwise be challenging to quantify (Kafetzis et al., 2010).

By employing FCM in interviewing the stakeholders, an effective communication of their opinions/beliefs regarding a particular problem can be achieved, thereby facilitating the following outcomes:

1. Express their current understanding and mutually enhance their knowledge in the process of constructing the model (single-loop learning).
2. Engage in a critical assessment of their current beliefs and assumptions (double-loop learning) after establishing the model.

Through utilising the FCM in the empirical study, the interviewee's judgement of the impact of cognitive biases on the lock-in of linear economy can be obtained in real time. The resultant FCM, which is a summation of all the interviewee FCMs, can be obtained through weighted geometric average of the matrices.

3.3 Interview Formation and Participation Selection

Questions were meticulously formulated to cover three critical phases: understanding circular economy knowledge and involvement, identifying and defining cognitive

biases, and constructing a Fuzzy Cognitive Map (FCM) to visualize the impact of cognitive biases on the adoption of CE practices. Participants were selected based on their engagement in circular projects and their capacity to provide insights into the industry's transition towards circularity. This selection criteria aimed to ensure the data collected was both relevant and informed by direct experience.

3.3.1 Summary of Questions:

The questions for the interview were divided into 3 main phases to facilitate systematic data collection and validation. The in-depth interview protocol for the below mentioned phases is available in the appendix.
1) Preliminary- introduction to the research topic, brief outline of the interview, consent confirmation.
2) Phase 1- knowledge regarding circular economy, involvement in circular projects, and socio-cultural barriers faced regarding the implementation of circular economy
3) Phase 2- introduction to cognitive biases, definition of each cognitive bias concerning the identified barrier and rating the impact on Mental Modeler, identification of interconnections between these cognitive biases.
4) Phase 3- confirming the constructed Fuzzy Cognitive Map, discussing mitigation strategies, and closing statements.

The framing of the interview questions is done with the aim to achieve the following:
1. Confirm and refine identified socio-cultural barriers through participant insights.
2. Identify and analyse cognitive biases relevant to the transition towards circular practices.
3. Validate the relationship between cognitive biases and socio-cultural barriers.
4. Develop an FCM to visualize and model the interrelations between identified cognitive biases and their impact on the lock-in of linear economy practices.
5. Develop semi-quantitative impact assessments using a Fuzzy Cognitive Map
These outcomes collectively contribute to a holistic understanding of the cognitive landscape (lock-in and biases) within the construction industry, offering actionable insights for overcoming the identified biases, thus catalysing the transition towards a circular economy.

It is important to note that the Participants were asked to rate the impact of the biases as observed within the industry.

3.3.2 Inclusion Criteria for Interviewees:

The research will adopt an organizational-level perspective to capture a comprehensive understanding of biases and barriers. This approach allows for a broader examination of influential factors that may transcend individual projects. The participant for the interviews must fall into the following criteria:

- Circular Project Engagement: Individuals actively involved in the execution or decision-making processes of at least one circular economy project within the construction industry will be eligible for participation.

- Regime-Level Stakeholders: The focus will be on engaging stakeholders at the regime level, ensuring representation from various facets of the construction process. This includes project managers overseeing multiple projects, architects responsible for design considerations, contractors managing construction aspects, and design heads influencing the creative and conceptual phases.

Through employing a purposive sampling method for selecting interviewees, considerations were made to balance both feasibility and generalizability of the results. The selected criteria ensured that interviewees were directly involved in circular economy projects, thereby enhancing the relevance and applicability of their insights to the research objectives. By including stakeholders such as project managers, advisors/consultants for circular economy, and architects, a diverse range of perspectives within the construction industry were represented, increasing the likelihood of capturing a comprehensive understanding of cognitive biases in relation to implementing CE within the industry. While the sample size was limited to seven interviewees for practical reasons, efforts were made to ensure that the selected participants offered a breadth of experience and expertise. The semi-quantitative data obtained from the interviews provides valuable insights and rich contextual understanding, which can be extrapolated to similar settings and contribute to a broader discourse on cognitive biases and circular economy adoption within the industry.

Based on the above-mentioned criteria, 7 interviews of 60 minutes each were conducted with the following credentials:

Participant	Designation	Experience (years)
P1	Project Manager	5
P2	Project Manager	10
P3	Advisor for CE	2
P4	Consultant for CE	4
P5	Built Environment Consultant	2
P6	Senior Architect	12
P7	Architect	8

Table 3: Interviewees' Description

In conclusion, the empirical study chapter reveals a consensus among interviewees on the significant influence of cognitive biases and socio-cultural barriers on the adoption of circular economy principles in construction. The development and analysis of Fuzzy Cognitive Maps (FCMs) detailed in the Data Analysis chapter underscore this connection, providing a visual and analytical representation of these impacts. Furthermore, discussions with interviewees on various mitigation measures, set to be elaborated in the Recommendations chapter, highlight the proactive steps being considered to navigate and overcome these challenges. This comprehensive approach not only validates the intricate relationship between biases and barriers but also paves the way for identifying effective strategies for advancing circular economy practices in the construction industry.

3.4 Data Analysis and Results

After the empirical study, the collected data on cognitive biases is subjected to further analysis to gain a comprehensive understanding of the cognitive lock-in of the linear economy within the construction industry. The structured approach taken to explore cognitive biases, particularly in relation to its impact on the cognitive lock-in of linear economy, is further interpreted to gain valuable results.

The content analysis method employed in this study is manifested content analysis. This approach involves staying close to the actual conversations that occurred during the impact rating of cognitive biases by the interviewees. It focuses on the explicit and visible aspects of the text, using the words and statements made by participants to derive insights (Bengtsson, 2016). By adhering to manifested analysis, the study aims to capture the surface-level content and explicit expressions of cognitive biases and cognitive lock-in as articulated by the participants. The study prioritizes a straightforward examination of the content to extract meaningful insights into the cognitive lock-in of the linear economy and its implications for the adoption of circular economy principles within the construction sector.

This analysis would provide the answer to sub-research question 3- the contribution of cognitive biases towards the cognitive lock-in of linear economy.

4 Relationship between Socio-Cultural Barriers and Cognitive Biases

After the meticulous examination of existing literature, a significant connection emerges between the identified relevant socio-cultural barriers and cognitive biases. Intrinsically, socio-cultural barriers are both a consequence and a cause for established norms, existing pathways, preconditions, and perceptions within a community or industry. Cognitive biases refer to the systematic patterns of deviation from rationality in judgment and decision-making that affect human thought processes. Similarly, socio-cultural barriers refer to the behavioural and managerial issues emerging from the attitudes, opinions and motivations of the stakeholders involved. Notably, the human thought process is the common ground for both cognitive biases and socio-cultural barriers.

While studying the impact of Cognitive Biases on the adoption of innovative sustainable technologies in the construction industry, Hofman et al. (2022) discussed the positive relationship between hassles and cognitive biases. Considering this connection between “hassles” and “barriers”, the definition of "hassle" is expanded beyond minor annoyances- to encompass any obstacle that impedes progress or complicates efforts to achieve a goal. For this research, the definition of "barrier" is broadened to not only include significant systemic obstacles, but also everyday challenges that, while seemingly minor, cumulatively have a substantial impact. Thus, the role of hassles as intensifiers of biases (Hofman et al., 2022) can also be extrapolated to the role of barriers on these cognitive biases.

The influence of these socio-cultural barriers upon rationality and decision making within an organisation or industry are undeniable. These barriers, often rooted in deeply ingrained norms and practices, seamlessly become proxies for cognitive biases, shaping decision-making processes and further reinforcing the resistance to circular practices. It can clearly be observed that socio-cultural barriers act as a pre-cursor to the presence of cognitive biases in the industry. Additionally, cognitive biases are also responsible for promoting certain socio-cultural barriers. Upon trying to relate the two concepts, socio-cultural barriers could be easily identified in the context of cognitive biases. This assumed relationship derived from the understanding of barriers and biases is depicted in fig. 5.

Due to this derived relationship, socio-cultural barriers are taken as a starting point for understanding cognitive biases in this research. In essence, the existence of socio-cultural barriers sets the stage for decision-making, and cognitive biases represent the deviations from the intended rational course of action within these complex socio-cultural contexts.

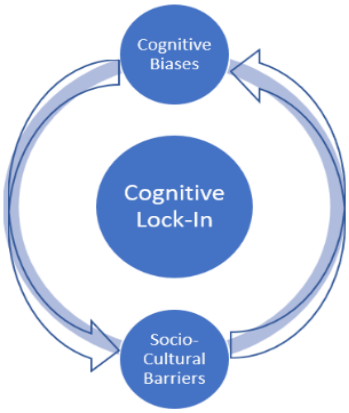

Figure 5: R/s of Barriers and Biases

As a result of the literature study, the identified socio-cultural barriers are placed within the categorisation of identified cognitive biases. For arriving at this categorisation, the definitions of individual socio-cultural barriers and cognitive biases were coded to find similarities. This categorisation is elaborated and discussed based on each cognitive bias. A detailed breakdown of the coded definitions is provided in the Appendix.

Status Quo bias placed with the barriers of: Resistance to change, ingrained linear mindset, construction sector inertia, and lack of lateral thinking.

Status quo bias refers to the preference for existing conditions to remain unchanged. Within the construction industry, there is a significant resistance to change, characterized by a deep-seated unwillingness to alter current practices and patterns. This resistance is further underscored by what is termed "Construction Sector Inertia," where there's a notable reluctance to deviate from established practices to embrace new innovations. These barriers are intrinsically linked to status quo bias, as they highlight a tendency among industry stakeholders to avoid change and maintain current practices, which is supported by the foundational work of Kahneman et al. (1991). The consequence of this bias is an "Ingrained Linear Mindset" where the traditional take-make-dispose economic model is preferred, and a "Lack of Lateral Thinking," indicating an adherence to established rules at the expense of innovative problem-solving. These barriers are illustrative of the status quo bias's influence, where the default option is to resist change and maintain existing behavioural patterns.

Cognitive Bias	Socio-Cultural Barrier
Status Quo *(Kahneman et al., 1991)*	Resistance to change *(Charef et al., 2021)*
	Ingrained linear mindset *(Osei-tutu et al., 2022)*
	Construction sector inertia *(Osei-tutu et al., 2022)*
	Lack of lateral thinking *(Charef et al., 2021)*

Figure 6: Status Quo + Barriers

Anchoring bias placed with the barriers of: Negative social pressures, lack of demand in composite construction, low image placed on reclaimed and recycled materials, and lack of trust and acceptance of reclaimed materials.

The barriers associated with this anchoring bias include "Negative Social Pressures," where there is a strong preference for traditional methods leading to resistance from key industry players such as manufacturers, builders, and owners, as highlighted by Ababio et al. (2022). It also encompasses a "Lack of Demand in Composite Construction," indicating a user preference for new over reclaimed materials, which obstructs market penetration of reclaimed materials, noted by Osei-Tutu et al. (2022). "Low Image Placed on Individuals Who Use Reclaimed and Recycled Materials," signalling a societal preference for standardized traditional materials over more sustainable options. Additionally, "Lack of Trust and Acceptance of Reclaimed Materials" is identified, where the preference is for materials that meet traditional standards over those that are recycled.

Cognitive Bias	Socio-Cultural Barrier
Anchoring Bias *(Strack et al., 1988)*	Negative social pressures *(Ababio et al., 2022)*
	Lack of demand in composite construction *(Osei-tutu et al., 2022)*
	Low image placed on reclaimed and recycled materials *(Osei-tutu et al., 2022)*
	Lack of trust and acceptance of reclaimed materials *(Osei-tutu et al., 2022)*

Figure 7: Anchoring Bias + Barriers

Overconfidence bias placed with the barriers of: Poor environmental perceptions, disbelief in the potential utility, and lacking sense of urgency.

The Overconfidence bias, detailed by Svenson (1981), is shown to lead to poor environmental perceptions (Ababio et al., 2022), where individuals believe they understand issues like climate change better than they actually do, potentially resulting in ineffective responses. It also fosters a disbelief in the utility of recycled materials (Charef et al., 2021), leading to an undervaluation of sustainable practices. Lastly, it contributes to a complacent attitude towards the urgency of industrial transformation (Mhatre et al., 2023), slowing down the adoption of necessary environmental changes.

Cognitive Bias	Socio-Cultural Barrier
Overconfidence Bias *(Svenson, 1981)*	Poor environmental perceptions *(Ababio et al., 2022)*
	Disbelief in the potential utility *(Charef et al., 2021)*
	Lacking sense of urgency *(Mhatre et al, 2023)*

Figure 8: Overconfidence Bias + Barriers

Confirmation bias placed with the barriers of: Lack of interest, bad image of CE, lack of trust in data, assumption that waste is inevitable, unrealistic hypothesis.

Confirmation bias, which is the tendency of individuals to favour information that affirms their pre-existing beliefs (Nickerson, 1998), leads to several interconnected barriers. Confirmation bias relates to a "Lack of Interest," as detailed by Ababio et al. (2022), where new information that could spark interest is disregarded if it conflicts with established beliefs. This bias also fosters "Unrealistic Hypotheses," with stakeholders clinging to unfounded assumptions about CE, only recognizing information that reinforces their scepticism (Osei-Tutu et al., 2022). "Lack of Trust in Data," where evidence supporting CE is dismissed because it does not align with current beliefs (Osei-Tutu et al., 2022). "Assumption that Waste is Inevitable," where any data contradicting the belief that waste is an intrinsic part of construction is mistrusted (Osei-Tutu et al., 2021). Lastly, it perpetuates a "Bad Image of CE," where misconceptions and negative stereotypes about CE are continuously validated by selectively accepting unfavourable information (Charef et al., 2021).

Cognitive Bias	Socio-Cultural Barrier
Confirmation Bias *(Nickerson, 1998)*	Unrealistic hypothesis *(Osei-tutu et al., 2022)*
	Bad image of CE *(Charef et al, 2021)*
	Lack of trust in data *(Osei-tutu et al., 2022)*
	Assumption that waste is inevitable *(Osei-tutu et al., 2022)*
	Lack of interest *(Ababio et al., 2022)*

Figure 9: Confirmation Bias + Barriers

Availability Heuristics placed with the barriers of: Lack of awareness, perception of second-hand materials being sub-standard, lack of empirical based literature, lack of education on CE strategies.

Availability Heuristics is a cognitive bias where people rely on immediate, easily recalled information, impacting perceptions and decision-making related to Circular Economy (CE) in the construction industry. This heuristic leads to a lack of awareness, as stakeholders default to familiar linear construction methods (Ababio et al., 2022) and perceive second-hand materials as inferior, influenced by the most readily available examples (Osei-Tutu et al., 2022). Furthermore, the bias contributes to a reliance on misconceptions rather than empirical evidence about barriers to CE (Osei-Tutu et al., 2022) and exacerbates the shortfall in CE education due to inadequate resources (Osei-Tutu et al., 2021).

Cognitive Bias	Socio-Cultural Barrier
Availability Heuristics *(Kahneman et al., 1991)*	Lack of awareness *(Ababio et al., 2022)*
	Perception of second-hand materials being sub-standard *(Osei-tutu et al., 2022)*
	Lack of empirical based literature on the barriers *(Osei-tutu et al., 2022)*
	Lack of education on CE strategies among stakeholders *(Osei-tutu et al., 2022)*

Figure 10: Availability Heuristics + Barriers

Sunk Cost Fallacy placed with the barriers of: Old production and consumption practices, strong belief that waste management is more expensive, Fear of additional construction costs.

The sunk cost fallacy is the inclination to continue an endeavour once an investment in money, effort, or time has been made (Kahneman et al. 1991). This cognitive bias can lead to a preference for old production and consumption practices due to an adherence to past investments rather than current efficiency or value, as noted by Ababio et al. (2022). The fallacy also reinforces a fear of incurring additional construction costs, with the misconception that continuing with old methods is more cost-effective than adopting new practices (Charef et al., 2021). Additionally, it supports the belief that waste management, specifically Construction and Demolition Waste Management (CDWM), is more expensive under new practices, reinforcing the continued use of outdated linear economy models (Osei-Tutu et al., 2021).

Cognitive Bias	Socio-Cultural Barrier
Sunk Cost Fallacy *(Kahneman et al., 1991)*	Old production and consumption practices *(Ababio et al., 2022)*
	Strong belief that waste management is more expensive *(Osei-tutu et al., 2022)*
	Fear of additional construction cost *(Charef et al., 2021)*

Figure 11: Sunk Cost Fallacy + Barriers

Short Termism placed with the barriers of: Lack of global vision, lack of incentives, uncertainty avoidance, hesitant company culture, want ROI quickly.

Green et al. (1994) characterizes short-termism as choosing smaller, immediate rewards over long-term benefits, leading to a lack of global vision for sustainability (Charef et al., 2021). This focus on the short term is linked to uncertainty avoidance, with organizations prioritizing quick gains over uncertain future benefits (Mhatre et al., 2023), and a lack of incentives for implementing CE due to inadequate immediate rewards (Osei-Tutu et al., 2022). The resultant company culture becomes risk-averse, seeking immediate return on investment and consequently, delaying or forgoing investment in long-term CE strategies.

Cognitive Bias	Socio-Cultural Barrier
Short Termism *(Green et al., 1994)*	Lack of global vision *(Charef et al., 2021)*
	Lack of incentives *(Osei-tutu et al., 2022)*
	Uncertainty avoidance *(Mhatre et al, 2023)*
	Hesitant company culture *(Mhatre et al, 2023)*
	Want ROI quickly *(Charef et al., 2021)*

Figure 12: Short Termism + Barriers

Professional Bias placed with the barriers of: Lack of expertise, Willingness to implement CE

Professionals who rely heavily on conventional practices due to a lack of expertise in newer, sustainable methods (Ababio et al., 2022) may develop a professional bias, where their perspective becomes limited by focusing only on the conventions of their profession (Linder, 1987). This bias reinforces deeply entrenched norms within the industry, making the familiar conventional practices more comfortable and preferable over the adoption of innovative CE approaches (Mhatre et al., 2023).

Cognitive Bias	Socio-Cultural Barrier
Professional Bias *(Linder, 1987)*	Lack of expertise *(Ababio et al., 2022)*
	Willingness to implement CE *(Mhatre et al, 2023)*

Figure 13: Professional Bias + Barriers

The following Table 4. summarises the integrated socio-cultural barriers and cognitive biases as discussed above. The sources for the socio-cultural barriers are also mentioned in the table. This table forms the answer to the 3rd sub-research question of this study.

Cognitive Bias	Socio-Cultural Barrier
Status Quo	Resistance to change
	Ingrained linear mindset
	Construction sector inertia
	Lack of lateral thinking
Anchoring	negative social pressures
	Lack of demand in composite construction
	Low image placed on individuals who use reclaimed and recycled materials
	Lack of trust and acceptance of reclaimed materials
Overconfidence	poor environmental perceptions
	Disbelief in the potential utility
	Lacking sense of urgency
Confirmation	Unrealistic hypothesis
	Bad image of CE
	Lack of trust in data
	Culture of waste behaviour: assumption that waste is inevitable
	lack of interest
Availability Heuristics	lack of awareness
	Perception of second-hand materials being sub-standard
	Lack of empirical based literature on the barriers
	Lack of education on CE strategies among stakeholders
Sunk Cost Fallacy	old production and consumption practices
	Strong belief that waste management is more expensive
	Fear of additional construction cost

Short Termism	Lack of global vision
	lack of incentives
	Uncertainty avoidance
	Hesitant company culture
	Want ROI quickly
Professional Bias	lack of expertise
	Willingness to implement CE

Table 4: Socio-Cultural Barriers + Cognitive Biases

After establishing the connection between the socio-cultural barriers and cognitive biases, it is important to validate the said connection and further the research on the cognitive biases. This builds the basis for carrying out the empirical research.

5 Data Analysis and Results

This chapter delves into the data analysis and results of the empirical study, focusing on understanding the intricate dynamics of cognitive biases and their impact on the lock-in of the linear economy within the construction industry. This analysis methodically examines the cognitive biases identified by the interview participants, discussing their highest and lowest-rated impacts within the framework of fuzzy cognitive maps (FCMs). Through this detailed examination, the nuances of cognitive biases as perceived by individuals directly involved in circular economy projects within the construction sector can be obtained.

Furthermore, the resultant FCM derived from the collective input of all interviewees is presented. This consolidated FCM provides a comprehensive overview of the cognitive lock-in landscape within the industry, highlighting common and divergent perspectives among participants.

In addition to discussing the resultant FCM, this chapter delves into the connections among cognitive biases and their influence on each other. By exploring the interrelationships between different biases, the complex web of cognitive biases shaping decision-making processes and behaviours within the construction industry can be uncovered.

Importantly, this section serves to provide a robust answer to sub-research question 3, which focuses on understanding the interplay between cognitive biases and cognitive lock-in, along with their implications for the adoption of circular economy principles in construction projects.

5.1 Interview Analysis

In this section, the analysis of seven interviews conducted as part of the empirical study is presented. This analysis exclusively talks about the highest and lowest rated impacts of cognitive biases, and the interviewee’s motivation behind it. Each participant is assigned the designation "P#" to maintain anonymity while facilitating clear discussion. Real-time impact scoring was employed during the second phase of each interview to gauge participants' immediate perceptions of cognitive biases’ impact on the lock-in of linear economy.

5.1.1 Participant P1

Anchoring Bias and Availability Heuristics received the highest impact scores, indicating their significant influence, while Professional Bias was assigned the lowest score, suggesting its relatively minor impact.

The participant's decision to assign a high score to Anchoring Bias and Availability Heuristics was influenced by the industry's lack of trust and acceptance of reclaimed materials. The prevalence of anchoring bias, characterized by a reliance on initial information or reference points, was said to be heightened in an industry where

scepticism towards unconventional materials is widespread. Similarly, the industry's limited awareness of circular economy (CE) principles amplifies the impact of availability heuristics, as stakeholders may rely on readily available information or existing practices due to their unfamiliarity with alternative approaches.

Conversely, the participant's decision to give a low score to Professional Bias was attributed to their perception of its diminished relevance in the current industry landscape. As the construction sector evolves and embraces innovative practices, the participant believes that traditional biases tied to professional identity or expertise are less influential. This perspective suggests that, compared to other biases, Professional Bias may hold less sway over decision-making processes in today's construction industry.

5.1.2 Participant P2

Confirmation Bias and Availability Heuristics received the highest impact scores, while Sunk Cost Fallacy was assigned the lowest score.

The participant's decision to assign a high score to Confirmation Bias was influenced by the prevailing hypothesis within the industry that circular economy (CE) is unrealistic and has a negative image due to its perceived complexity.

Similarly, the participant's ranking of Availability Heuristics higher was attributed to the industry's lack of awareness where stakeholders have limited exposure to CE concepts and rely on familiar practices. Additionally, the absence of comprehensive empirical literature on CE was said to exacerbate reliance on heuristic decision-making, further reinforcing the participant's perception of Availability Heuristics as a prominent bias.

Conversely, the participant decided to assign a low score to Sunk Cost Fallacy while suggesting that the industry is ready to invest in technologies departing from the linear economy.

5.1.3 Participant P3

Professional Bias received the highest impact score, while Anchoring Bias, Overconfidence Bias, and Short-termism were assigned the lowest scores.

The participant's decision to assign a high score to Professional Bias was influenced by the industry's shortage of trained professionals knowledgeable about circular economy (CE) principles. The participant noted a lack of expertise in identifying suitable CE strategies for specific projects, coupled with a general reluctance among professionals to embrace the complexities of CE.

Conversely, the participant's decision to assign low scores to Anchoring Bias, Overconfidence Bias, and Short-termism suggests a perception of diminishing relevance for these biases in the industry. For Anchoring Bias, the participant observed a positive shift in perception towards reclaimed materials, driven by client demand and

stakeholder initiatives. This indicates a departure from entrenched reference points, reducing the impact of Anchoring Bias. Similarly, the participant highlighted the industry's awareness of the negative global impact of construction industry on the environment, mitigating the influence of Overconfidence Bias. Additionally, Short-termism was deemed less relevant, reflecting industry trends towards longer-term sustainability goals and practices.

5.1.4 Participant P4

Confirmation Bias received the highest impact score, indicating its significant influence, while Anchoring Bias and Sunk-cost Fallacy were assigned the lowest scores.

The participant's decision to assign a high score to Confirmation Bias was influenced by the industry's general lack of interest in understanding and implementing circular economy (CE) principles. They noted a prevailing sentiment among stakeholders that CE is complex and low yielding, leading to a reluctance to invest time and resources in adopting CE practices. This suggests that Confirmation Bias, which involves favoring information that confirms pre-existing beliefs.

Conversely, the participant's decision to assign low scores to Anchoring Bias and Sunk-cost Fallacy reflects a perception of diminishing relevance for these biases in the industry. For Anchoring Bias, the participant observed an industry-wide adoption of reclaimed materials as a symbol of environmental stewardship. This indicates a departure from entrenched reference points, reducing the impact of Anchoring Bias. Similarly, Sunk-cost Fallacy was deemed less relevant, reflecting ongoing investments in transitioning towards more sustainable projects to enhance the company portfolio. This suggests a willingness among stakeholders to prioritize long-term sustainability goals over short-term financial considerations.

5.1.5 Participant P5

The highest impact scores were assigned to Status Quo Bias, Overconfidence Bias, Availability Heuristics, and Short-termism, while giving the lowest score to Anchoring Bias.

The participant's decision to assign high scores to Status Quo Bias and Overconfidence Bias was due to their perception of the construction industry as rigid and lacking awareness of the impact of the linear economy. This entrenched mindset is perpetuated by the industry's reluctance to deviate from established practices and its overconfidence in the effectiveness of current approaches.

Availability Heuristics was emphasized by P5, who noted that circular economy (CE) is still treated as a black box within the industry. This reliance on heuristic decision-making, based on readily available information, hinders the industry's understanding and adoption of CE principles.

Short-termism was also given a high score by P5, attributed to the industry's focus on immediate tangible benefits. The lack of immediate rewards from CE initiatives reinforces a short-term mindset, impeding long-term sustainability goals.

Conversely, P5 assigned a low score to Anchoring Bias, noting a shift in the industry towards embracing reclaimed materials and sustainable practices. However, P5 also highlighted a concerning trend of companies attempting to "green wash" their projects, indicating that while the industry is evolving, biases such as Anchoring Bias still persist in certain contexts.

5.1.6 Participant P6

Participant 6 (P6) allocated the highest impact scores to Confirmation Bias and Availability Heuristics, while awarding the lowest scores to Overconfidence Bias and Sunk-cost Fallacy.

Confirmation Bias was said to lead stakeholders to selectively interpret information that confirms their existing beliefs about circular economy (CE), reinforcing the reluctance to embrace CE principles. Availability Heuristics, characterized by decision-making based on readily available information, may exacerbate this scepticism by highlighting the perceived overload of information on CE without clear practical applications.

Moreover, P6 highlighted the practicality of CE as a key concern, reflected in their decision to assign a high score to Availability Heuristics. The participant noted that despite the abundance of information on CE, there remains a lack of tangible projects or evidence demonstrating its practicality in real-world contexts. This uncertainty contributes to stakeholders perceiving CE as unrealistic, fostering a closed mentality towards its adoption.

Conversely, P6 assigned low scores to Overconfidence Bias and Sunk-cost Fallacy, indicating a perception of diminishing relevance for these biases in the industry. P6 argued that investments in CE would be made once its tangibility and practicality are established through real-world projects and successes.

5.1.7 Participant 7

Participant 7 (P7) assigned the highest impact scores to Availability Heuristics and Confirmation Bias, while rating Professional Bias, Sunk-cost Fallacy, and Anchoring Bias the lowest.

Availability Heuristics were noted to contribute to a lack of consensus among stakeholders regarding circular economy (CE) strategies and business models. P7 observed that stakeholders often interpret CE differently, leading to communication challenges and differing perspectives on its implementation.

Confirmation Bias was also deemed influential by P7, who attributed it to the industry's lack of successful examples and the ambiguity surrounding the social impact of CE. This

bias may lead stakeholders to selectively interpret information that aligns with their existing belief.

Conversely, Professional Bias was deemed less relevant due to its limited applicability to the current context, suggesting that industry professionals have other reluctancies to implement CE, rather than their lack of expertise.

Sunk-cost Fallacy was rated low by P7, while reflecting a willingness among companies to invest in social value and capitalize on the first mover's advantage in adopting CE practices. This suggests a departure from past investment patterns driven solely by sunk costs, towards a more forward-thinking approach focused on long-term sustainability.

Anchoring Bias was also rated low, indicating a shift in the industry towards embracing new perspectives and practices, particularly in relation to the adoption of reclaimed materials and sustainable construction methods.

5.2 Resultant FCM

Based on the information obtained through the interviews, 7 FCMs were obtained, which can be viewed in the Appendix. These maps were then synthesised by computing the weighted geometric mean of matrices, assigning a minimal weight of 0.1 to null values, ensuring comprehensive data retention. This method while enriching analysis, also aided in visualising the complex nature of the impact of cognitive biases in transitioning towards a circular economy.

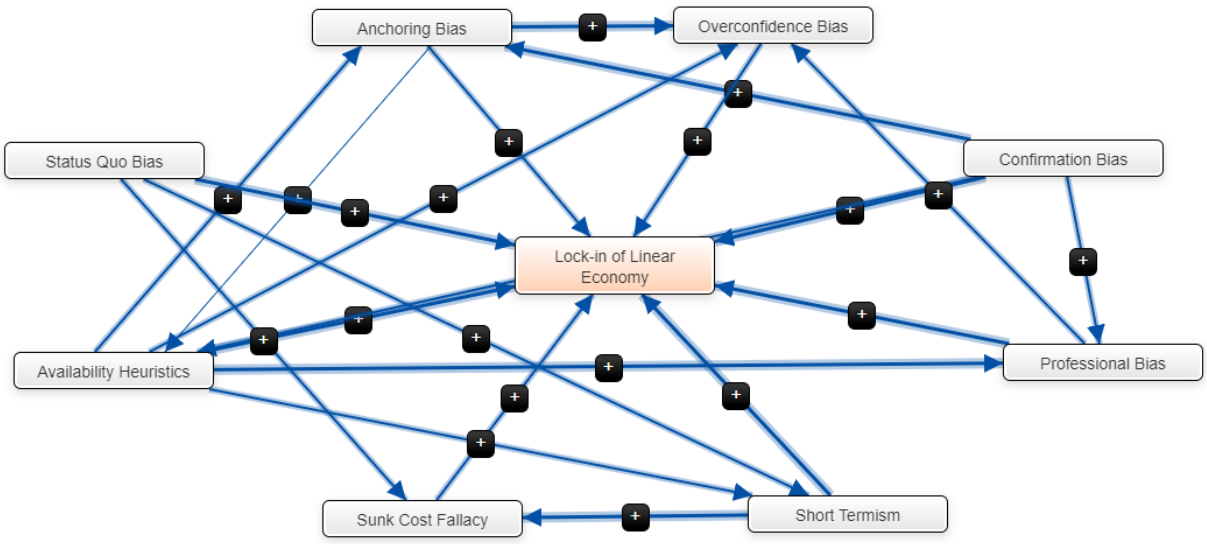

Figure 14: Resultant Fuzzy Cognitive Map

Figure 13 depicts the complex nature of the resultant map with several connections between each component. This map can be read easily through the resultant matrix with the impact scores for each component in Figure 14.

Notably, the components with the highest impact are Confirmation Bias and Availability Heuristics. Additionally, Status Quo Bias, Professional Bias and Short Termism also have a significant impact on the lock-in. In contrast, Anchoring Bias and Sunk Cost Fallacy have the least impact according to the resultant matrix. This matrix is placed in a bigger size in the Appendix for readability.

	Sunk Cost Fallacy	Short Termism	Availability Heuristics	Confirmation Bias	Overconfidence Bias	Anchoring Bias	Lock-in of Linear Economy	Status Quo Bias	Professional Bias
Sunk Cost Fallacy							0.41		
Short Termism	0.5						0.57		
Availability Heuristics		0.47			0.31	0.31	0.79		0.66
Confirmation Bias			0.47			0.53	0.71		0.47
Overconfidence Bias							0.46		
Anchoring Bias			0.16		0.63		0.39		
Lock-in of Linear Economy									
Status Quo Bias	0.31	0.31					0.54		
Professional Bias					0.47		0.54		

Figure 15: Resultant FCM Matrix

5.2.1 Highest Impact

The analysis of the resultant Fuzzy Cognitive Maps (FCMs) reveals that Anchoring Bias and Confirmation Bias were consistently rated with the highest impact scores, indicating their significant influence on the cognitive lock-in of the linear economy within the construction industry. Across the participants, all but one (P4) assigned a high impact score to Anchoring Bias, underscoring its influence on cognitive lock-in. Even in the case of P4, a relatively high impact score was assigned to Anchoring Bias, further highlighting its importance in shaping perceptions and behaviours within the industry.

Furthermore, Availability Heuristics high impact score reflects the widespread concern about the industry's limited awareness and education regarding CE. This bias was deemed particularly influential due to the perceived overload of information on CE, coupled with a lack of practical implementation examples. Participants emphasized the need for increased education and awareness initiatives to address this barrier effectively.

Similarly, Confirmation Bias emerged as a key bias, with the majority of participants (P2, P3, P4, P6, and P7) assigning it the highest impact score. While P5 and P1 rated it with a medium impact, the overall trend indicates its significant influence on cognitive lock-in of linear economy. Participants attributed the high impact of Confirmation Bias to lack of trust and acceptance of reclaimed materials, coupled with the perception of CE as unrealistic. Participants cited the absence of successful CE project references and a general scepticism about the feasibility of CE as reasons for this bias's influence.

Overall, the high impact scores assigned to Anchoring Bias, Confirmation Bias, and Availability Heuristics underscore the significant role of cognitive biases in

perpetuating the cognitive lock-in of the linear economy within the construction industry. Addressing these biases through targeted education, awareness initiatives, and practical implementation examples is essential to facilitating the transition towards a circular economy paradigm.

5.2.2 Lowest Impact

The analysis of the impact scores assigned to cognitive biases reveals that Anchoring Bias and Sunk-cost Fallacy received the lowest ratings across the participants, indicating a diminishing influence of these biases within the construction industry's decision-making processes.

Anchoring Bias was consistently rated with the lowest impact by the majority of participants (P3, P4, P5, and P7), reflecting a positive shift within the industry towards embracing reclaimed and recycled materials. Participants highlighted the growing influence of client demand and stakeholder interests in driving this change, leading to a reduced reliance on anchoring biases in decision-making processes. However, it is worth noting that one participant (P1) assigned the highest impact score to Anchoring Bias, suggesting some variability in perceptions among stakeholders.

Similarly, Sunk-cost Fallacy received low impact scores from several participants (P2, P4, P6, and P7), indicating a decreasing relevance of this bias in the industry. Participants noted a shift towards companies prioritizing the first mover's advantage in incorporating sustainable practices for construction projects. This strategic shift away from sunk-cost fallacy-driven cognitive lock-in reflects a growing awareness and commitment to long-term sustainability goals within the industry.

Overall, the decreasing impact scores assigned to Anchoring Bias and Sunk-cost Fallacy signal a positive trend towards more informed and forward-thinking decision-making processes within the construction sector. This shift is driven by evolving market dynamics, stakeholder expectations, and a growing recognition of the benefits associated with embracing circular economy principles. By acknowledging and addressing these biases, stakeholders can further accelerate the transition towards a more sustainable and circular construction industry.

5.3 Metrics of the Resultant FCM

Additionally, the software also provides information on the driver components of the resultant map. Driver components in a Fuzzy Cognitive Map (FCM) are elements (concepts or variables) that have a significant impact on the system modelled by the FCM. These components are identified based on their ability to influence other components within the map, acting as key drivers of behaviour or outcomes in the modelled system. Since they have a higher outdegree, these elements can influence many parts of the system. In the figure 7 below, the driver components are identified to be Status Quo Bias and Confirmation Bias. The receiver component in this map is the Lock-in of linear economy.

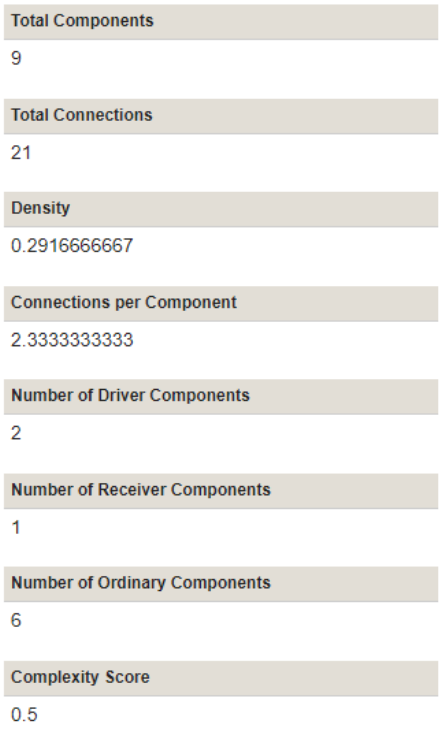

Figure 16: Metrics of Resultant FCM

Analysing these connections established within the resultant Fuzzy Cognitive Map (FCM), it becomes evident that the prominent driver components shaping the cognitive lock-in of the linear economy within the construction industry are Status Quo Bias and Confirmation Bias. These biases exert significant influence on decision-making processes and contribute to the resistance towards adopting circular economy principles.

Among the identified connections, a consensus emerges regarding the influence of Confirmation Bias on Anchoring Bias. This connection is consistently highlighted by multiple participants (P1, P2, P3, P6, and P7), indicating a widespread acknowledgment of the reinforcing relationship between these biases. Confirmation Bias, characterized by the tendency to seek information that confirms existing beliefs or hypotheses, reinforces Anchoring Bias by perpetuating entrenched attitudes and preferences within the industry. This connection underscores the importance of addressing Confirmation Bias to mitigate its impact on decision-making processes and facilitate a more open-minded approach towards embracing circular economy principles.

Overall, the identified connections in the resultant FCM highlight the interplay between different cognitive biases and their collective influence on the cognitive lock-in of the linear economy within the construction industry. This forms the answer to the sub-research question 4. Recognizing and understanding these connections is essential for developing targeted interventions and strategies aimed at overcoming cognitive barriers and promoting the adoption of circular economy principles.

6 Discussions

6.1 Implications of the Study

This study was conducted in the context of the hampered implementation of CE in the construction industry. Existing research analyses the shortcomings of CE in detail and provide mitigation measures. However, solving the problems within the principles of circularity do not automatically imply that the industry will adopt these practices. Looking inward, the construction industry also needs to be examined on the basis of its' openeness and attatiude towards CE or any other new innovations. The apparent cognitive lock-in of linear economy is an important concept to address through this research as it aptly describes the current situation of the industry. The study acknowledges that while CE itself may require refinement, the industry's readiness to adopt such changes is also crucial. Combining the need for CE to evolve with the industry's inherent resistance creates a formidable challenge for integrating CE into mainstream construction practices.

While Socio-cultural barriers are for hampered CE adoption; cognitive biases are for cognitive lock-in of linear economy. Together, they form the landscape of the research. Moreover, the connection between socio-cultural barriers and cognitive biases is an important step to fully understand the interconnectedness of the challenge. This connection implies that the challenges to implementing Circular Economy (CE) in the construction industry are deeply intertwined with both the cultural context and the mental models of stakeholders. It also suggests that addressing merely the technical and economic aspects of CE may not be sufficient; a comprehensive approach that also seeks to transform underlying attitudes, beliefs, and social norms is required. It indicates that stakeholders' perceptions and decision-making processes are influenced by existing societal practices and their inherent cognitive patterns, which can either facilitate or obstruct the adoption of CE. Understanding this relationship is crucial for developing targeted interventions that can effectively address both the external socio-cultural influences and the internal cognitive barriers to promote the circularity transition.

Considering the lack of existing research of cognitive sciences within the industry, this study explores the cognitive biases and their impact on the current state of the construction industry- which is the cognitive lock-in of linear economy. Through the data obtained on the impact of cognitive biases on the lock-in of linear economy, several implications can be made with respect to the attitudes and behaviours of stakeholders within this context.

Having the highest impact, Confirmation bias and Availability Heuristics relay a profound effect on reinforcing this lock-in. Confirmation bias leads stakeholders to favour information that supports their current practices, actively dismissing evidence that advocates for CE, thereby stifling innovation and the adoption of new and circular practices. Availability Heuristics exacerbates this by causing decision-makers to rely on the most immediately accessible information, which is often shaped by the prevalent

linear economic model, rather than seeking out or considering the long-term benefits and potential of CE practices. These biases together create a feedback loop that entrenches the current state of lock-in and significantly hampers the transition to CE.

The medium impact of Status Quo bias, Professional bias, Short Termism and Overconfidence bias also has significant implications on the involved stakeholders. Status quo bias induces a resistance to change, causing stakeholders to maintain existing, less sustainable practices due to a comfort with the known and fear of the new. This bias supports a mindset that is averse to the systemic shifts required for CE. Professional bias results in stakeholders viewing CE solutions through a narrow lens, based on their specialized knowledge and experiences, potentially discounting innovative solutions outside their expertise. Short termism limits the ability to plan for the future, as immediate gains are prioritized over the long-term benefits of CE, leading to decisions that might yield quick profits but are unsustainable. Additionally, Overconfidence bias leads stakeholders to underestimate the challenges of integrating CE, resulting in poor planning and execution, and ultimately to a dismissal of CE principles due to perceived failure or inefficiency.

Given their impact on other biases, Status Quo bias and Confirmation bias can skew the collective decision-making process within organizations and across the industry. These biases can lead to a widespread culture of conservatism, where innovative solutions and evidence supporting CE are not just ignored by individuals but systematically undervalued within group decision-making settings. Status Quo bias and Confirmation bias can amplify cognitive lock-in by creating a reinforcing cycle where stakeholders' pre-existing beliefs and preferences are continuously validated, which in turn strengthens the resistance to change. This cycle makes it particularly challenging to introduce new concepts and practices associated with CE, as stakeholders may not only resist these changes but also influence others within their professional networks to do the same.

Although on the lower scale of impact, Anchoring bias and Sunk Cost Fallacy provide significant insights into the current state of the construction industry. Anchoring bias leads to a reliance on initial information or traditional practices, skewing stakeholder perceptions away from CE adoption. However, the low impact score can be attributed to stakeholders looking to re-assess the value and potential of CE in the industry. Furthermore, Sunk Cost Fallacy's low score is a clear indication that the industry is ready to invest past linear practices. These low scores signify that the industry has not completely dismissed Circular Economy.

Recognising the prevalence of these biases informs us of several considerations and lessons, which form the basis for the mitigation strategies discussed in the subsequent chapter.

6.2 Theoretical and Practical Implications

This study enriches the theoretical landscape of construction management by providing empirical evidence on the dynamics of cognitive lock-in within the

construction industry. It contributes to the body of knowledge by highlighting the interplay between socio-cultural barriers and cognitive biases, thereby extending existing theories on circular economy adoption in construction. By empirically demonstrating how cognitive biases influence stakeholder decision-making and perpetuate linear economy practices, this research offers a nuanced understanding of the barriers to circular economy implementation. This could lead to the development of new frameworks or models that better explain the cognitive lock-in in the construction industry, contributing to theory on change management, sustainability, and innovation diffusion within this sector.

Practically, the findings offer actionable insights for industry stakeholders, policymakers, and practitioners aiming to facilitate the transition towards a circular economy in the construction sector. By identifying specific cognitive biases and socio-cultural barriers, this study provides a basis for targeted interventions, such as educational programs, policy reforms, and strategic initiatives designed to mitigate these biases and foster a more conducive environment for circular practices. Furthermore, the research underscores the importance of addressing both the cognitive and socio-cultural dimensions of change within organizations and the industry at large, suggesting that efforts to promote circular economy principles must consider the psychological and social aspects of decision-making processes. This could lead to the development of more effective strategies for overcoming the apparent lock-in, ultimately influencing the adoption of circular economy in the construction industry.

6.3 Comparing Theory and Results

The literature on implementing Circular Economy (CE) within the construction industry commonly cites the sector's rigidity and resistance to change as a significant barrier. This aligns with the concept of Status Quo Bias discussed in Section 4. However, the empirical results of this study reveal that Availability Heuristics and Confirmation Bias exert a more substantial influence on maintaining the lock-in of linear economy. This discrepancy highlights the nuanced nature of cognitive biases in shaping industry dynamics, underscoring the importance of considering multiple factors in addressing the industry's resistance to CE adoption.

Moreover, the resultant Fuzzy Cognitive Map (FCM) presented in Section 5.2 illustrates the intricate connections among cognitive biases within the landscape of cognitive lock-in. This interconnectedness suggests that cognitive biases do not operate in isolation but interact with each other, exacerbating the cognitive lock-in phenomenon. Furthermore, the identified socio-cultural barriers categorized within these cognitive biases in Section 4 demonstrate significant connections and mutual impacts, as evidenced by the empirical findings. While the literature extensively discusses socio-cultural barriers, this research contributes to understanding the potential interconnections among these barriers, shedding light on their complex dynamics within the construction industry.

Additionally, while the literature describes the concept of cognitive lock-in, it often overlooks its explicit connection to the hampered implementation of CE in the industry. Through the empirical study conducted in this research, interviewees discuss the profound impact of cognitive biases on cognitive lock-in within the linear economy. This discussion, contextualized within the scope of CE implementation in the construction industry, provides empirical evidence supporting the assertion that cognitive lock-in impedes the adoption of circular economy principles. This finding further enriches the understanding of the barriers hindering CE implementation within the industry.

6.4 Reflection on Methodology

This study utilised content analysis for deriving the relationship between Socio-cultural barriers and Cognitive biases, and Fuzzy cognitive mapping for identifying the impact of cognitive biases on the lock-in phenomena.

Content analysis offered a structured, qualitative approach that enabled the identification and understanding of socio-cultural barriers and cognitive biases from existing literature. This method's systematic nature allowed for a comprehensive review that highlighted recurring themes and patterns within the industry, contributing to a nuanced understanding of the factors that influence the transition to Circular Economy (CE).

While content analysis is a powerful tool for qualitative research, it does have limitations in its ability to capture the full complexity of how socio-cultural factors and cognitive biases interact in real-world scenarios. The method's reliance on published texts may also introduce a selection bias, as not all relevant opinions and experiences, especially those that are unpublished or exist within practice rather than theory, are captured.

Fuzzy cognitive mapping served as a valuable tool for quantifying the impact of various cognitive biases on cognitive lock-in. By incorporating elements of participant's knowledge and qualitative data, FCM provided a means to visualize and interpret complex relationships, offering a clear representation of how different biases might influence the adherence to linear practices. This approach helped quantify the abstract concept of cognitive lock-in, grounding it in measurable terms that can inform strategic decision-making.

Fuzzy cognitive mapping, though insightful for understanding and visualizing complex systems, may be constrained by the subjective nature of determining impact scores. The interpretation of impact can vary among experts, and while FCM attempts to mitigate this subjectivity through a consensus-building approach, it can still reflect the biases or knowledge gaps of those involved in the mapping process. Additionally, FCM's reliance on the availability and quality of the participant's input means that the results are only as reliable as the participant's current understanding.

In conclusion, while the methodologies employed in this study have provided valuable insights into the barriers to CE implementation in the construction industry, it is essential to acknowledge their limitations. Future research might address these by incorporating longitudinal studies, real-time industry observations, or a broader range of expert insights to validate and enrich the findings from content analysis and FCM.

6.5 Limitations

Despite the comprehensive synthesis of socio-cultural barriers and cognitive biases from the literature review, a limitation arises from this synthesis irrespective of their specific levels within the construction industry—be it regime, niche, or landscape. Since this research is scoped within the regime level, it overlooks the granularity required to pinpoint socio-cultural barriers and cognitive biases unique to this level, thereby potentially missing contextually relevant factors.

While the empirical study delves into the relationship between cognitive barriers and socio-cultural barriers, it neglects to explore potential associations with technical factors. Although discussions during the empirical study hinted at such connections, the research scope constrained the investigation to only socio-cultural aspects. Consequently, the full spectrum of factors influencing cognitive biases remains unexplored.

Practical constraints limited the sample size of the empirical study to seven participants. While this size was sufficient to gain valuable insights, a larger and more diverse participant pool could have provided richer data and enhanced the generalizability of the findings. A broader sampling scope would offer a more comprehensive understanding of the cognitive lock-in phenomenon within the construction industry, thus strengthening the validity of the research outcomes.

The empirical study involved building a FCM with the participant who would be reflecting on the impact of the cognitive biases as observed in the industry. It is important to note that the participant, while being objective of the impact, would inevitably rate the impact scores with a certain bias since they are a part of the very same industry that they are reflecting upon. The level of objectivity required would then also be varying between each participant, thus impacting the scores they assigned to the biases. This unaccounted bias of the participant is another limitation of this study.

7 Conclusions

This chapter synthesizes the findings from the empirical study on the adoption of circular economy principles within the construction industry, addressing each sub-research question and culminating in an answer to the main research question. This section encapsulates the insights garnered from the interviews, Fuzzy Cognitive Maps (FCMs) analysis, and literature review, highlighting the intricate dynamics of cognitive biases and socio-cultural barriers that influence cognitive lock-in within the sector.

Sub-research Question 1: Sociological Barriers to Implementing Circular Economy in Literature

The literature review identified several sociological barriers to implementing CE in the construction industry, including resistance to change, entrenched linear economy practices, and a lack of awareness and understanding of CE principles. These barriers reflect the industry's rigidity and the scepticism for circular economy, which impede the adoption of innovative and sustainable practices. The resultant Table 1: Synthesis of Socio-Cultural Barriers, is the answer to this sub-research question.

Sub-research Question 2: Cognitive Biases contributing toward the Cognitive Lock-in of Linear Economy

The concept of cognitive lock-in was first established in the literature review, and cognitive biases were identified as contributing factors for the persistence of cognitive lock-in of linear economy. Among the number of biases, relevant cognitive biases were identified through studies in the fields of construction industry and building energy decisions. The resultant Table 2: List of Cognitive Biases, is the answer to this sub-research question.

Sub-research Question 3: Relationship between Socio-cultural barriers and Cognitive Biases

The content analysis of the literature review revealed a significant relationship between socio-cultural barriers and cognitive biases. This question explores the relationship between the two, providing a foundation for understanding how external factors contribute to cognitive patterns that favor a linear economy. This interplay between sociological barriers and cognitive biases creates a self-reinforcing loop that perpetuates linear economy practices within the industry. The resultant Table 3: Socio-Cultural Barriers + Cognitive Biases provides the answer to this sub-research question.

Sub-research Question 3: Implications of Cognitive Biases to Cognitive Lock-in

Cognitive biases, particularly Confirmation Bias, Availability Heuristics, and Status Quo Bias play a crucial role in contributing to the cognitive lock-in of linear economy practices. These biases skew perception and decision-making processes, leading stakeholders to favour familiar linear practices over circular alternatives. The empirical findings highlighted how these biases manifest in the industry, affecting stakeholders' willingness to consider and adopt CE practices. The Figure 15: Resultant FCM Matrix,

provides the broad picture of the cognitive biases impact on cognitive lock-in of the linear economy. Furthermore, Section 6.1 in the Discussions chapter explores the implications of Cognitive biases in detail.

Main Research Question: Cognitive Lock-In at the Regime level impacting the Implementation of Circular Economy in the construction industry

Cognitive lock-in at the regime level of the construction industry, driven by a complex interplay of cognitive biases and socio-cultural barriers, significantly impedes the implementation of CE. The study's findings underscore the need for targeted interventions to address these biases and barriers. This includes increasing awareness and understanding of CE principles, showcasing successful implementations of CE to challenge existing biases, and fostering a cultural shift within the industry towards openness and innovation. Overcoming cognitive lock-in requires a concerted effort from all stakeholders to create an enabling environment for CE, characterized by a willingness to challenge and change existing practices and beliefs.

In conclusion, the transition to a circular economy within the Dutch construction industry is hindered by cognitive lock-in at the regime level, which manifests through deeply ingrained cognitive biases and socio-cultural barriers. Addressing these challenges is essential for fostering circular practices and achieving the industry's long-term sustainability goals. This study contributes to the understanding of these dynamics and offers a foundation for future research and practical interventions aimed at overcoming the barriers to CE implementation.

8 Recommendations

As we move forward from analysing the pivotal role of cognitive biases in the construction industry, a natural progression would be to delve into strategies for mitigating these biases. However, it is important to clarify that the scope of this research is centred on the exploration and identification of these biases rather than on developing comprehensive mitigation measures. Consequently, the recommendations presented in this chapter should be viewed as suggested directions for improvement rather than prescriptive solutions.

These measures are informed by an understanding of the context of cognitive lock-in within the industry, and supplemented by insights gained through the empirical study. While these recommendations are grounded in a careful examination of the current landscape, the extent of their effectiveness in directly counteracting the cognitive biases cannot be conclusively determined within the bounds of this research. They are, therefore, starting points for further investigation and practical application, aimed at enhancing the industry's approach to Circular Economy implementation amidst the challenges posed by cognitive biases.

1. Awareness and Education: (Sparrevik et al., 2021)

Education plays a pivotal role in mitigating cognitive biases by making stakeholders aware of their existence and impact. It is recommended to develop comprehensive training programs that include modules on recognizing and overcoming cognitive biases, promoting critical thinking, and exploring the benefits of Circular Economy practices. Such education initiatives should target all levels of the industry, from executives to on-site workers, ensuring a broad understanding and appreciation for CE principles. This recommendation would address Confirmation bias and Status Quo bias by providing stakeholders with new information and skills to challenge their existing beliefs and practices.

2. Feedback and Accountability: (Charef et al., 2021)

Implementing mechanisms for feedback on decision outcomes can help stakeholders understand the implications of their choices, fostering a culture of accountability. Regular reviews and audits of project decisions should be conducted to evaluate their alignment with CE principles and identify areas for improvement. This approach encourages reflective practice and learning from past decisions, promoting a shift towards more sustainable practices. This tackles Confirmation bias and Availability Heuristics by confronting stakeholders with objective data about their practices versus what the industry needs.

3. Long-Term Vision: (Sparrevik et al., 2021)

Promoting the long-term benefits of CE is crucial for overcoming the short-termism prevalent in the construction industry. Stakeholders should be encouraged to adopt a long-term perspective, with rewards and incentives aligned with the achievement of CE

goals. This might include recognition programs, tax incentives for sustainable practices, or preferential treatment in public procurement for projects demonstrating strong CE principles. This would directly counter the Short Termism bias and Sunk Cost Fallacy.

4. Circular Economy Manager: (Shanker & Sagi, 2017)

The appointment of a dedicated Circular Economy Manager for construction projects can significantly enhance the focus on CE practices. This role would be responsible for championing CE within projects, facilitating collaboration among stakeholders, and ensuring that CE principles are integrated into all phases of project planning and execution. This would tackle the Professional bias, Overconfidence bias and also impact all the other biases.

The impact of the above mentioned measures on the Cognitive biases is depicted in the figure 17. below. Additionally, certain measures which are not targeted at specific biases but at the industry overall are noted below.

Measure \ Bias	Status Quo	Anchoring	Overconfidence	Confirmation	Availability Heuristics	Sunk-Cost	Short Termism	Professional
Awareness and Education								
Feedback and Accountability								
Long-Term Vision								
Circular Economy Manager								

Figure 17: Measures vs Biases

5. Emphasizing the Role of Cognitive Biases:

Given the profound impact of cognitive biases on decision-making, it is crucial to highlight these biases in professional education and training programs. Workshops and seminars focusing on the identification and mitigation of biases such as Confirmation Bias, Availability Heuristics, and Status Quo Bias can empower professionals to make more informed and sustainable decisions.

6. Foster Collaborative Networks:

Encourage the formation of collaborative networks among construction firms, suppliers, academia, and government agencies to share knowledge, resources, and best practices related to CE. Such networks can facilitate the exchange of innovative ideas, foster partnerships for material reuse and recycling, and advocate for policy changes that support CE.

7. Leverage Technology and Innovation:

Invest in research and development of new technologies and materials that support CE principles. This includes modular construction techniques, reclaimed materials, and digital tools for resource management. Encouraging innovation through competitions, grants, and incubation programs can accelerate the development and adoption of CE solutions.

By implementing these recommendations, the Dutch construction industry can overcome the challenges posed by cognitive lock-in and socio-cultural barriers, paving the way for a more sustainable and circular future.

9 Future Work

The limitations identified in the research provide a valuable foundation for outlining future work. Addressing these limitations will not only enhance the understanding of cognitive lock-in within the construction industry but also broaden the scope of research to encompass a wider range of factors influencing the adoption of Circular Economy (CE) practices. The following areas for future research are recommended:

1. Granular Analysis of Socio-Cultural Barriers and Cognitive Biases:

Future studies should aim to dissect the socio-cultural barriers and cognitive biases at different levels of the construction industry, with a particular focus on niche and landscape levels, in addition to the regime level. Such granular analysis would enable a more nuanced understanding of the barriers and biases unique to each level and how they interact to influence the industry's transition towards CE. This approach could uncover contextually relevant factors previously overlooked, offering targeted insights for overcoming specific challenges.

2. Exploration of Technical Factors:

The identified gap in the exploration of technical factors and their potential associations with cognitive and socio-cultural barriers presents an opportunity for further research. Future work should include a comprehensive analysis of technical challenges, such as material compatibility, design limitations, and technological advancements, and how these challenges interact with cognitive biases and socio-cultural barriers. This broader perspective would provide a more complete picture of the obstacles to CE adoption and identify potential leverage points for intervention.

3. Expanding Empirical Study Scope and Participant Diversity:

To overcome the limitations posed by the small sample size and enhance the generalizability of the findings, future research should aim to include a larger and more diverse group of participants. This could involve engaging stakeholders from different segments of the construction industry, including policymakers, material suppliers, construction firms, and end-users. A broader sampling scope would allow for a richer data set, enabling a more comprehensive understanding of cognitive lock-in phenomena and the effectiveness of different mitigation strategies.

4. Longitudinal Studies:

Conducting longitudinal studies to track changes and developments over time would provide insights into the dynamic nature of cognitive lock-in and the long-term effectiveness of interventions aimed at promoting CE practices. Such studies could help

identify trends, patterns, and shifts in attitudes towards CE, contributing to a deeper understanding of how cognitive biases and socio-cultural barriers evolve.

5. Cross-Cultural Comparisons:

Exploring cognitive lock-in and barriers to CE adoption in different cultural and geographical contexts would enrich the global understanding of these challenges. Comparative studies across countries or regions could reveal how cultural differences impact the perception and implementation of CE practices, offering valuable lessons for tailoring strategies to specific contexts.

6. Integration of Multi-Disciplinary Approaches:

Future work could benefit from integrating perspectives from psychology, sociology, economics, and environmental science to create a multi-disciplinary framework for analysing and addressing the challenges of transitioning to CE. This approach would encourage the development of holistic solutions that consider the complex interplay between human behaviour, industry practices, and environmental sustainability.

By addressing these areas, future research can build on the findings of this study to further advance the knowledge and implementation of Circular Economy practices within the construction industry and beyond.

10 References

Ababio, B. K., & Lu, W. (2023). Barriers and enablers of circular economy in construction: a multi-system perspective towards the development of a practical framework. *Construction Management and Economics*, *41*(1), 3-21.

Adams, K. T., Osmani, M., Thorpe, T., & Thornback, J. (2017). Circular economy in construction: current awareness, challenges and enablers. Proceedings of the Institution of Civil Engineers-Waste and Resource Management,

Attia, S. (2018). *Regenerative and positive impact architecture: Learning from case studies*. Springer.

Bao, Z., & Lu, W. (2020). Developing efficient circularity for construction and demolition waste management in fast emerging economies: Lessons learned from Shenzhen, China. *Science of the Total Environment*, *724*, 138264.

Bengtsson, M. (2016). How to plan and perform a qualitative study using content analysis. *NursingPlus open*, *2*, 8-14.

Bocken, N. M., De Pauw, I., Bakker, C., & Van Der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of industrial and production engineering*, *33*(5), 308-320.

Busenitz, L. W., & Barney, J. B. (1997). Differences between entrepreneurs and managers in large organizations: Biases and heuristics in strategic decision-making. *Journal of business venturing*, *12*(1), 9-30.

Çetin, S., De Wolf, C., & Bocken, N. (2021). Circular digital built environment: An emerging framework. *Sustainability*, *13*(11), 6348.

Charef, R., Morel, J.-C., & Rakhshan, K. (2021). Barriers to implementing the circular economy in the construction industry: A critical review. *Sustainability*, *13*(23), 12989.

Circular Economy Action Plan. (2020).

A circular economy in the Netherlands by 2050. (2016).

Daniel, P. A. (2022). Multi-level perspective framework in macro project studies: Towards a complex project organizing approach to sustainability transitions. *International Journal of Project Management*, 865-870.

de Koning, A., & van der Voet, E. (2022). Verwachte vraag naar grondstoffen in Nederland in 2030.

Densley Tingley, D., Giesekam, J., & Cooper-Searle, S. (2018). Applying circular economic principles to reduce embodied carbon. *Embodied carbon in buildings: Measurement, management, and mitigation*, 265-285.

The European Green Deal. (2019).

Flores-Colen, I., & Silvestre, J. (2017). Emphasizing the Importance of Life Cycle Assessment and Ecotoxicological Studies of Construction Materials. *Environ Toxicol Stud J*, *1*(1), 02.

Foxon, T. J. (2013). Technological lock-in. *Encyclopedia of Energy, Natural Resource, and Environmental Economics*, *1*, 123-127.

Geels, F. W. (2011). *The multi-level perspective on sustainability transitions: Responses to seven criticisms*.

Ghufran, M., Khan, K. I. A., Ullah, F., Nasir, A. R., Al Alahmadi, A. A., Alzaed, A. N., & Alwetaishi, M. (2022). Circular Economy in the Construction Industry: A Step towards Sustainable Development. *Buildings 2022*, no.7.

GlobalABC. (2019). *Global Status Report for Buildings and Construction*.

Green, L., Fristoe, N., & Myerson, J. (1994). Temporal discounting and preference reversals in choice between delayed outcomes. *Psychonomic Bulletin & Review*, *1*, 383-389.

Hanemaaijer, A., Kishna, M., Koch, J., Lucas, P., Rood, T., Schotten, K., & van Sluisveld, M. (2023). *Integrale Circulaire Economie Rapportage 2023*. PBL Planbureau voor de Leefomgeving.

Hofman, B., de Vries, G., & van de Kaa, G. (2022). Keeping things as they are: How status quo biases and traditions along with a lack of information transparency in the building industry slow down the adoption of innovative sustainable technologies. *Sustainability*, *14*(13), 8188.

Iacovidou, E., Millward-Hopkins, J., Busch, J., Purnell, P., Velis, C. A., Hahladakis, J. N., Zwirner, O., & Brown, A. (2017). A pathway to circular economy: Developing a conceptual framework for complex value assessment of resources recovered from waste. *Journal of cleaner production*, *168*, 1279-1288.

Initiative, C. G. R. (2021). *Circularity gap report 2021*.

Jacowitz, K. E., & Kahneman, D. (1995). Measures of anchoring in estimation tasks. *Personality and Social Psychology Bulletin*, *21*(11), 1161-1166.

Jetter, A. J., & Kok, K. (2014). Fuzzy Cognitive Maps for futures studies—A methodological assessment of concepts and methods. *Futures*, *61*, 45-57.

Jones, B. D. (2002). Bounded rationality and public policy: Herbert A. Simon and the decisional foundation of collective choice. *Policy Sciences*, *35*(3), 269-284.

Jones, P., & Comfort, D. (2018). The construction industry and the circular economy. *International Journal of Management Cases*, *20*(1), 4-15.

Kafetzis, A., McRoberts, N., & Mouratiadou, I. (2010). Using fuzzy cognitive maps to support the analysis of stakeholders' views of water resource use and water quality policy. In *Fuzzy cognitive maps: Advances in theory, methodologies, tools and applications* (pp. 383-402). Springer.

Kahneman, D., Knetsch, J. L., & Thaler, R. H. (1991). Anomalies: The endowment effect, loss aversion, and status quo bias. *Journal of Economic perspectives*, *5*(1), 193-206.

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, conservation and recycling*, *127*, 221-232.

Klotz, L. (2011). Cognitive biases in energy decisions during the planning, design, and construction of commercial buildings in the United States: an analytical framework and research needs. *Energy Efficiency*, *4*, 271-284.

Linder, S. H. (1987). On cogency, professional bias, and public policy: an assessment of four views of the injury problem. *The Milbank Quarterly*, 276-301.

MacArthur, E. (2013). Towards the circular economy. *Journal of Industrial Ecology*, *2*(1), 23-44.

MacArthur, E. (2015). Towards a circular economy: business rationale for an accelerated transition. *Greener Manag International*, *20*.

Marcon Nora, G. A., & Alberton, A. (2021). Sociotechnical Transitions Towards Sustainability in a Multilevel Perspective: overview and future perspectives. *Revista De Gestão Social E Ambiental*, *15*.

Mhatre, P., Gedam, V. V., Unnikrishnan, S., & Raut, R. D. (2023). Circular economy adoption barriers in built environment-a case of emerging economy. *Journal of cleaner production*, *392*, 136201.

Miller, N. (2021). *The industry creating a third of the world's waste*. https://www.bbc.com/future/article/20211215-the-buildings-made-from-rubbish

Murray, K. B., & Häubl, G. (2007). Explaining Cognitive Lock-In: The Role of Skill-Based Habits of Use in Consumer Choice. *Journal of Consumer Research*, *34*(1), 77-88. https://doi.org/10.1086/513048

The next normal in construction. (2020).

Nickerson, R. S. (1998). Confirmation bias: A ubiquitous phenomenon in many guises. *Review of general psychology*, *2*(2), 175-220.

Nodehi, M., & Taghvaee, V. M. (2022). Applying Circular Economy to Construction Industry through Use of Waste Materials: A Review of Supplementary Cementitious Materials, Plastics, and Ceramics. *Circular Economy and Sustainability*, 987-1020.

Norouzi, M., Chàfer, M., Cabeza, L. F., Jiménez, L., & Boer, D. (2021). Circular economy in the building and construction sector: A scientific evolution analysis. *Journal of Building Engineering*, *44*, 102704.

Osei-Tutu, S., Ayarkwa, J., Osei-Asibey, D., Nani, G., & Afful, A. E. (2023). Barriers impeding circular economy (CE) uptake in the construction industry. *Smart and Sustainable Built Environment*, *12*(4), 892-918.

Rakitta, M., & Wernery, J. (2021). Cognitive Biases in Building Energy Decisions. *Sustainability*, *13*(17), 9960. https://www.mdpi.com/2071-1050/13/17/9960

Rood;, A. H. M. K. J. K. P. L. T., & Sluisveld;, K. S. M. v. (2023). *Integral Circular Economy Report* P. N. E. A. Agency.

Shanker, M., & Sagi, R. (2017). A study on circular economy manager's skills in construction projects. *Anveshana's International Journal of Research in Engineering and Applied Sciences*, *VOLUME 2*(ISSUE 7).

Sparrevik, M., De Boer, L., Michelsen, O., Skaar, C., Knudson, H., & Fet, A. M. (2021). Circular economy in the construction sector: advancing environmental performance through systemic and holistic thinking. *Environment Systems and Decisions*, 1-9.

Svenson, O. (1981). Are we all less risky and more skillful than our fellow drivers? *Acta psychologica*, *47*(2), 143-148.

Unruh, G. C. (2000). Understanding carbon lock-in. *Energy policy*, *28*(12), 817-830.

van Teeffelen, I., Romijn-TU, H., & Kirkels-TU, I. A. (2020). Circular economy in the global south: A multi-level perspective case study analysis of waste-to-briquettes emerging technology in sub-Saharan Africa.

Voinov, A., & Gaddis, E. B. (2017). Values in participatory modeling: Theory and practice. *Environmental Modeling with Stakeholders: Theory, Methods, and Applications*, 47-63.

Zvirgzdins, J., Plotka, K., & Geipele, S. (2019). Circular economy in built environment and real estate industry. Proceedings of the 13th International Conference "Modern Building Materials, Structures and Techniques, Vilnius, Lithuania,

11 Appendix:

11.1 Coding for Barriers and Biases

Biases	Deducted Codes
Status Quo Bias	Established behaviours
	Do not change
	Unwillingness to change
Anchoring bias	Preference towards predefined practices
	Predefined standards preference
Overconfidence Bias	Overestimate one's ability
	Knowledge overestimation
	Inaccurate beliefs
Confirmation Bias	Beliefs they already have
	Deep-seated belief
	Disregard for new information
Availability Heuristics	Readily available information
	Available experiences
Sunk Cost Fallacy	Resources already spent
	Continue outdated methods
	Invested already
Short Termism	Immediate rewards
	Tangible benefits
Professional Bias	Entrenched norms
	Conventions of profession

Table 5: Code Sheet for Biases

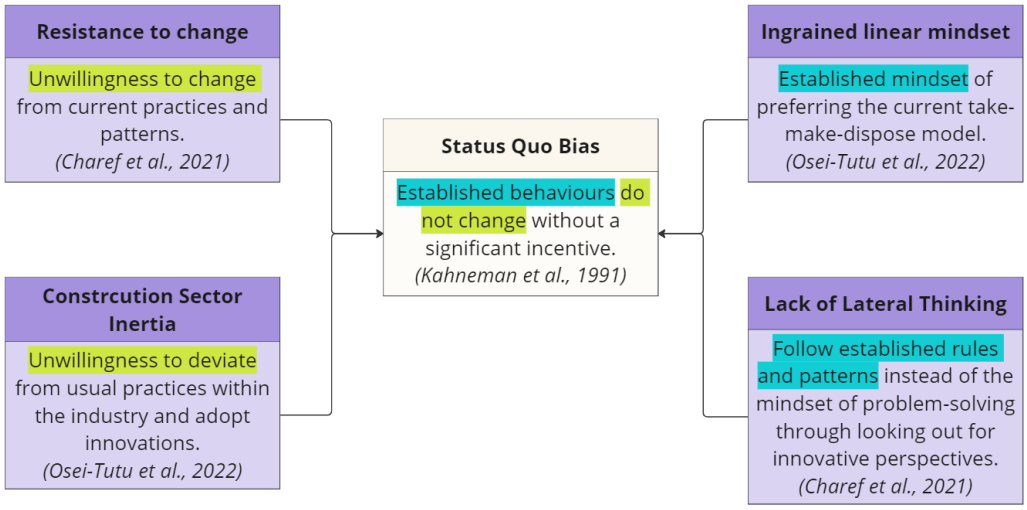

Figure 18: Status Quo Bias + Barriers

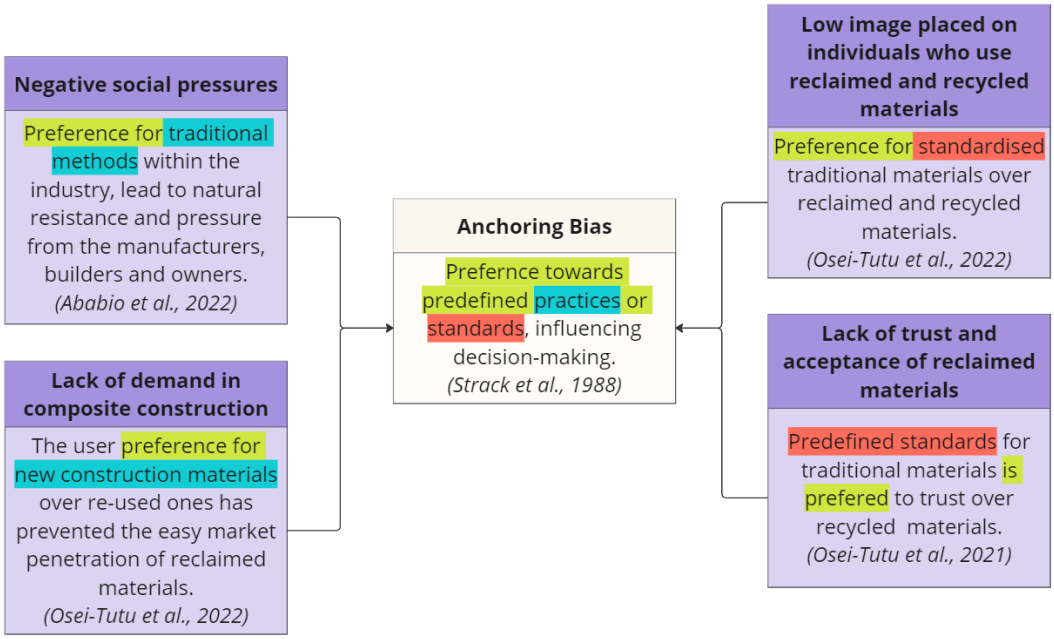

Figure 19: Anchoring Bias + Barriers

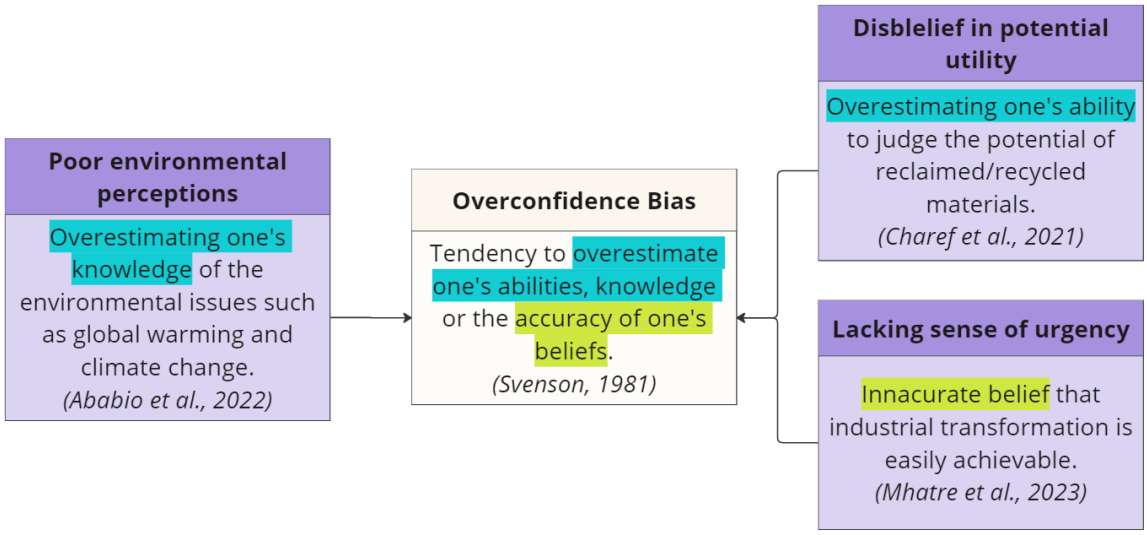

Figure 20: Overconfidence Bias + Barriers

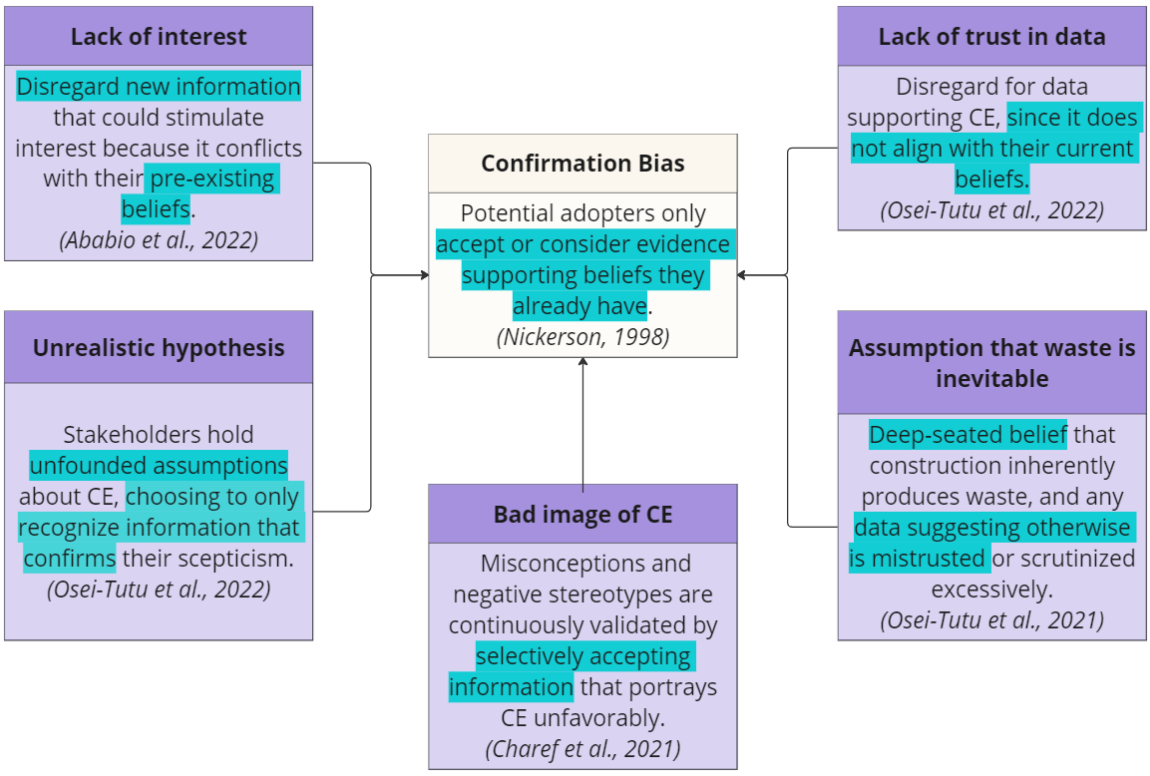

Figure 21: Confirmation Bias + Barriers

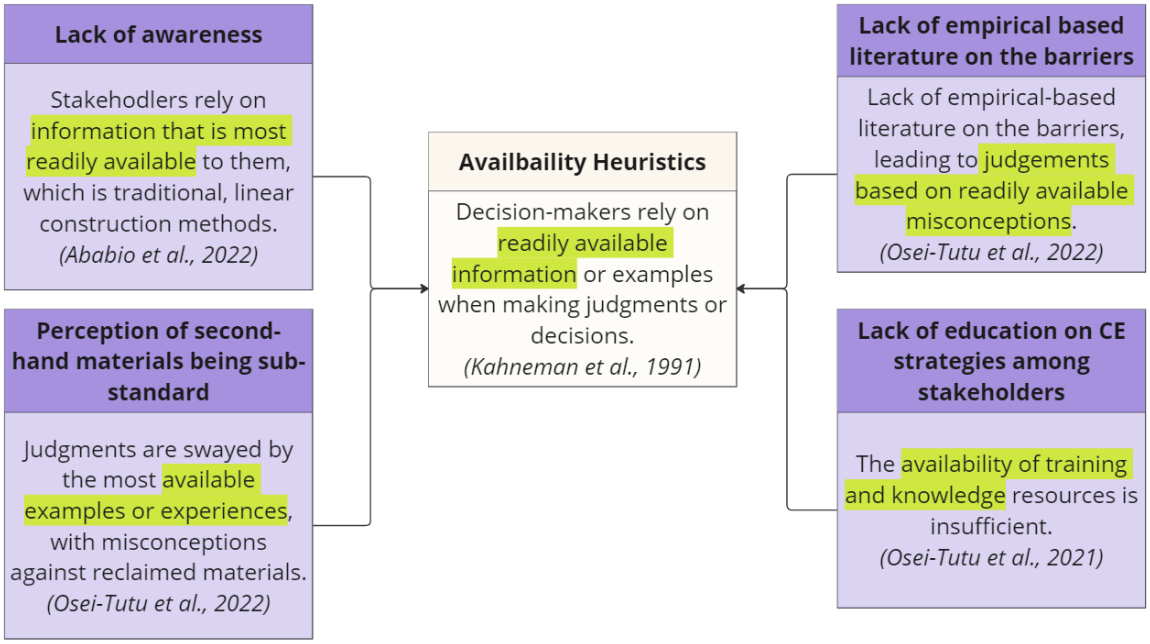

Figure 22: Availability Heuristics + Barriers

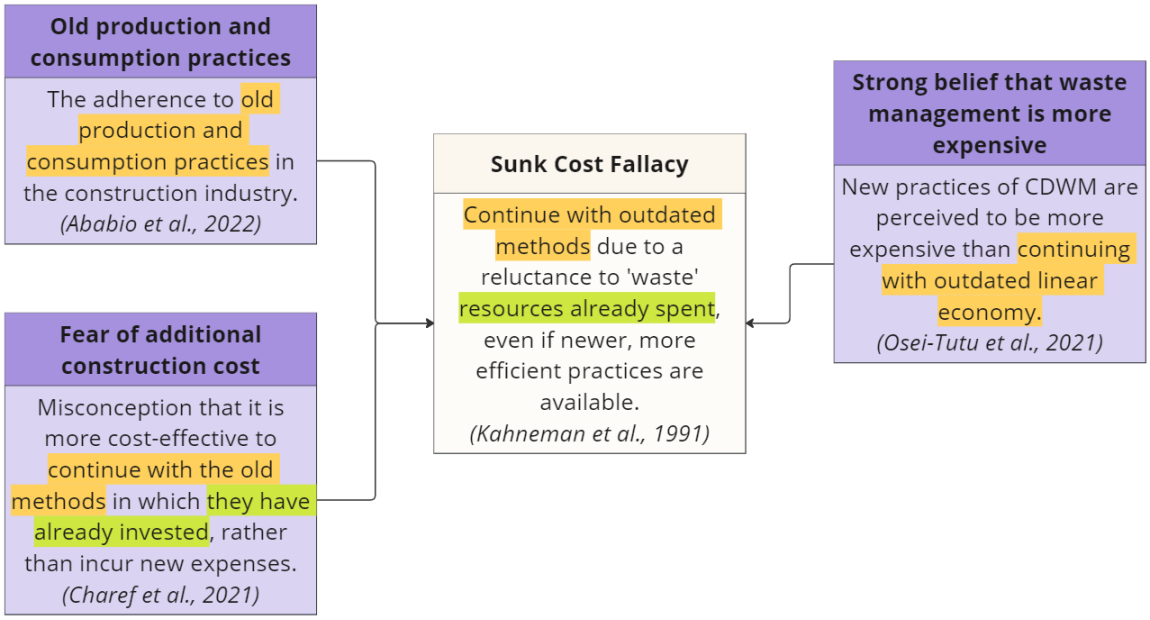

Figure 23: Sunk Cost Fallacy + Barriers

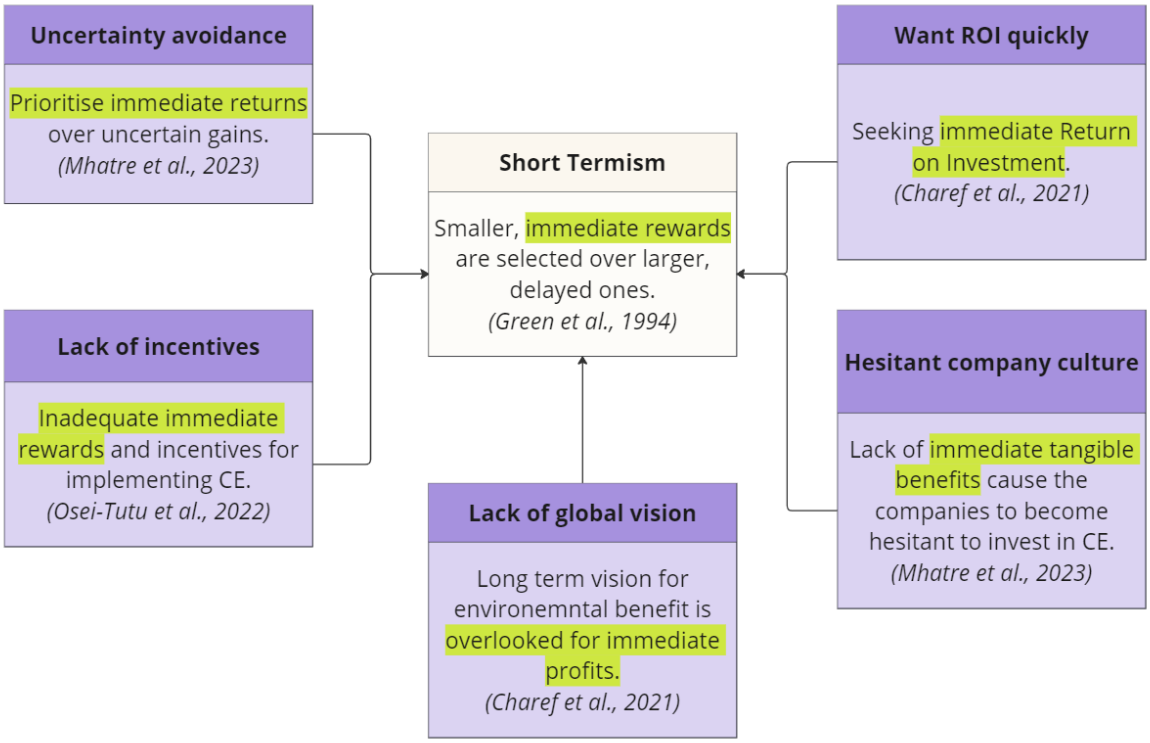

Figure 24: Short Termism + Barriers

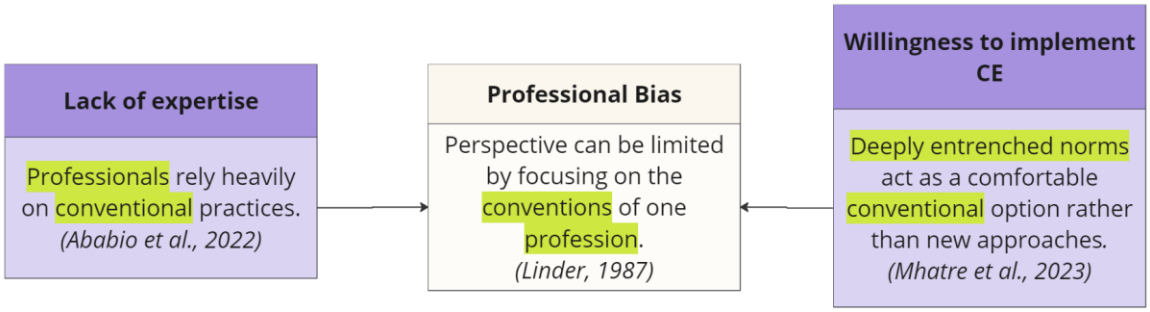

Figure 25: Professional Bias + Barriers

11.2 Interview Script:

[The text in blue italics is for the reference of the committee, depicting the flow of the interview. Actions of the interviewer and the interviewee are also mentioned in this blue text.]

Greetings! I am Sana Firdous, a student of MSc. Construction Management and Engineering. Today, we are about to delve into the topic of "Exploring cognitive lock-ins hindering the transition towards a circular economy in the construction industry". Within this topic, I will be looking to gather data regarding the various sociocultural barriers to implementing circular economy in this industry. More importantly, I will also be looking to identify and analyse the various cognitive biases that exist within the industry, hindering the Circularity Transition.

The 1 hour of this semi-structured interview, data will be collected in three phases. In the first phase, I will ask you questions regarding your knowledge and perception of circular economy in the construction industry. We will also be discussing the various barriers you would have identified/faced while working on a circular project. In the second phase, I will introduce to you the concept of Cognitive Biases and define the identified relevant biases. In this phase, we will together build a Fuzzy Cognitive Map through a software, upon which you will be asked to rate the impact of each cognitive bias. I will give you further details at the beginning of this phase. In the third phase, we will review the resultant Fuzzy Cognitive Map, and discuss possible mitigation measures in that context.

I encourage you to give comprehensive answers, along with your experiences that might motivate your replies. Let us begin with the first phase.

1) Considering the goals of the Netherlands of becoming fully circular by the year 2050, what is your perspective on the implementation of Circular Economy in the construction industry? Specifically, its current level of implementation and future scope within the sector?

2) Have you been involved in projects where circular practices were employed, and if so, what was your experience with their implementation?
3) To what extent do you believe stakeholders' attitudes towards Circular Economy influence its implementation within a project?
4) Can you identify reasons why the adoption of Circular Economy is not gaining widespread acceptance in the industry? In particular, what socio-cultural challenges are associated with its implementation?
5) Expanding on the previously mentioned challenges, can you provide instances where these barriers have hindered or led to the rejection of Circular Economy practices?

[Through this first phase of the interview, I expect to gather barriers that the interviewee would be able to name. Regarding this as a brainstorming session, I will simultaneously be noting the barriers mentioned, correlating them with the identified cognitive biases. This correlation would be for my reference only, so that I can bring it up when explaining the Cognitive Biases to the interviewee.]

Transitioning to the next segment of our discussion, I would like to explore cognitive biases that may be impeding the adoption of Circular Economy. As you can see on the screen, I have determined a list of biases which are relevant to the Circularity Transition in the construction industry *[proceeds to show fig.1].* As I go into the definition of each cognitive bias, I will also talk about the implications of these biases on the implementation of circular economy, so you can fully grasp these cognitive biases. *[Proceeds to show Table 2 and Table 3.]*

Considering these biases we have just discussed, I would like to review their connections with the barriers we discussed in the first phase of the interview. While reviewing the table, please give your thoughts on whether you deem this connection to be appropriate. Additionally, you are encouraged to think of any more barriers in relation to these biases. *[Proceeds to show Table 1 for validation from the interviewee. The placement of each barrier within its respective cognitive bias is discussed.]*

Through this thorough understanding of the manifestation of the cognitive biases in the industry, let us move on to assessing their impact. Please rate the impact of each bias on a scale of low-medium-high upon the lock-in of linear economy in the construction industry. You can use this scale for your reference *[proceeds to show fig.2].*

Let us move to the Mental Modeler software, where our Fuzzy Cognitive Map will be created. A Fuzzy Cognitive Map (FCM) was developed to structure expert knowledge using a soft systems programming approach that is "fuzzy". This approach is believed to closely resemble human decision-making processes and is particularly useful in analyzing societal perceptions in scenarios where uncertainty prevails and empirical data is scarce.

[I will be defining each cognitive bias as mentioned in table 2 and table 3. After explaining that specific cognitive bias to the interviewee, they will be directly asked to

rate that particular bias's impact on the lock-in of linear economy on the construction industry based on the scale in fig.2.

Simultaneously, the FCM will be prepared on the Mental Modeler, an example of which is depicted in fig.3. The end resultant FCM would have all the impact scores of the cognitive biases fed into the map.]

6) In your view, are there interconnections between different cognitive biases that impact or contribute to each other within this context? If so, how would you rate their interconnection, on the same scale [*fig.2*] as we have used so far?
7) Based on the definitions and implications of the cognitive biases we have discussed so far, I would like to bring back the discussion to the sociocultural barriers to the implementation of Circular Economy as we discussed in phase 1. We will now be looking at the interconnection between the barriers and biases- where, I have noted down several socio-cultural barriers from literature into the different categories of cognitive biases as shown in this table *[Proceeds to show table 1.]* As we look through each row, I would like you to validate the placement of the socio-cultural barriers into that particular cognitive bias. Additionally, I encourage you to add any new socio-cultural barriers that may come to your mind during this discussion.

[Proceeds to read out each socio-cultural barrier placed within each cognitive bias, and ask for the validation of the interviewee.]

8) Moving on to the last phase of the interview, does the resultant FCM relay what we have discussed so far? Would you like to make any changes to it?
9) In order to mitigate your identified cognitive biases, what impact do you think awareness would have on the stakeholders?
10) Do any mitigation measures come to your mind when we look at each cognitive bias and its manifestation in practice?

[Certain mitigation strategies will be discussed with the interviewee for validation. The strategies will be discussed as mentioned in fig. 5]

[Ending statements will follow]

11.3 Interview script- Sub Appendix:

Status Quo Bias	**Anchoring Bias**	**Overconfidence Bias**	**Confirmation Bias**
Availability Heuristics	**Sunk Cost Fallacy**	**Short Termism**	**Professional Bias**

Figure 26: List of Cognitive Biases

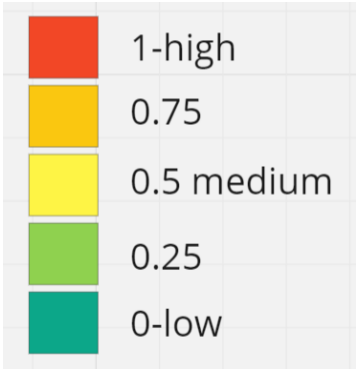

Figure 27: Scale for Grading FCM

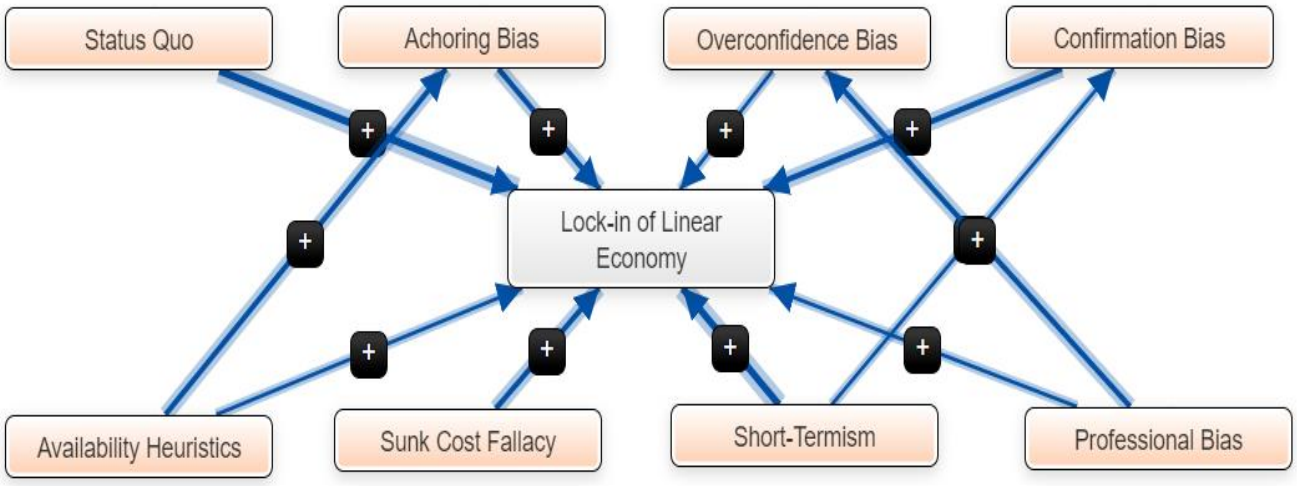

Figure 28: Reference FCM

	Lock-in of Linear Economy	Status Quo	Achoring Bias	Overconfidence Bias	Confirmation Bias	Availability Heuristics	Sunk Cost Fallacy	Short-Termism	Professional Bias
Lock-in of Linear Economy									
Status Quo	1								
Achoring Bias	0.5								
Overconfidence Bias	0.25								
Confirmation Bias	0.75								
Availability Heuristics	0.25		0.5						
Sunk Cost Fallacy	0.75								
Short-Termism	1				0.25				
Professional Bias	0.25			0.75					

Figure 29: Reference matrix with graded values for the above FCM

Bias	Barriers						
Status Quo	Resistance to change	Ingrained linear mindset	Construction sector inertia	Lack of lateral thinking			
Anchoring	negative social pressures	Lack of demand in composite construction	Low image placed on individuals who use reclaimed and recycled materials	Unrealistic hypothesis	Lacking sense of urgency: awareness and sense of urgency in society to transition	Lack of trust and acceptance of reclaimed materials	
Overconfidence	poor environmental perceptions	Disbelief in the potential utility					
Confirmation	lack of interest	Bad image of CE	Lack of trust in data	Culture of waste behavior assumption that waste is inevitable	Willingness to implement CE		
Availability Heuristics	lack of awareness	lack of resource availability	Perception of second-hand materials being	Lack of empirical based literature on the barriers	Lack of education on CE strategies among stakeholders	Aesthetic trend	
Sunk Cost Fallacy	old production and consumption practices	Strong belief that waste management is more expensive					
Short Termism	Lack of global vision	lack of incentives	Market preparedness	Uncertainty avoidnce	Hesitant company culture: inhibits willingness to engage in CE projects with lower initial returns/	Want ROI quickly	Fear of additional construction cost
Professional Bias	lack of expertise						

Table 6: Socio-Cultural Barriers + Cognitive Biases

Cognitive Bias	Cognitive biases refer to the systematic patterns of deviation from rationality in judgment and decision-making that affect human thought processes.
Status Quo	The tendency to prefer the current state of affairs and resist change. Individuals with status quo bias may exhibit reluctance to deviate from existing norms or practices
Anchoring	Relying too heavily on the first piece of information encountered when making decisions. The initial information, or anchor, influences subsequent judgments, often leading to biased decision-making.
Overconfidence	The tendency to overestimate one's abilities, knowledge, or the accuracy of one's beliefs. Individuals with overconfidence bias may exhibit unwarranted confidence in their judgments or capabilities.
Confirmation	The tendency to favour information that confirms pre-existing beliefs or attitudes while avoiding or downplaying information that contradicts them. Confirmation bias influences the interpretation of information in a way that aligns with existing views.
Availability Heuristics	Relying on immediate examples or information readily available when making judgments. Individuals employing availability heuristics may prioritize information that is easily accessible or comes to mind quickly, potentially leading to biased decision-making.
Sunk Cost Fallacy	The irrational decision to continue an a project based on previously invested resources, even if the costs outweigh the benefits. Sunk cost fallacy occurs when individuals consider past investments rather than objectively evaluating current and future outcomes
Short Termism	The tendency to prioritize short-term gains or outcomes over long-term benefits. Individuals exhibiting short-termism may focus on immediate advantages while neglecting the potential long-term consequences of their decisions.
Professional Bias	The influence of one's professional background, experiences, or expertise on decision-making. Professional bias occurs when individuals rely on their specialized knowledge, potentially overlooking alternative perspectives or solutions.

Table 7: Definitions of Cognitive Biases

Cognitive Bias	
Status Quo	Individuals may resist adopting circular practices, favouring traditional linear methods due to comfort with the existing state of affairs.
Anchoring	Initial information or practices may strongly influence decisions, potentially limiting the exploration of diverse circular alternatives; and leading to skewed decision-making.
Overconfidence	Actors may underestimate the resources, time, and organizational changes required for a successful transition to circular economy practices.
Confirmation	Individuals may selectively interpret data that aligns with existing beliefs, potentially overlooking evidence supporting the benefits of circular economy practices
Availability Heuristics	Relying on readily available information about traditional construction practices may bias decisions against exploring less familiar but potentially more sustainable circular alternatives.
Sunk Cost Fallacy	The industry may prioritize short-term gains, potentially overlooking the substantial long-term benefits associated with circular economy practices.
Short Termism	The construction industry's tendency to prioritize immediate gains or cost savings over the long-term benefits associated with the adoption of circular economy practices.
Professional Bias	Professionals with deep expertise in conventional construction materials and methods may be hesitant to adopt new, circular alternatives due to their familiarity with existing practices.

Table 8: Implications of Cognitive Biases

Mitigation Measures

1. **Awareness and Education**: Educate decision-makers about the existence and impact of cognitive biases. Awareness can prompt more deliberate consideration of alternatives. Provide training on recognizing cognitive biases and encourage critical thinking.(Sparrevik et al., 2021)
2. **Feedback and Accountability**: Provide feedback on decision outcomes. (Charef et al., 2021)
3. **Long-Term Vision**: Promote the benefits of CE over time and align rewards with circular practices.(Sparrevik et al., 2021)
4. **Circular Economy Manager:** CEMR to champion CE practices within construction projects, thus improving collaboration and awareness. (Shanker & Sagi, 2017)

Figure 30: Mitigation Measures

11.4 Consent Form:

Title of the Study: Exploring Cognitive Lock-in impacting Circular Economy Adoption within the Construction Industry

Researcher: Sana Firdous
Email: sanafirdous@student.tudelft.nl

Introduction: You are invited to participate in a research study aimed at understanding the cognitive factors influencing the adoption of circular economy practices in the construction industry. Before deciding to participate, it is important that you understand the nature of the study and your role as a participant.

Purpose: The purpose of this study is to gain insights into the socio-cultural barriers and cognitive biases affecting decision-making processes in the transition to circular practices within the construction industry.

Procedure: You will be asked to participate in a one-on-one, semi-structured interview. The interview will explore your experiences, perceptions, and opinions related to circular economy practices in the construction sector. The session is expected to last approximately 1 hour.

Confidentiality: All information obtained during the interview will be kept confidential. Your identity will be anonymized, and data will be securely stored. Only the researcher will have access to the recorded information.

Voluntary Participation: Your participation is entirely voluntary. You have the right to withdraw from the study at any time without consequence.

Potential Risks: There are minimal risks associated with participating in this study. However, if you feel uncomfortable or distressed during the interview, you are encouraged to express your concerns.

Benefits: Your participation will contribute to valuable insights that may enhance our understanding of cognitive influences on circular economy adoption, potentially

benefiting the construction industry in the future. By proceeding with the interview, you indicate your informed consent to participate in this study.

Participant's Name: _____

Participant's Signature: _____

Date: _____

This consent form aims to provide a concise overview of the study, ensuring that participants understand the purpose, procedures, and their rights. It is recommended to discuss any additional details verbally and address any questions participants may have before obtaining their consent.

11.5 Interview Summaries

Based on the discussed guidelines, interviews were conducted with 7 participants to obtain semi-quantitative data. Each interview lasted for 60minutes and was conducted after the participants signed the Consent Form in the appendix. The summaries of each interview (excluding the Fuzzy Cognitive Maps that were formed) are presented as follows.

Participant 1 (P1):

In Phase 1 of the interview, Participant 1 (P1) provided an overview of their understanding and experiences regarding the Circular Economy (CE) in the construction sector. P1 emphasized the growing interest in CE but noted its relative immaturity compared to energy transition initiatives. P1 shared insights from personal involvement in projects with circular components, highlighting the need for tangible evidence and data to support claims of circularity, especially from suppliers. The conversation identified several barriers to CE adoption, including financial constraints, time pressures, a lack of understanding of circular principles, safety concerns, and comfort with traditional methods. P1 also discussed the significant impact of socio-cultural factors, such as prevailing mindsets and behaviours, on the transition to circular solutions in construction. P1 emphasised the complexities and challenges involved in integrating CE principles into the construction industry.
In Phase 2, P1 examined the cognitive biases that impact the transition to Circular Economy (CE) in the construction industry. P1 discussed how various biases, such as the status quo, anchoring, overconfidence, and confirmation biases, contribute to the resistance to adopting CE principles. They provided insights into the extent to which these biases influence decision-making and maintain a preference for linear economy practices. P1 rated the impact of these biases, emphasizing their interconnected nature and the collective challenge they pose to the adoption of CE. This part of the interview highlighted the psychological and cognitive barriers to shifting towards sustainable practices in construction, suggesting a deep-rooted challenge beyond just technical and economic factors.

In Phase 3 of the interview, P1 focused on mitigation strategies for overcoming cognitive biases in adopting Circular Economy (CE) principles in construction. P1 reviewed and confirmed the accuracy of the Fuzzy Cognitive Map (FCM) developed during the interview, which outlined the interplay between various biases and their impact on CE adoption. This phase emphasized strategies to counteract these biases, highlighting the importance of increasing awareness among stakeholders in the construction industry. P1 suggested that a deeper understanding and acknowledgement of these biases could lead to more sustainable and circular decision-making processes. The discussion in this phase revolved around transforming the mindset of individuals and organizations to facilitate a smoother transition towards CE practices, reiterating the need for a holistic approach that addresses both psychological and practical aspects of this shift.

Participant 2 (P2):

In the interview with Participant 2 (P2), comprehensive view on the application and challenges of integrating a circular economy within industries is gained from P2's perspective. Considering the vast experience of the participant, P2 highlights the lack of awareness of CE as a concept among key stakeholders as a major barrier. Here, P2's suggests raising awareness and educating stakeholders on the benefits and practicalities of CE.

In phase 2, P2 agrees upon the importance of identifying and addressing persisting biases among stakeholders. P2 establishes that status quo is not a relevant bias anymore considering the willingness of the industry to shift towards energy-neutrality and zero carbon emissions. However, P2 also mentions the lack of expertise and the disbelief in the potential utility of CE as a major concern. P2 places the most importance on Availability Heuristics, Short-Termism and Confirmation bias. P2 also pointed out the impact of Confirmation on the other biases.

In phase 3, while discussing the mitigation measures, P2 states that identifying the mindsets and persisting biases among the stakeholders is an important 1st step. The inclusion of a Circular Economy Manager was enthusiastically agreed upon by P2. P2's optimism about the industry's capacity for transformation, was additionally supported by the importance of targeted education, and collaborative efforts. P2 also advocated for the positive long-term implications of these strategies for circularity and resilience in the face of global environmental challenges.

Participant 3 (P3):

Participant 3 (P3) initiates the dialogue by outlining the advantages of the circular economy (CE) in the construction sector, such as reduced waste and enhanced sustainability. However, the conceptualization of CE as a "black box" by many within the industry highlights a significant barrier—its perceived impracticality. There's a distinction in objectives between public and private projects, where alignment with CE principles isn't always guaranteed. Additionally, the social impact of CE, though recognized, often fails to resonate as a compelling value proposition for users. This

phase might further discuss the need for clearer demonstrations of CE's tangible benefits to bridge this gap.
The conversation deepens in the second phase, where P3 emphasizes the impact of confirmation and professional biases in the industry's reception of CE. These biases contribute to a resistance against new methodologies, favouring conventional practices. P3 stated that the availability heuristic plays a critical role, affecting stakeholders' comprehension of CE's full scope and potential. The linkage between professional experiences and the availability of CE-related knowledge suggests an intertwined challenge of perception and education. Expanding on this, addressing these biases requires targeted information dissemination strategies and educational programs to enhance CE understanding and acceptance.
In the concluding phase, the focus shifts to actionable solutions for overcoming the outlined barriers. The awareness around CE concepts is identified as a foundational step towards change. Introducing a role such as a Circular Economy Manager within organizations is proposed as an innovative approach to tackle availability heuristics and professional biases head-on. This role could serve as a culmination point for CE advocacy, education, and implementation, ensuring that the principles of CE are not only understood but actively integrated into projects. Additionally, P3 mentions the potential for these managers to facilitate cross-disciplinary collaborations and spearhead initiatives that demonstrate the practical and economic viability of CE practices in construction.

Participant 4 (P4):

Participant 4 (P4) emphasizes the crucial role of education in fostering an understanding of Circular Economy (CE) principles. However, P4 also critiques the paradox of information overload, where the abundance of data and guidelines can obscure the core values and practical steps toward CE implementation. While there's a growing focus on understanding and reducing embedded carbon—a critical aspect of CE—the industry's broader goal is evolving towards achieving net-zero emissions. P4 notes the complexity of CE as a significant challenge, indicating that its comprehensive adoption remains elusive.
In the second phase, P4 discusses how the inherent complexity of CE acts as a deterrent, intertwined with cognitive biases like availability heuristics and confirmation bias that further complicate adoption efforts. Interestingly, there's a mention of a recent departure from the status quo in the Dutch construction industry, signalling a shift towards more sustainable practices. P4 highlights how availability heuristics could exacerbate overconfidence and professional biases, with short-termism identified as another significant obstacle to the widespread implementation of CE principles.
The conversation shifts towards the transformative potential of CE pilot projects on stakeholder perceptions and behaviours. P4, aligning with the role of a Circular Economy Manager, reflects on the advantages and inherent challenges of this position in driving CE initiatives. The acknowledgment of cognitive biases and their impact on the industry's progression towards CE underscores the importance of awareness and strategic interventions. By understanding these biases, stakeholders can develop more

effective strategies to overcome barriers and foster a more sustainable, circular construction industry.

Participant 5 (P5):

In Phase 1 of the interview, Participant 5 (P5), a built environment consultant focusing on the Circular Economy (CE) in construction, delved into the challenges and perceptions among various stakeholders, including those in the financial sector, manufacturers, suppliers, architects, and contractors. P5 pointed out a significant gap in the understanding of CE concepts among investors and banks, which adversely affects the funding of circular projects. P5 observed a more robust grasp of circularity principles among architects and contractors but noted the critical lack of practical examples. Emphasizing the necessity of expanding the narrative to encompass social impacts, P5 highlighted the absence of a standardized framework for measuring these impacts. The discussion also covered the varying levels of acceptance and implementation of CE principles globally, with Europe leading due to policy drivers, in contrast to the bottom-up approach seen in the Global South. P5 concluded this phase by highlighting efforts to involve building users in circular initiatives, citing material passports and open design principles.

In Phase 2 of the interview, P5 focused on the cognitive biases affecting the transition to a Circular Economy (CE) in construction. P5 discussed biases like the status quo, anchoring, and confirmation biases, emphasizing their role in favouring traditional construction methods over CE practices. P5 highlighted the difficulty in altering long-established mindsets within the industry, pointing out the necessity for specific strategies to mitigate these biases. This phase emphasised the importance of addressing psychological barriers to facilitate the adoption of sustainable and circular practices in the construction sector.

In Phase 3, Participant 5 (P5) emphasized the importance of tailored approaches to mitigate cognitive biases impeding the adoption of Circular Economy (CE) in the construction industry. P5 discussed the critical role of education and training in altering entrenched mindsets and behaviours. By enhancing industry-wide understanding of CE concepts and benefits, P5 suggested that stakeholders could be more open to embracing sustainable practices. P5 also highlighted collaborative efforts, including partnerships between different industry players and policymakers, as essential in creating an enabling environment for CE. The need for policy interventions and incentives to drive behavioural change was also discussed. This phase focused on a holistic approach, combining education, collaboration, and policy support.

Participant 6 (P6):

Participant 6 (P6) discusses the significant barriers of financial constraints and time limitations in project execution, which hinder the implementation of Circular Economy (CE) principles in the construction industry. Despite a receptive industry eager for innovative solutions, the complexity of CE poses challenges in its practical application. P6 also highlights a critical mismatch between the demand for and the supply of CE

implementation strategies, underscoring the need for a more balanced approach to facilitate CE adoption.

P6 delves into the cognitive biases that impact the transition towards CE, with a particular focus on the status quo and confirmation biases. The discussion extends to the influence of availability heuristics, which exacerbates the challenge by affecting stakeholders' understanding of CE's practicality. P6 notes the interplay between status quo bias leading to short-termism and the sunk cost fallacy, which collectively stifle innovation and prolong dependence on traditional practices. The relationship between confirmation bias and availability heuristics further complicates stakeholders' ability to objectively assess CE's benefits and feasibility.

In this phase, P6 advocates for the phased implementation of CE across different projects to enhance acceptance and mitigate resistance. The emphasis on awareness programs and the identification of biases is recognized as crucial for advancing CE principles. P6 acknowledges the potential benefits of appointing a Circular Economy Manager but also reflects on the need for versatility in this role to address the multifaceted challenges of CE adoption. The concept of a first mover's advantage in CE initiatives, coupled with the importance of conducting feasibility studies, is highlighted as essential for promoting CE and demonstrating its viability to the industry.

Participant 7 (P7):

In the interview, Participant 7 (P7) discussed the integration of circular economy principles in construction. They observed that despite growing interest, circularity remained less developed than energy transitions, underscoring a need for concrete evidence to validate circular claims. Reflecting on projects incorporating circular elements, they note a trend beginning five years ago, with. They identified financial, time, and knowledge barriers, along with safety and comfort concerns, as obstacles to circular solutions. The architect also addresses socio-cultural challenges, emphasizing the role of financial incentives and market demand in encouraging circular practices. They point out that external pressures, such as client expectations and public opinion, drive companies towards circularity, despite the difficulties in achieving complete sustainability.

In Phase 2 of the interview, Participant 7 delved into cognitive biases impeding the shift towards a Circular Economy (CE) in construction. They discussed the dominance of biases such as the confirmation, short-termism and professional bias which collectively hinder the departure from traditional practices to embrace CE principles. Participant 7 highlighted the challenge of promoting CE as an efficient way towards sustainability among stakeholders and clients alike. This challenge also stemmed from the lack of expertise in the subject among the stakeholders.

In Phase 3, Participant 7 (P7), stressed the necessity for customized strategies to overcome cognitive biases against the Circular Economy (CE) in construction. P7 advocated for targeted education and training to change deep-seated industry mindsets and encourage the adoption of sustainable practices. Highlighting the significance of collaboration, P7 encouraged the inclusion of a Circular Economy Manager to help mitigate the challenges involved in a circular project.

11.6 Fuzzy Cognitive Maps (FCMs) of individual interviewees:

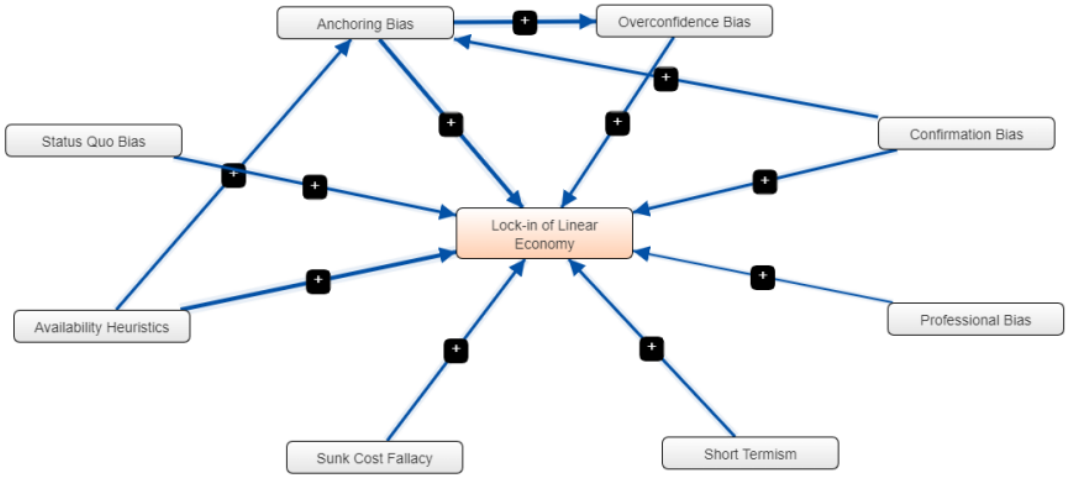

Figure 31: FCM of P1

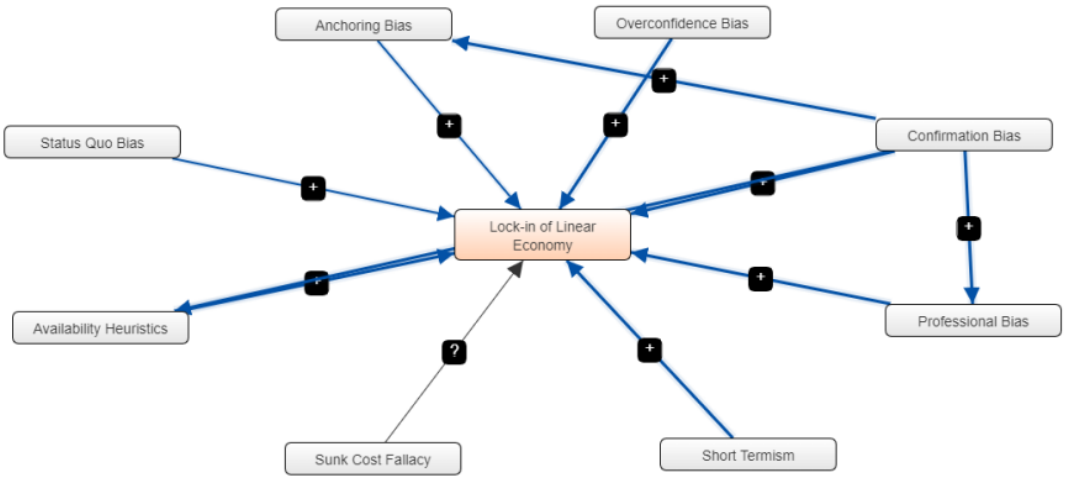

Figure 32: FCM of P2

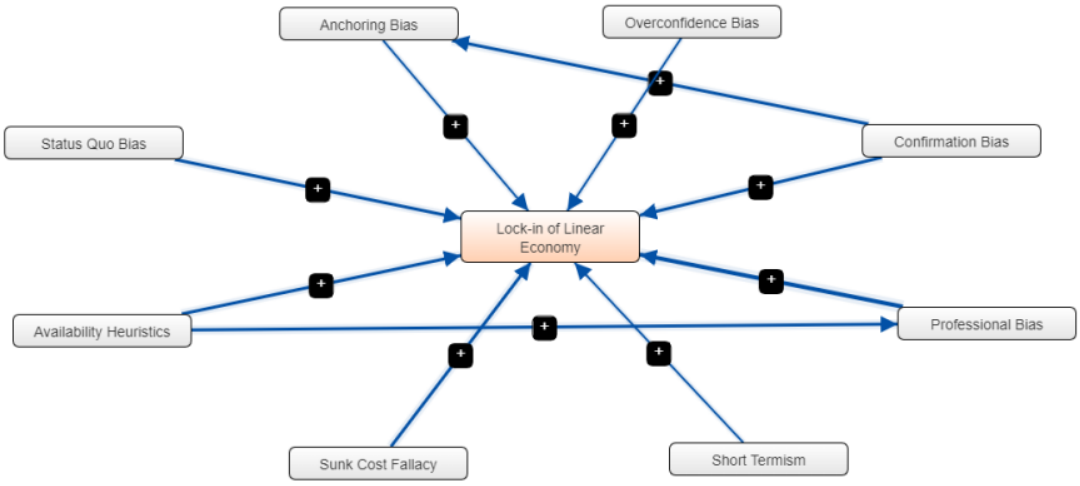

Figure 33: FCM of P3

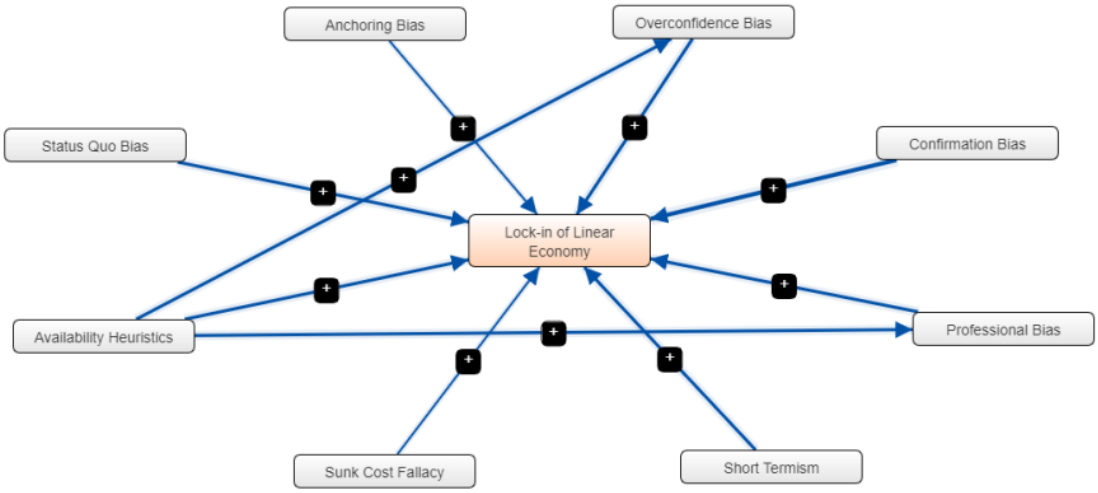

Figure 34: FCM of P4

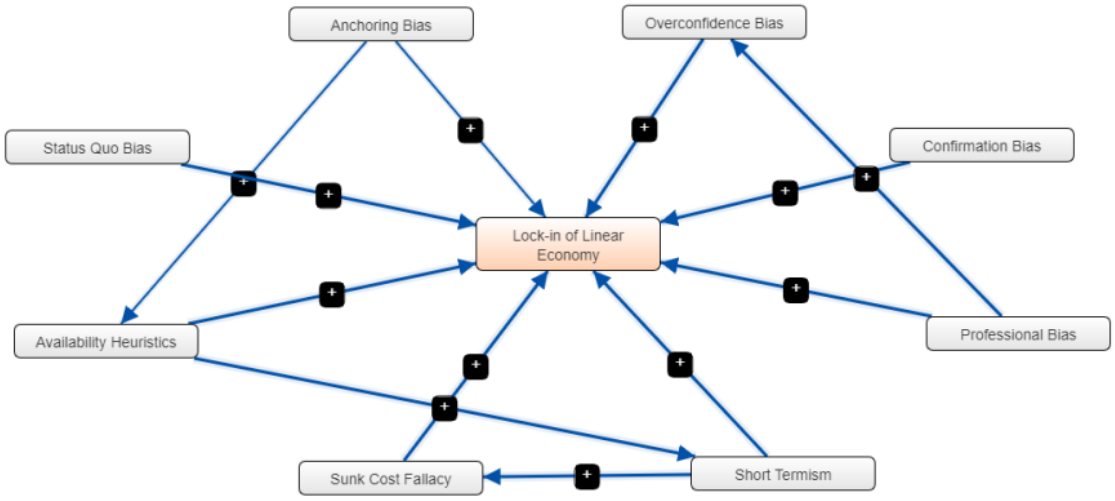

Figure 35: FCM of P5

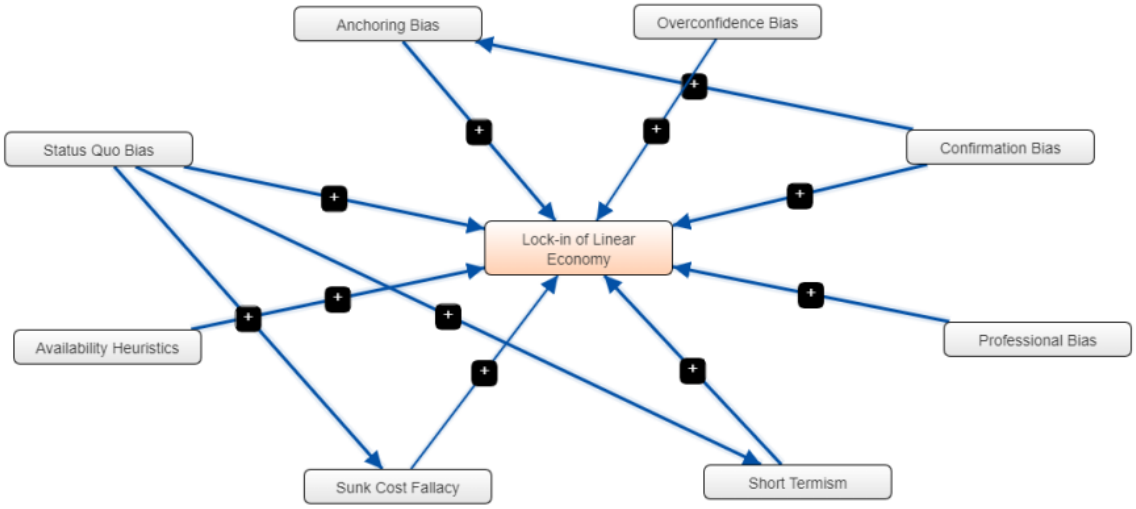

Figure 36: FCM of P6

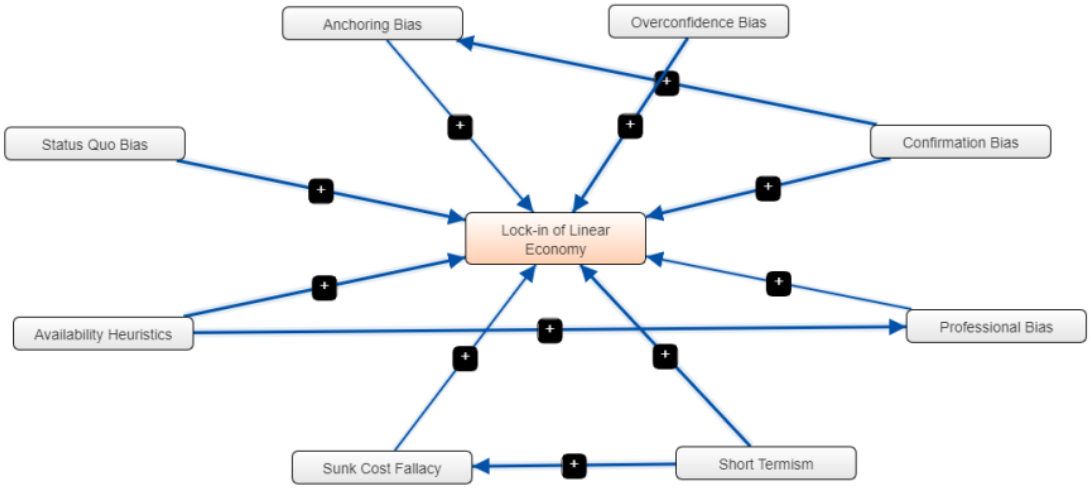

Figure 37: FCM of P7

	Sunk Cost Fallacy	Short Termism	Availability Heuristics	Confirmation Bias	Overconfidence Bias	Anchoring Bias	Lock-in of Linear Economy	Status Quo Bias	Professional Bias
Sunk Cost Fallacy							0.41		
Short Termism	0.5						0.57		
Availability Heuristics		0.47			0.31	0.31	0.79		0.66
Confirmation Bias			0.47			0.53	0.71		0.47
Overconfidence Bias							0.46		
Anchoring Bias			0.16		0.63		0.39		
Lock-in of Linear Economy									
Status Quo Bias	0.31	0.31					0.54		
Professional Bias					0.47		0.54		

Figure 38: Resultant FCM Matrix