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TRANSITIONS from THEORY of 'PRACTICES' to 'PRACTICAL IMPLEMENTATION' for CIRCULAR ECONOMY:
A Systemic Study of
Vienna's Construction Industry

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Abstract (DE)[1]

Die Kreislaufwirtschaft (Circular Economy, CE) bietet eine vielversprechende Alternative zum derzeitigen linearen Wirtschaftssystem. Die Umsetzung der CE-Theorie in die Praxis bleibt jedoch eine Herausforderung. Diese Forschungsarbeit befasst sich mit dieser Lücke, indem sie die Hindernisse untersucht, denen sich Akteure auf verschiedenen Systemebenen (Mikro-Meso-Makro) bei der Umsetzung zirkulärer Praktiken in der Wiener Bauindustrie gegenübersehen. Unter Verwendung einer mehrstufigen Systemperspektive, die sich an der kybernetischen Hierarchie von Parsons und dem Rahmenwerk von Ababio & Lu (2023) orientiert, untersucht die Studie das Zusammenspiel zwischen kulturellen, politischen, ökologischen, sozialen und wirtschaftlichen Faktoren, die die Einführung von Kreislaufwirtschaft beeinflussen. Die Studie verwendet einen qualitativen Forschungsansatz in Form einer Fallstudie und eine gemischte Technik der quantitativen Analyse zur Interpretation der qualitativen Daten. Die Datenerhebung umfasst eine Dokumentenanalyse, halbstrukturierte Interviews und Online-Umfragen. Diese Studie zielt darauf ab, die wichtigsten Hindernisse und Förderer für die praktische Umsetzung von Kreislaufwirtschaft in der Wiener Bauindustrie zu identifizieren.

Die Forschung hat eine Vielzahl von Barrieren identifiziert, die die Implementierung von CE in der Wiener Bauindustrie behindern. Diese Barrieren umfassen kulturelle Widerstände, wirtschaftliche Unsicherheit, Wissenslücken und einen Mangel an standardisierten Vorschriften. Darüber hinaus stellen die fragmentierte Zusammenarbeit und ein schwaches Netzwerk für Sekundärmaterialien operative Herausforderungen dar. Trotz dieser Herausforderungen ist Wiens Übergang zu einer kreislauforientierten Bauwirtschaft im Gange. Unterstützende Faktoren wie technologische Fortschritte, politische Initiativen und die Beteiligung der Öffentlichkeit treiben diesen Wandel voran. Insgesamt ist die Wiener Bauindustrie bereit für einen signifikanten Wandel hin zu Kreislaufwirtschaft und ebnet damit den Weg in eine nachhaltigere Zukunft.

Stichworte: Kreislaufwirtschaft, Bauwirtschaft, Übergang, Hindernisse, Förderer

[1] Übersetzt mit www.DeepL.com/Translator (kostenlose Version)

Abstract (EN)

Circular Economy (CE) offers a promising alternative for the current linear based economic system. However, translating CE theory into practical implementation, remains a challenge. This research addresses this gap by investigating the barriers faced by actors at different systemic levels (micro-meso-macro) in implementing circular practices within Vienna's construction industry. Employing a multi-level systems' perspective informed by Parsons' cybernetic hierarchy and Ababio & Lu's (2023) framework, the research explores the interplay between cultural, political, environmental, social, and economic factors influencing CE adoption. The study employs a qualitative research approach of a case study and a mixed technique of quantitative analysis for qualitative data interpretation. Data collection involves document analysis, semi-structured interviews, and online surveys. This study aims to identify key barriers and enablers for practical implementation of circular practices in Construction Industry of Vienna.

The research identified a multitude of barriers hindering the CE implementation in Vienna's construction industry. These barriers span cultural resistance, economic uncertainty, knowledge gaps, and a lack of standardized regulations. Additionally, fragmented collaboration and a weak network for secondary materials pose operational challenges. Despite these challenges, Vienna's transition towards circular construction industry is underway. Enablers such as technological advancements, policy initiatives, and public participation are propelling this transition. Overall, Vienna's construction industry is poised for a significant shift towards circular practices, paving the way for a more sustainable future.

Keywords: Circular economy, construction industry, transition, barriers, enablers

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Enjoy reading!

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Contents

Abbreviations

BIM	*Building Information Modelling*
B2B	Business-to-Business
B2C	Business-to-Consumers
B2G	Business-to-Government
CCSC	Circular Construction Supply Chain
C&D	Construction and Demolition
CE	Circular Economy
CEAP	Circular Economy Action Plan
CI	Construction Industry
CSC	Construction Supply Chain
DTCC30	DO-TANK program-Circular City Wien 2020-2030
EGD	European Green Deal
EOL	End of Life
EPR	Extended Producer Responsibility
EU	European Union
GDP	Gross Domestic Product
GHGs	Greenhouse Gases
GIS	Geographical Information System
Gt CO_2e	Billion Tonnes of CO_2 equivalent
IE	Industrial Ecology
LCA	Life cycle assessment
MLP	Multi-level Perspective
Mt CO_2e	Million Tonnes of CO_2 equivalent
PaaS	Product-as-a-Service
R&D	Research and Development
SDGs	Sustainable Development Goals
SLR	Systemic Literature Review
SMEs	Small and Medium Enterprises
SRL	Societal Readiness Level
SWOT	Strength, Weakness, Opportunity, and Threat
3M	Micro-Meso-Macro

List of figures

Chapter 1 Introduction

Only the most uncurious individual could be uninformed of the current scourges of the natural world, and associated rising invasions into our daily lives (Hart & Pomponi, 2021). A prevailing consensus now exists regarding the deleterious impact of current human production and consumption patterns on environmental integrity, social justice, and economic viability-endurance (Millar et al., 2019). Alarming signs of resource depletion, bio-chemical flow disruption, biodiversity loss, and the sharp volatility in the global economic order, amidst geopolitical instability, pronounce the limits of the linear economic model based on a '*take-make-dispose'* approach (Ellen MacArthur Foundation, 2022). The call for a new economic order has grown louder than ever.

In response to the above-stated challenges vis-à-vis our current production-consumption nexus, the concept of Circular Economy (CE) has been proposed as "***an alternative****, based on the sustainable management of natural resources, the closing of material loops, the preservation of natural capital, and circular consumption and production behaviours in the economy*" (United Nations Economist Network, 2022). CE seeks a systemic shift beyond just closing material loops. While resource recovery through reuse and recycling remains crucial, it is equally important to slow down these loops by designing products for longevity and reduction of new materials/products into the loop. The 'Circular Economy' is gaining traction as a solution to our current "take-make-dispose" model, and governments like European Union (EU), are actively promoting its adoption through policy changes. However, a successful transition requires more than just top-down policy instruments. Drawing from Parson's Cybernetics Hierarchy of Control, it can be understood that cultural values heavily influence resource use (Johnson, 2008). Here, cultural systems, encompassing shared beliefs, norms, and symbols, act as guiding force. In the field of academics, the researchers are vehemently decoding the topics within CE. While academics are actively researching the theories and frameworks of CE and governments are crafting policies, a key challenge lies in bridging the gap between theory and practical implementation. In essence, even with supportive policies, cultural mindsets that prioritize convenience and traditional linear practices, can hinder wider adoption of circular practices.

The idea of '*systems thinking*' posits that everything is connected and inter-related (Sparrevik et al., 2021). To understand the mighty process of CE systems, it is important to have a granular analysis within an industrial system. The Construction Industry (CI), a resource guzzler and waste generator, exemplifies this (Cruz Rios et al., 2021; Lines et al., 2015; Särkilahti et al., 2021). By examining the CI, the interconnected process of CE can be illuminated. From the industry's reliance on raw materials to the vast amount of construction waste, it offers microcosm for exploring circular practices like design to disassembly and deconstruction (Bertino et al., 2021). Furthermore, the intricate web of actors involved highlight the need of a deep dive into the CI (Hart et al., 2019). The CI can be understood with the Multi-Level Perspective (MLP). It emphasizes how changes at one level can trigger or hinder changes at other levels. However, it has been criticized to possess a broader outlook (Whitmarsh, 2012). Ababio & Lu (2023)'s integrated framework refines MLP for practical use by acknowledging the role of actors at 3M system (micro-meso-macro) levels and their varying barriers in practical implementation of circular practices. This research aims to investigate the practicality of Ababio & Lu (2023)'s framework in the construction industry. This study employs a case study approach to empirically examine how this framework functions in the CI.

Austria, like the EU, is also actively pursuing CE as a key strategy to become more sustainable and reduce its dependence on virgin raw materials. The Austrian Circular Economy Strategy 2050, outlined by the Environment Agency Austria, provides a roadmap for this transition (Holly et al., 2023). This strategy offers crucial support to industries across various sectors as they transform their practices to minimize waste generation and CO_2 emissions. Despite a positive outlook on CE, with over 80% of participants in an Austrian survey believing it will impact their organizations, challenges remain. A significant knowledge gap exists regarding CE principles, with more than 60% from various sectors requesting more information (Huber-Heim & Kronenberg, 2019). Besides, there is a tendency to conflate CE solely with waste management or recycling, overlooking its broader scope encompassing product lifecycles and resource efficiency (Schöggl et al., 2022).

Here is where the real gap lies. A report by Federal Environment Agency[2] predicts Austria's efforts to curb Greenhouse gases (GHGs) may fall short. The report estimates a concerning possibility: By 2050, Austria's CO_2 emissions could remain high at around 55 million metric tons of CO_2 (Mt CO_2e), far exceeding zero emissions and achieving only a modest 30% decrease compared to 1990 levels. Vienna, the Austrian capital known for its exceptional recycling program and pioneering waste-to recovery initiatives, is facing challenge to its sustainability legacy. Even though it has been named the most livable city for more than 10 times, Vienna is no exception to the climate change (Holzer & Tschannett, 2022). Vienna, although recognised for its sustainability efforts, might also struggle to meet its climate targets, including those aligned with national goals.

Therefore, Vienna serves as an ideal case study to explore the practical barriers faced by different players (micro-meso-macro systems level) in implementing circular construction practices. In the quest to do so, the present study aims to answer the following question:

"What barriers are faced by actors at different systemic levels in the 'practical implementation' of circular practices within Vienna's construction industry?"

[2] Pramer, P. (2023). Österreich droht an Klimazielen krachend zu scheitern. DerStandard. Retrieved 28 April 2024, from (*website*)

Chapter 2 Literature Review

2.1. Circular Economy – a conceptual understanding

2.1.1. Circular Economy – Definition and Relevance

There is *no single, universally accepted definition* of Circular Economy (CE) (Norouzi et al., 2021). Experts constantly point out the overwhelming number of definitions of CE which continue to increase and evolve (Borrello et al., 2020; Kirchherr, Yang, et al., 2023). Though, scholars and practitioners largely agree that CE prioritizes extending the life cycle of products and materials through practices like reuse, recycling, remanufacturing, and refurbishing (Sáez-de-Guinoa et al., 2022). Some scholars emphasize CE as a systemic transformation. Prieto-Sandoval et al. (2018) defined CE as a system-level shift that decouples economic activity from resource depletion by closing material and energy loops.

He proposed a basic notion of CE as:

"*An economic system that represents a change of paradigm in the way that human society is interrelated with nature and aims to prevent the depletion of resources, close energy, and materials loops, and facilitate sustainable development through its implementation at the micro (enterprises and consumers), meso (economic agents integrated in symbiosis) and macro (city, regions, and governments) levels. Attaining this circular model requires cyclical and regenerative environmental innovations in the way society legislates, produces, and consumes*" (Prieto-Sandoval et al., 2018).

This definition posits a critical re-evaluation of the current economic system and suggests a transition, emphasizing the closed-loop material and energy flows. This systemic transformation necessitates innovation across legislative frameworks, production methods, and consumption patterns through collaborative efforts at various levels (micro, meso, and macro). This aligns with the definition offered by Kirchherr et al. (2023), who analysed 221 definitions of CE and underlined the regenerative economic system and the alliance of stakeholders as the core tenet of CE. Another key theme centers on resource efficiency. Antwi-Afari et al. (2021) highlight CE's role in recovering resources and minimizing waste. Similarly, Liu et al. (2021) describe CE as a framework for achieving sustainable development through reduced resource input and systematic waste avoidance. Others focus on its restorative and regenerative nature, minimizing waste generation by design (Górecki et al., 2019), stationing with Ellen Mac Arthur Foundation's (2022) definition of CE as a "*system where materials never become waste and nature is regenerated*".

Value retention also features prominently in CE definitions. Dewagoda et al. (2022) defined CE as keeping products, components, and materials at their highest value for as long as possible. This concept resonates with the broader goal of resource efficiency within a circular system. It also echoes with the European Union (EU)'s cited CE definition in the Circular Economy Action Plan (CEAP) 2020, which is an update on its 2015 plan after the European Green Deal (EGD) 2020.

The deal incorporates CE as a policy instrument by "*demanding additional measures to achieve a carbon-neutral, environmentally sustainable, toxic-free and fully circular economy by 2050, including tighter recycling rules and binding targets for materials use and consumption by 2030*". EU defines CE as "*a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing, and recycling existing materials and products as long as possible. In this way, the life cycle of product is extended*."[3]

EGD 2020's greater emphasis on "recycling rules" might direct the narrative of 'circularity' towards recycling as a preferred practice, however, it is important to note that CEAP 2020 does include other practices as well.

Contrary to popular portrayals of the CE as a brand-new concept, it is more accurate to view it as a reframing of existing concepts and strategies (Corvellec et al., 2022). Inspirations drawn from, for example, Kenneth Boulding's work on resource limitations, Frosch and Gallopoulos's sustainable manufacturing, Stahel's 'closed loop' Performance Economy, and Biomimicry (nature-inspired innovation), have intricately built a linkage of CE with previous efforts for resource conservation (Marin & De Meulder, 2018).

Boulding (1966) presented the concept of '*The Economics of the Coming Spaceship Earth*'[4], and envisioned a self-sustaining system where materials are continuously reused, even with ongoing energy input ("*Cyclical ecological system which is capable of continuous reproduction of material form*...") (Leising et al., 2018). Industrial Ecology (IE) emphasizes closed-loop material use in production (Andersen, 2007). Cradle to Cradle (C2C) promotes designing products for material cycles, separating biological and technical materials (Geisendorf & Pietrulla, 2018). Thus, steering CE's roots in environmental and ecological economics (Marin & De Meulder, 2018). These integrations and linkages of various established concepts bolster the positionality of circular economy as a '*comprehensive framework*' for achieving a more sustainable future (Ellen MacArthur Foundation, 2022). This multifaceted approach highlights CE's potential to address environmental concerns while fostering economic growth (Hossain et al., 2020).

[3] European Parliament (*website*) on the topic, "*Circular economy: definition, importance and benefits*" published on 24 May 2023

[4] Kenneth Ewart Boulding at the Sixth Resources for the Future Forum on Environmental Quality in a Growing Economy in Washington, D.C. on March 8,1966.

However, some literature have called the idea of CE as "*superficial*" because "*the practical implementation of CE appears to remain at an early stage*"(Kirchherr, Urbinati, et al., 2023; Korhonen et al., 2018). In the span of approximately three years and a quarter year (2021-2024)[5], 39,463 articles were published related to the Circular Economy. The wide expanse of subject areas has come under the purview of varied research interests ranging from Business, Management and Accounting to Earth and Planetary Sciences. The extensive character of the concept depicts the continuous impetus to CE in academia. This not only reflects a sense of fervor and enthusiasm surrounding the concept, but most importantly, it highlights the ongoing intensified critical examination of the concept due to its attempted operationalization by agencies into theories of 'practices' (a well-established explanation of CE practices that is grounded on empirical evidence) for addressing contemporary problems and issues.

The scholarship of CE which has been "*almost exclusively developed and driven by practitioners*" is becoming more academic, with research focusing on theoretical concepts, for example, recent research has focused on the relationship between CE and economic growth, including degrowth (Corvellec et al., 2022). Scholars propagating degrowth, wholeheartedly don't embrace CE, "*yet they accept the principle of circularity itself, viewing it as an actually existing transformative business practice with the potential to contribute to bring about degrowth and to become an inherent part thereof*" (Nesterova & Buch-Hansen, 2023). The shift towards academia may lead to the field becoming too theoretical and dogmatic, moving away from its original focus on practical implementation (Kirchherr, Urbinati, et al., 2023). The widespread proliferation of diverging theoretical approaches hinders effective CE implementation experience and dissemination of the CE as an alternative system (Kalmykova et al., 2018).

The framework of CE is being currently promoted by governments globally, seemingly to bring economic growth in line with environmental sustainability (Hossain et al., 2020). In the EU, 21 countries, including Austria, Belgium, Denmark, Netherlands, and others, have formulated a strategy to achieve CE principles across various sectors[6]. However, the practical implementation poses several risks. A disregard for social and cultural dimensions and the simultaneous role of possible power symmetries, interdependencies, and other political constraints may be neglected. Policymakers embracing CE might be dependent on suggestive assumptions from the theory of 'practices' and their approach may be cited as a "technological fix" that overlooks the demand side of CE implementation, the role of the actors-producers and consumers, and persisting global inequalities (Schulz et al., 2019).

[5] According to the Database- Scopus (as derived on 7 April 2024) with a keyword search of '*Circular Economy*'
[6] Circular economy.earth (*website*) on Policies (as of April 2024)

The benefits of CE have been excogitated in literature (Antwi-Afari et al., 2021) but achieving a circular economy in 'practicality' requires a multi-level systemic perspective (nano, micro, meso, macro, and meta-level) that considers businesses, consumers, academia, and governments working together as a system (Kirchherr, Yang, et al., 2023; Liu et al., 2021; Prieto-Sandoval et al., 2018). It is not the interconnectedness just at the national or supranational level but also at the global (meta) level underlining the product/material being consumed by the user at the nano level. This systemic approach is crucial to minimizing waste, closing resource loops, and achieving sustainable development across socio-economic as well as environmental spheres.

2.2. Systemic Approach and Multi-level Perspective in CE implementation

2.2.1. Systems and Subsystems – A theoretical approach

Systems Theory has been established as an approach, suggesting that the only way to understand something fully, it is indispensable to understand the parts in relation to the whole (Iacovidou et al., 2021). Donella Meadows, a system's expert defines a system as "an interconnected set of elements that are coherently organized in a way that achieves something."[7]

In the late 20th century, advances in science, culture, and society led to the development of a new paradigm known as the 'systems paradigm'. The Cybernetic 'hierarchy of control,' developed by sociologist Talcott Parsons, explores how interconnected subsystems within a larger system influence each other (Johnson, 2008). According to Parsons, Economic system is the subsystem of Social system that performs the function of the society for adaptation to the environment through labour, production, and allocation of resources. He argues that economic actors like producers and consumers determine the market interactions majorly based on social norms and cultural values.

The actors are guided by four 'action' systems i.e. analytical tools to understand the real world. They are: Organismic system (Biological Needs), Personality system (Internal Motivation), Social system (Economic, Political, Social Control and Socialization) and Cultural System (Shared values, beliefs, and symbols-language). These systems are organized based on information processing and flow of energy.

"Energy" refers to the physical resources and processes that fuel the system. It encompasses material resources (raw materials, manufactured goods, and anything tangible used in production and consumption) and biological processes (the physical

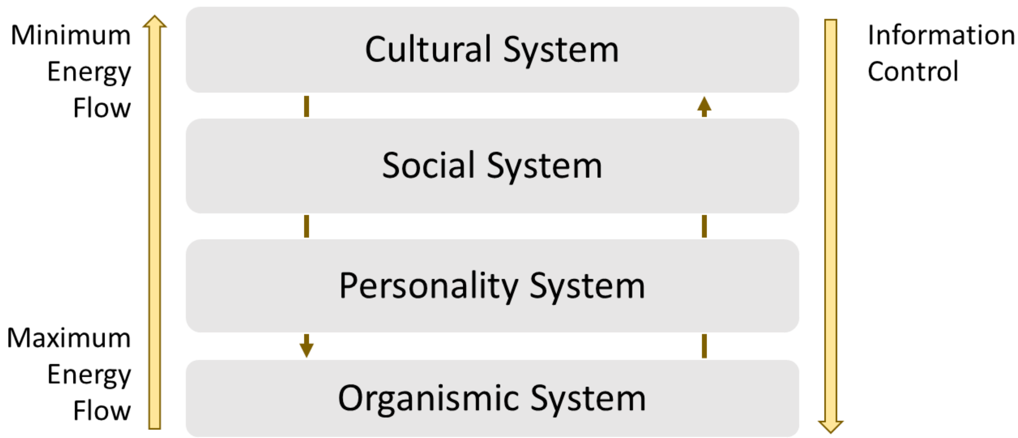
[7] Ellen Mac Foundation *(website)* on "Systems and the circular economy – deep dive"

functioning of the human body, its needs, and limitations related to resource use). "Information" refers to the intangible elements that guide and shape behavior within the system (Sangwan et al., 2022).

This theory highlights how seemingly separate parts of a system are interconnected through a flow of information and energy, with cultural values ultimately shaping resource use. The flow of information works like a control mechanism. Cultural values and social norms set the boundaries and expectations for how resources are used within a system.

Figure 1 explains the inter-relational between various systems and the flow of energy and information control among them. At the base lies the biological system, the source of physical energy for actions. This energy flows upwards, but it diminishes as it reaches the cultural system.

Figure 1: Parson's Cybernetic Hierarchy of Control



Source: 1- Sangwan et al., 2022

The cultural system, unlike the lower biological and personality systems, deals with abstract concepts like values and norms. It does not require the same level of energy to function, but instead acts as a guiding force, influencing how the lower systems, brimming with energy, to take actions in the world. So, while the cultural system plays a crucial role in shaping behaviour, its own energy needs are minimal.

Despite criticisms of oversimplification with a broader outlook and ignoring the role of technology, the cybernetic hierarchy provides a valuable lens for understanding how information-rich systems like cultural values exert control over energy-rich systems like individual consumption patterns (Sangwan et al., 2022).

2.2.2. Systems Approach for Circular Economy

The concept of a circular economy (CE) has gained traction as an alternative to the linear 'make-use-dispose' model of production and consumption (Hart & Pomponi, 2021). It involves developing new technologies, sustainable business models, and regulatory measures to address environmental challenges. The transition from linear to circular economic systems necessitates a multifaceted approach encompassing changing, comparative, and directional aspects (Guzzo et al., 2022). The 'changing' facet centers on the crucial transformations required to change the nexus of production-consumption patterns. This necessitates a shift from the current, linear socio-technical regime – a well-established system of practices, cultural norms, and institutions towards a new regime founded on circular economy principles (Geels, 2011). In transition studies, The Multi-level Perspective given by Geels (2011), offers a systemic view of socio-technical change, where an organization employs people with capabilities (actors), works towards a goal, follows the 'processes', uses a technology operating within physical infrastructure and sharing certain cultural 'assumptions' and 'norms'. However, its focus on the whole system could be enhanced by incorporating behavioral and political science to understand stakeholder dynamics (Whitmarsh, 2012).

According to the 'comparative' facet, decision-makers must choose between circularity paths based on CE principles, like remanufacturing, recycling, reusing, or reducing, while considering resource use and environmental impact. This comparison allows them to explore options that bridge the gap between the current linear system and the envisioned circular future. Lastly, the 'direction of change' highlights the trajectories towards circularity. These trajectories can be steered by top-down policy instruments like legislation and infrastructure investment, fostering an environment conducive to CE practical implementation. Conversely, bottom-up initiatives focus on value creation through innovation in products, services, and business models.

To understand the functioning of a CE system, in this research, only three systemic levels (micro, meso, and macro) are focussed upon due to time constraints. The three key systemic levels (Ghisellini et al., 2016; Kirchherr et al., 2017) :

Micro-level systems (Individual/ Company) include transformation inside a single organization, family, or individual. This level focuses on individual consumers, businesses, and product design. Here, changes involve eco-design, cleaner production, and consumer behaviour.

Meso-level systems (Local Collaborations) emphasizes collaboration among local players. Examples include eco-industrial parks and urban symbiosis, where resources like materials and energy are shared geographically.

Macro-Level systems (National/Industry) tackles change throughout industries, regions, or nations. The focus is on global or national domains, including complete production and consumption networks. Construction (built environment), transportation (mobility), food (nutrition), textiles, electronics are the key value chains for achieving circular economy implementation as they leave significant environmental footprints globally (Guzzo et al., 2022).

However, there are complexities and challenges associated with implementing a CE at systemic levels (Khan et al., 2022). Micro-level issues include actors' resistance to involvement in the CE supply chain and the technological need for redesigning products for disassembly. At the meso level, fostering collaboration among local players and overcoming infrastructure limitations for resource circulation pose complexities. Macro-level challenges encompass policy incoherence and the intricate nature of industrial supply chains that hinder responsible material management.

Although the circular economy (CE) necessitates a comprehensive understanding of interconnected systems, a granular analysis of a single industry/sector can illuminate the intricate web of dependencies within the larger system. More importantly, such an analysis will help in transcending theoretical discussions and delve into the practicalities of CE implementation. By examining the specific challenges and opportunities encountered by an individual industry, invaluable insights can be gained into the various barriers and enablers that determine the feasibility and effectiveness of translating CE **theory of 'practices**' into '**practical implementation'** (Hofstetter et al., 2021).

2.3. Construction Industry- a granular analysis for systems transition

2.3.1. A notorious waste producer and GHGs emitter

The Construction Industry (CI), a critical sector for global development, faces a growing challenge: mitigating its environmental footprint. Fueled by urbanization and population rise, construction consumes a vast amount of natural resources – accounting for 32% globally, though lower than the 40% reported in the 1990s (Norouzi et al., 2021). However, a significant issue persists: over 75% of construction waste lacks proper management, often ending up in landfills (Komkova & Habert, 2023).

This inefficiency stems from the traditional linear economic model employed in construction, which emphasizes extraction, production, and disposal (Górecki et al., 2019). Construction and demolition waste (C&D waste), i.e. any leftover materials from construction, renovation, or demolition, represents a substantial portion of global waste generation, reaching 30% (Dewagoda et al., 2022). Under the traditional approach, construction relies on resource-heavy extraction and processing to create building materials. However, most construction elements are not designed for easy disassembly at the end of their lifespan, leading them to be dumped in landfills or incinerated (Purchase et al., 2022). With over 35% of C&D waste landfilled annually, the environmental consequences are significant (Bertino et al., 2021).

The industry's environmental impact extends beyond waste generation. The construction sector is a major consumer of energy and a significant greenhouse gas (GHG) emitter. Construction is responsible for 39% of global GHG emissions, with 10% attributed to embodied emissions – those associated with material production (Komkova & Habert, 2023).

Specifically, in the European Union (EU), the construction industry is a significant source of carbon emissions. New construction alone is estimated to have produced 190 million tonnes of CO_2 equivalent (Mt CO_2e) in 2024, with projections indicating an annual average of 245 Mt CO_2e between 2024 and 2050 (Thung et al., 2024). The industry also generates massive amounts of waste, with demolition activities producing an estimated 124 Million Tonnes (Mt) in 2022. Following a business-as-usual approach, where construction is expected to add 22 billion square meters of floor space by 2050, the sector is on track to release an additional 6.6 billion tonnes of CO_2e (Gt CO_2e) (more than 3000 times of the present- 2024 level).

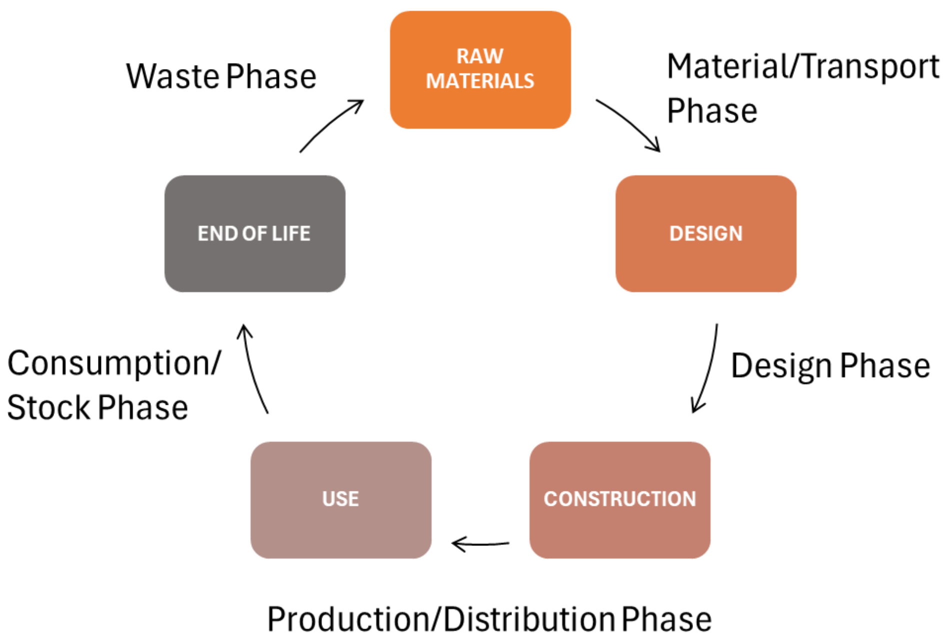
Maintaining current practices is simply not sustainable. This trajectory will push the EU's residential and utility construction sector beyond the critical 1.5°C warming limit by 2026, and a possibility of even surpassing the 2°C threshold by 2031 (Thung et al., 2024). While green buildings offer a positive step, their focus on operational energy use overlooks the environmental burden throughout a building's lifecycle (Pomponi & Moncaster, 2017). A paradigm shift is a critical urgency. The circular economy (CE) offers a promising alternative, promoting resource efficiency and closed-loop systems (Hossain et al., 2020). It encourages practices like reuse, recycling, and designing for disassembly, minimizing waste and environmental impact.

2.3.2. Theory of 'Practices' of CE in CI

The CE in the Construction Industry(CI) is *"the use of practices, in all stages of the life-cycle of a building, to keep the materials as long as possible in a closed loop, to reduce the use of new natural resources in a construction project"* (Benachio et al., 2020). The scientometric analysis conducted by Antwi-Afari et al. (2021) revealed that in the CI, the circular economy is currently being applied along themes such as sustainable development, life cycle, recycling, C&D waste, and supply chain management (Antwi-Afari et al., 2021). Traditional construction often discards materials after use, despite their inherent value and durability. While CE in construction is still in its early stages, rapid development and positive implications are emerging (Hossain et al., 2020).

There is currently no one-single technique that can address all the difficulties within the industry. Circularity is about demonstrating that it is feasible to aim for circular solutions at the material, process, and construction levels[8]. CE emphasizes on a closed loop system where materials are recovered or recycled throughout their lifecycle. While CE typically account for the entire life cycle of a building, most studies have focused exclusively on the "End of the Life" (EOL) or the Waste Phase, ignoring the practices throughout the entire building life cycle. Figure 2 depicts the circular construction process and the different phases in CI, articulating the entire building's lifecycle: Material/transport phase, Design phase, Production/Consumption phase, Consumption/Stock phase, and Waste phase.

Figure 2: Circular Construction Process and Phases in the Construction Industry



Source: 2- Compiled by author

<u>Circular Practices in Material Phase/Transport Phase:</u>

Prioritizing use of secondary material than virgin primary raw materials, Utilizing of nature based materials (example-earthen structures, straw bales, hemp to produce tiles – having favorable thermal properties or fungi-based Insulation-mycelium), Product standardization

[8] Circular Berlin (*website*) on "The steps to realise circularity in construction projects"

for reducing material waste facilitating future reuse (standards and certifications), Prolonged lifespan of material, Multi-functional materials (living walls-vertical garden), Life cycle assessment (LCA) promoting informed choices for circularity, Material Passport (tracking the materials used in a building, including their origin, composition, and maintenance needs- enhances transparency and allows for informed decisions about reuse and repurposing later), Low impact virgin materials (where necessary) with low-embodied energy materials (self-healing concrete, concrete debris v/s monolithic concrete or red bricks), Policy and regulations (Procurement policies prioritizing projects that utilize high recycled content and promote circular practices can drive market demand for circular solutions), Localization (with natural aggregates decreasing and transport distances increasing, for example-locating recycling plants near urban areas) and Reverse Logistics (developing efficient systems for collecting, sorting, and transportation of the used construction materials back into the production cycle).

Circular Practices in Design Phase:

Design for disassembly (easy to separate into components for reuse, recycle, reconfigure), Design for adaptability and flexibility, Design out of Waste, Design to reintegrate secondary production, Design for Efficiency (building shape, building orientation, building envelope, passive design strategies, window design), Design for material optimization, Design for Serviceability, User-centric design for longevity, Digital Twins and BIM (Building Information Modelling) integration, Biomimicry (self-healing materials, modular structures inspired by biological growth patterns, or rainwater harvesting systems that mimic natural water cycles), and Life-cycle Thinking (expanding the design focus beyond the construction phase and considering the entire life cycle of a building, including its maintenance, potential upgrades, and eventual deconstruction).

Circular Practices in Production/Distribution Phase:

Local production and material sourcing (supporting local businesses, urban mines, by-products/waste streams as resources, for example, agricultural byproducts**:** rice husks or bamboo can be used for insulation or lightweight building panels), Digitalization and Online Platforms (BIM, online material marketplace, digital guides), Distribution and on-demand production (prefabricate building components off-site in a controlled environment, minimizing waste and maximizing efficiency, utilize 3D printing for on-site creation of specific building components, reducing transportation needs and material waste), and Product-as-a-Service (PaaS) (shift from selling building materials to offering building materials-as-a-service models, where ownership remains with the provider and materials are recovered at the end of the use cycle)

Circular Practices in Consumption/ Stock Phase:

Policy and regulations (Standardized labelling system), Optimized strategies (active cooling systems, energy efficient buildings), prioritizing extension, multi-functional buildings, and spaces (co-housing, co-working spaces, interim spaces, pop-up houses etc.), adaptive re-use of buildings (underutilized buildings like warehouses or factories), Urban farming and green roofs (improving resource efficiency and providing additional benefits like air quality improvement and rainwater management).

<u>Circular Practices in Waste Phase:</u>

Maintenance (process of interventions concerning repair, renovation, and replacement of building parts without altering the overall volume and without changing the intended use), Refurbishment (process of restoring a structure to a former better condition or to revive it, including alterations such as remodelling and retrofitting, which can result in a completely different building), Deconstruction (process of selective dismantling of building components, part by part and avoiding damage, specifically for reuse, repurposing, and recycling) (Bertino et al., 2021). Extended Producer Responsibility (EPR) (holding manufacturers responsible for the end-of-life management of their building products incentivizes them to design for disassembly and recyclability) is a practise based on policy intervention to leverage the continuation of the loop. It should be highlighted about the importance of considering the entire building lifecycle, particularly the EOL waste management through Reverse Logistics, as crucial for achieving CE. There is a need for government, digital platforms, and professional communities to act as "*information brokers*" to bridge the structural holes in the CI (Wijewickrama et al., 2021).

It is worth noting that demolition can also be one of the options at the EOL of any building/infrastructure, defined as "*process of arbitrary disassembling or destroying of a building in order to clear the construction site with use of heavy machineries*"(Bertino et al., 2021). The wastes from demolition (if only available option, for example in case of dilapidated buildings) can be targeted to be re-used and recycled for another construction activities. Although, demolition stands as a major obstacle to achieving circular economy in construction industry. This process often involves brute force methods that damage and break down the material. This not only reduces the potential for reuse of high-quality materials, forcing them to be downcycled into lower-grade applications or sent to the landfills. Moreover, the embodied energy (energy used to extract, process, and transport materials) already invested in these materials is lost, requiring additional energy to produce new ones. Economically, demolition can be faster and cheaper than deconstruction. Despite the long-term benefits of circular practices, demolition is a prevalent practice, acting as a major barrier to the practical implementation of CE in CI.

2.3.3. Barriers to the 'Practical Implementation' of CE in CI

While CE holds great promise for the Construction Industry, putting it into practicality remains difficult due to several roadblocks. A study adhering to Systemic

Literature Review (SLR) while evaluating 53 research, reported on the key obstacles using Pareto analysis. It acknowledged 11 taxonomies of barriers including cultural, market, knowledge, financial, management, regulatory, technological, supply chain, stakeholder, technical, and organizational barriers. The study identified resistance to change, complex products, and lack of digitalization as the most significant barriers to transitioning towards the circular economy in the construction industry. It also calls for integrated strategies to overcome financial, knowledge, regulatory, management and supply chain barriers (Wuni, 2022).

Another study, in a review of barriers, drivers, and stakeholders, identified 41 barriers and revealed that major issues include lack of awareness and clarity on circular practices, lack of collaborative platforms, lack of governance plan and strategic vision, lack of business grants or financial aid, and lack of integrated CDW processes and tools. It also highlighted the role of stakeholders in implementing CE in the construction industry (Munaro & Tavares, 2023). Ghisellenі et al. (2018), specifically in construction waste management, highlighted twofold barriers. First, uneven recycling rates across regions show a lack of consistent practices or infrastructural bottlenecks. Second, the design often fails to consider future disassembly or reuse of materials, limiting the potential for a closed-loop system.

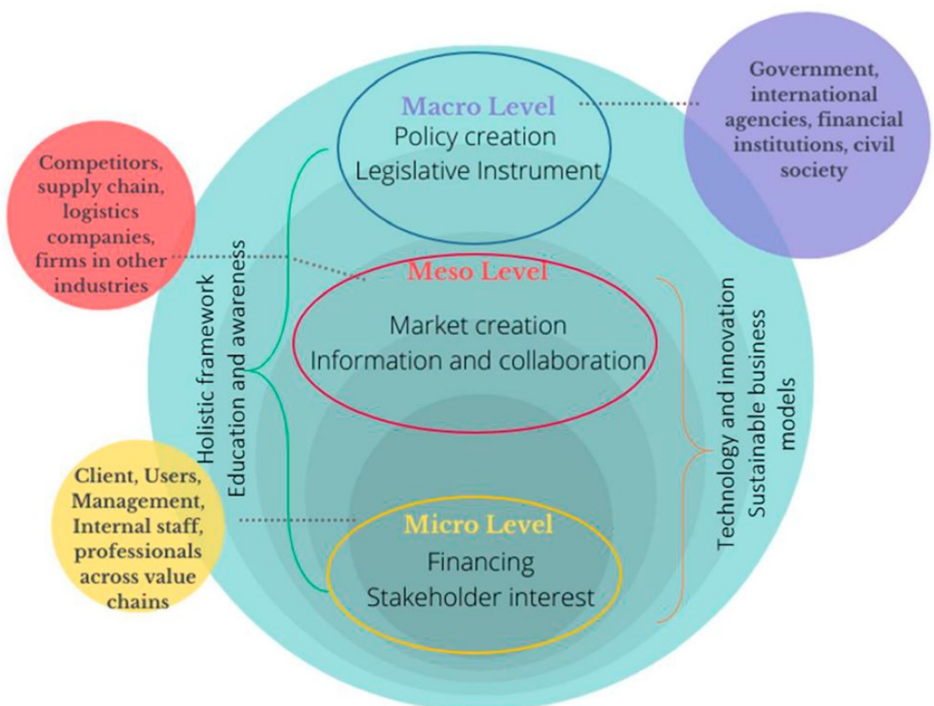
Different stakeholders involved in the various stages of a building's life cycle create a lot of information, but due to a lack of connection and information sharing between these stages, this valuable 'information' is not readily available to stakeholders who need it for decision-making. This cavity creates 'information silos' that hinder overall efficiency (Jorge et al., 2016).

The Construction Supply Chain (CSC) (processes and practices that are employed to manage the flow of 'energy' and 'information' within the CI) is a system connecting a diverse group of stakeholders with varying interests, categorized as 'actors.' These actors include suppliers, architects, developers, contractors, clients, demolishers, and waste transport and management companies. They oversee activities at each stage of the CSC (Ghaffar et al., 2020) . There are other actors as well, including government, politicians, and local councils, regulate and provide incentives, control and monitor each stage's processes (Wijewickrama et al., 2021). Actors from academic institutions conduct Research and Development (R&D) to increase CE 'Practice' efficacy. The CSC in the CI is an interconnected process where each stage's functionality is influenced by the effectiveness of the previous one.

While existing studies have explored the factors influencing the adoption of CE in construction, there are significant gaps within the research, which often tends to lack a multi-level perspective (Korhonen et al., 2018). They focus on broad industry trends, overlooking the diverse challenges faced by different levels within the CSC. Additionally, there is a lack of systemic categorization of barriers to the practical implementation of CE in CI (Ababio & Lu, 2023).

The implementation of CE practices in construction faces challenges due to inconsistencies in how the concept is understood. Especially, the terminology around CE, such as principles, practices, and aspects, varies across studies (Adams et al., 2017; Benachio et al., 2020; Guerra & Leite, 2021). Addressing the challenge of lack of systemic and inconsistent application, a study conducted by Ababio & Lu (2023) identifies critical enablers for each system level as well as its key actors whose efforts are necessary for the implementation of CE at that level. Figure 3 represents the onion diagram by Ababio & Lu (2023).

Figure 3: Actors and enablers of CE implementation at different system levels



Source: 3- Ababio & Lu (2023)

At the micro level, technological advancements, educational initiatives, and client demand for circular solutions are key enablers. The actors at the micro level are Clients, users, management, internal staff, and professionals across value chains. To the organizations (meso-level), fostering collaboration, market creation for secondary materials, and transparent information are crucial. These meso-level enablers ensure efficient and effective CSC and logistics. The actors at the meso level are competitors, logistics companies, firms at other companies, and supply chains. At the macro level, legislative instruments like regulations or awareness programs by civil society are essential to drive the CI with enablers like a comprehensive CE framework impacting all levels (micro, meso, and macro) and a systemic influence. The key actors at macro level are government, international agencies, and society.

However, an empirical test of the framework presented by Ababio & Lu (2023) is yet to be performed. The study has also highlighted that circular practices at the micro-level are least researched among the systemic levels.

2.4. Research Gap

The CE offers a promising alternative to the traditional linear economic model in the CI, but the practical implementation faces challenges. The foundation of CE lies in systems thinking. The interconnectedness of systems emphasizes the flow of 'information' from governments, civil society, and other international agencies which is reciprocated in the form of flow of 'energy' from the companies, users, and their market interactions. These flows of 'information' and 'energy' shape the resource consumption and production within the society guided by respective cultural values (Sangwan et al., 2022). For example, cultural values can be seen in the country's architectural styles. The elaborate facades of European architecture reflect a historical emphasis on social status and outward appearances. On the other hand, minimalist design in Japanese architecture reflects a cultural value placed on public safety and preparedness due to its history of earthquakes. Pre-fabricated homes in North America mirror the fast-paced lifestyle and emphasis on convenience. In some Latin American countries, local residents participate in the design and construction process, reflecting a cultural value of collective action and social responsibility.

Parson's Cybernetic Hierarchy of Control illustrates this concept, highlighting how cultural values influence lower-level systems with abundant energy, such as individual consumption patterns and to a much extent company's innovation capability. In the context of CE, this translates to the importance of effectively designed top-down initiatives (legislations, regulations, educational and awareness programs) within the prevailing socio-technical regime. These initiatives, informed by cultural norms, strive to harmonize the roles and expectations of diverse actors.

Networks of actors at systemic levels (micro-meso-macro) can be aligned to create a fertile ground for the practical implementation of CE within CSCs at different phases through conducive policies. However, studies are absent for examining the economic, social, and cultural dimensions of CE in the construction industry, despite some studies have prioritized these dimensions as important to any new business model and social wellbeing (Hossain et al., 2020).

Studies have taken a narrow approach by reviewing CE concepts without presenting a detailed overview of the practical implementation of the theory of CE practices. There could be the opportunity to understand the prevailing challenges and barriers with a comprehensive practical approach (Corvellec et al., 2022; Kirchherr, Urbinati, et al., 2023; Korhonen et al., 2018). There is a demand for a holistic assessment to enable the translation of the CE framework from 'theory to practice' for CE implementation in the Construction Industry (Antwi-Afari et al., 2021).

The construction industry is one of the major industries, globally responsible for resource consumption, waste generation, and Greenhouse Gases (GHGs) emissions. The transition to a circular economic system is crucial for reducing the impacts of the sector. However, the lack of clarity and understanding of CE amongst actors and the complexities of the Construction Supply Chains (CSC), make it difficult to implement CE (Munaro & Tavares, 2023). There is a call for research focusing on empirical studies to analyze economic, environmental, and social impacts of circularity in the CSCs (Munaro & Tavares, 2023).

A key research gap identified in the literature is the lack of studies that examine CE in construction from a multi-level perspective, though Ababio & Lu (2023) have placed an integrative framework with systemic categorization of enablers for the actors.

This Master's thesis is a call to address the critical gaps in understanding how to implement a circular economy within the construction industry, focusing on the systemic levels (Corvellec et al., 2022; Kirchherr, Urbinati, et al., 2023). While the potential of CE is acknowledged, existing studies lack a holistic approach and there is a need to move beyond the theoretical discussions and delve into the practical implementation challenges. This research is an examination of various barriers and enablers in the cultural and social system that influence actors across micro, meso, and macro levels within Construction Supply Chains (CSCs) to implement Circular Economy practices. It also aims to assess the social, economic, and environmental impacts of CE practices by the actors at the micro-level to bridge the research gaps as called by Munaro & Tavares (2023) and Ababio & Lu (2023). It will help in catalyzing the transition with the actor-based framework. Firstly, from linear to Circular Economic systems and secondly, from the **theory of 'practices**' to '**practical implementation of CE**.' The practical implementation requires a full understanding of barriers and enablers. The research of Ababio & Lu (2023) has provided a foundation for moving forward by categorizing the actors within systemic levels. Now, it is time to take another step, so that we can begin to practice it not just as a framework, but as a tool for assessing change.

Chapter 3 Research Methodology

3.1. Problem Statement and Research Question

Historically, economic prosperity has been intricately linked to the consumption of resources, with many development practices neglecting the health of natural ecosystems and broader environmental considerations. In response to the growing concern over these detrimental societal and environmental impacts, the Circular Economy (CE) framework has emerged as a potential solution. CE is "*an economic system that represents a change of paradigm in the way that human society is interrelated with nature and aims to prevent the depletion of resources, close energy, and materials loops, and facilitate sustainable development through its implementation at the micro (enterprises and consumers), meso (economic agents integrated in symbiosis) and macro (city, regions, and governments) level"* (Prieto-Sandoval et al., 2018). Implementation of CE is expected to yield a multitude of advantages at the organizational level, encompassing improved resource security and efficiency, increased organizational agility in adapting to changing market conditions, and the capacity to generate value through the development and deployment of novel business models. While the CE presents a compelling approach for various industries including the Construction industry (CI), transitioning this concept from theory to practical implementation has proven a significant challenge. While prior research has demonstrably contributed to identifying barriers and enablers, a critical gap remains. Many existing studies fail to adequately consider the inherent multi-level systemic nature of barriers that actors face and subsequently the enablers for CE implementation. Addressing this research gap is essential to fostering the widespread adoption of CE within CI. To achieve successful implementation of CE within the complex socio-economic context of CI, a larger systemic perspective is needed that seems to be majorly guided by the cultural systems.

The focus of this research is on the comprehensive understanding of associated barriers and enablers, and impacts of CE practices. Further, the research is conducted in the city of Vienna, exploring its cultural and socio-economic systems, and offering a way to understand CE implementation in CI in a real-world setting. To achieve this, the following research question is formulated to decode the translation of theory to practice of CE in CI and to identify key barriers and enablers and their inter-relationships from a systemic perspective.

"What barriers are faced by actors at different systemic levels in the 'practical implementation' of circular practices within Vienna's construction industry?"

3.2. Research Paradigm – Ontology and Epistemology

The research adopts a relational ontological approach. Ontology encapsulates the underlying assumptions, type of entities, and the relationship between the entities, diving deeper into the nature of reality. Complexity science, systems theory, and cybernetics say reality is constructed in systems. Here the ontological position is "how things are and how they exist in systems?" These systems in this research are understood with the help of the construction industry (CI).

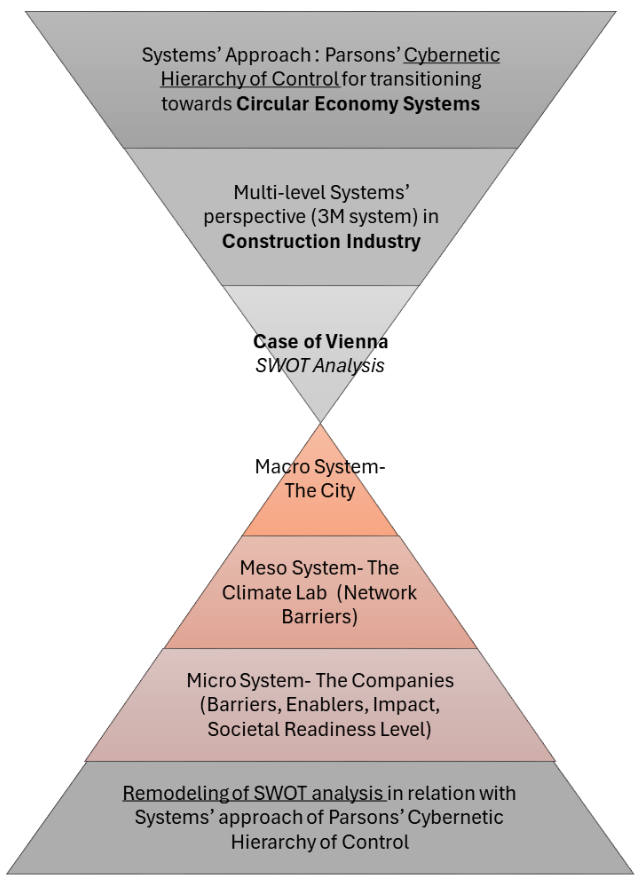
In this view, the CI is not a collection of isolated parts, but rather a network of interconnected elements. This highlights the importance of collaboration throughout the supply chain, from design to deconstruction/demolition. Furthermore, the CI and the environment are seen as interdependent, with circular economy promoting resource efficiency to minimize waste and foster a sustainable relationship. This holistic approach emphasizes the entire building lifecycle, requiring integrated knowledge across all phases for successful CE implementation. This research is only limited to the actors and the abstract concepts of CE and systemic thinking and does not focus on the physical objects (buildings, materials). The main aim of the current research is to examine the relationship between CE practices and actors.

The epistemological understanding helps understand "how these systems can be understood?" The epistemological approach is also central to generating knowledge about Circular Economy (CE) implementation in Vienna's construction industry. Epistemology, the theory of knowledge, asks fundamental questions about how we can justify what we know to be true, i.e. it helps in deciding how to approach. This is further consolidated with the interpretivist approach within the paradigm. Interpretivism aims to prioritize an understanding of the subjective experiences and interpretations of individuals within the Construction Industry at various systemic levels. So, the multi-level perspective provides an epistemological framework for understanding change in systems. Through interviews with construction professionals, policymakers, and other relevant actors, the research delves into the lived realities of CE implementation. This approach goes beyond simply identifying the barriers and enablers. It allows us to uncover the meanings, motivations, challenges, and interpretations that shape how actors navigate CE practices (Neuman, 2014). This depth of understanding is crucial for the successful transition of the construction industry towards Circularity. While other approaches, such as positivism, might offer a more objective overview, interpretivism provides to capture the richness and complexity of human experience. Vienna's Circular Economy policies are still being developed, thus making it difficult to evaluate and analyze the CE practices with a critical lens. The nuanced understanding with an interpretivist approach transcends mere knowledge of challenges and opportunities. It provides a window into the very soul of CE implementation in Vienna, revealing the interplay of beliefs, values, and social dynamics that ultimately determine the success or failure of this critical initiative within its cultural and socio-economic context.

3.2. Operationalization of 'Theoretical and conceptual framework'

This thesis adopts a Multi-level Perspective (MLP) as its core methodological approach to understanding change in the CE systems. The journey towards a circular construction industry, where resources are kept in use for as long as possible, necessitates a nuanced understanding of the complex interactions between actors and the systems they operate within. This requires a theoretical framework that goes beyond static descriptions and captures the dynamism of change, considering not just the "what" but also the "how" of the transition. Here, this thesis explores how systems theory, Parsons' cybernetic hierarchy of control, the Multi-level Perspective (MLP), and Ababio & Lu (2023) integrated framework contribute to this understanding, each building upon the last. The research framework has been presented in figure 4.

Figure 4: Research Framework



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a) Systems Theory: The Interconnected Web

Imagine the construction industry as a vast web. Construction companies, suppliers, government agencies, and other stakeholders are all interconnected nodes in this web. Systems theory postulates that these entities are not isolated but function as a whole, with decisions and actions at one level rippling through the entire network. For instance, a government policy encouraging the use of secondary material (macro) can influence a construction company's (micro) decision to invest in prefabricated components made from such materials. This, in turn, can lead to increased demand for recycled materials from suppliers (meso), impacting the entire supply chain.

b) Parson's Cybernetic Hierarchy: Inside the Nodes of the Web

Parsons' cybernetic hierarchy of control delves deeper by focusing on the internal dynamics within each node of the web. It proposes four interconnected action systems that work together.

Cultural System (Flow of Information)

Within the construction industry's shift towards circular economy, the cultural system acts as the foundation. Shared values like sustainability can create a powerful force for change. Consumers demanding eco-friendly spaces, professional associations promoting circular design, and public pressure for reduced environmental impact all contribute to a cultural shift. The rise of co-housing and community housing exemplifies this, with their focus on shared spaces, resource efficiency, and resident involvement potentially fostering a more sustainable culture. This cultural influence extends beyond housing, with inspiring adaptable building designs and a growing appreciation for renovation over demolition.

Social System (Flow of Information)

This system encompasses the formal and informal rules, regulations, and professional networks that influence how actors interact and what practices are acceptable. Building codes, professional certifications, and collaboration platforms for knowledge sharing are all crucial aspects of social systems. However, the social system is highly influenced by sub-systems:

- Economic sub-system: Economic forces play a crucial role in shaping the feasibility of circular construction. Government incentives for using secondary materials, tax breaks for companies implementing CE practices, and creating a stable market for secondary materials (recovered, or recycled) can all stimulate economic activity and encourage industry-wide adoption of circularity.

- Political sub-system: Political will and leadership are essential for driving systemic change. Government policies mandating minimum recycled content or a percentage of materials will be reused in new buildings, investing in green infrastructure that facilitates the use of materials, and funding research and development in circular construction technologies. It all can create a supportive environment for the construction industry to transition towards a circular economy.

- Socialization and Social Control: Through socialization, various institutions transmit cultural values and norms, including those related to knowledge sharing and collaboration. This fosters a shared understanding within the social system and facilitates the flow of knowledge (the information) between individuals. Social control mechanisms further reinforce these norms, ensuring knowledge exchange remains within acceptable boundaries and contributes to the overall stability of the system.

Personality system (Flow of Energy)

Beyond the cultural and social forces, the personality system within Parsons' framework sheds light on the power of individuals. Company leaders with a sustainability focus can champion CE practices, while visionary policymakers can create supportive regulations. Architects, engineers, planners, and entrepreneurs can translate CE principles into innovative designs and technologies. "Sustainability champions" within organizations can further amplify these efforts by raising awareness and fostering a culture that embraces circularity. While individual motivations can sometimes pose challenges, recognizing the power of leadership, innovation and a personal commitment to sustainability is critical.

Organismic system (Flow of Energy)

The organismic system, the physical foundation of the CI, heavily influences its environmental impact and ability to adopt circular practices. Material choices like recycled or bio-based alternatives with lower embodied energy can significantly reduce the industry's footprint. Investing in energy-efficient equipment, prefabricated components, and innovative technologies like 3D printing can further minimize resource consumption and waste. Additionally, optimizing operational processes by promoting on-site recycling, and adopting deconstruction techniques in design and reverse logistics, all contribute to a more circular material flow. However, limitations like existing infrastructure with limited recycling facilities or inefficient transportation systems can pose challenges. These challenges can be addressed through research on sustainable materials and collaboration on waste management infrastructure.

c) The Multi-Level Perspective (MLP): Zooming Out and In

The MLP offers a valuable bird's eye view of systemic transitions like the shift towards a circular construction industry. The MLP emphasizes how changes at one level can trigger or hinder changes at other levels. While Geels' work established the MLP for understanding systemic transitions, its abstract nature and broad categorizations limit its direct application in empirical research (Whitmarsh, 2012). Guzzo et al. (2022) also utilize MLP to understand specifically the transition toward Circular Economy (CE). However, this approach falls short of comprehensively capturing the role of actors within the MLP framework. While the study acknowledges the three systemic levels of 3M systems (micro, meso, and macro), their focus on CE principles and value chains within each level neglects the dynamic interplay of actors at different levels. The MLP of Guzzo et al. (2022) emphasizes how actors with vested interests (individuals, companies, policymakers) can influence and be influenced by transition across all levels but only provide a more static view of the CE system.

d) Ababio & Lu's Integrated Framework: Bridging the Gaps

Ababio & Lu's (2023) integrated framework offers a solution by enabling the operationalization of the MLP for empirical testing. This integration enhances the MLP's utility by facilitating its application in concrete studies. This framework highlights the importance of engaging all stakeholders throughout the project lifecycle, acknowledging that different actors (for example construction companies v/s suppliers) face varying barriers in implementing circular practices. Furthermore, it emphasizes the positive cross-level impacts of certain actors, like educational institutions, and the power of a bottom-up approach where individual companies can champion circularity and drive systemic change. This integrated framework refines the MLP for practical research, providing a more comprehensive understanding of the actors and their roles in the CI's transition towards CE.

e) Micro-level Study: Investigating Circular Practices and their Impacts

Building upon Ababio & Lu's (2023) framework, further research is crucial is understand how construction companies can overcome the barriers and enablers identified by Wuni (2023) and effectively implement CE practices. (11 taxonomies of barriers including cultural, market, knowledge, financial, management, regulatory, technological, supply chain, stakeholder, technical, and organizational barriers). Furthermore, assessing the social, economic, and environmental impacts of these companies provides benefits and drawbacks. This can empower individual companies to become champions of CE, ultimately accelerating the industry's transition towards a circular economic future.

3.2.1. Case Selection: The City of Vienna (Macro System study)

A city, rather than a country, is chosen as the macro system for studying CE in construction due to its targeted focus. Cities are hubs of resource consumption and face unique challenges in waste and environmental impact. They offer greater control over planning and infrastructure depending on the political system. Moreover, the city's cultural values like focus on sustainability or climate neutrality, can influence the CI's willingness to embrace CE practices. Public awareness campaigns and collaboration between professionals, fostered by the city's cultural environment, can further shape norms and behaviors towards circularity. By studying a city, we can examine how cultural factors paint the canvas upon which CE principles are adopted within CI. Vienna, Austria's most populous city and a global leader in liveability, emerges as a compelling case study for investigating the Circular Economy (CE) transition within the construction industry. This selection is driven by a confluence of factors that create a fertile ground for analyzing the implementation of CE principles in practice.

<u>Accessibility and Firsthand Observation:</u>

Firstly, Vienna's geographical proximity offers a distinct advantage for me as a researcher. This ease of access facilitates direct interaction with key stakeholders involved in the Construction Supply Chains. Engaging with platforms like The Climate Lab and DO Tank Circular City Wien (DTCC30) allowed for firsthand observation and participation in the ongoing efforts. This immersive experience provides invaluable insights into the practical implementation of CE within CI, moving beyond theoretical frameworks.

<u>Unwavering Commitment and a Legacy of Sustainability:</u>

Beyond accessibility, Vienna's unwavering commitment to sustainability strengthens its appeal as a case study. Renowned for its high quality of life, Vienna demonstrates a long-term vision for well-being. This focus extends to its ambitious "*Smart Climate City Strategy*"[9] which sets a clear goal of achieving climate neutrality by 2040. Embedded within this strategy is a strong emphasis on circular construction practices. Specific goals, such as "*circular planning and construction becoming standard*" for new builds and refurbishments by 2030, and a 70% target reuse rate for building materials by 2040, exemplify Vienna's unwavering dedication to a circular future for its construction industry.

Vienna has demonstrably embraced the CE principle with improved waste collection and enhanced recycling techniques. The iconic Spittelau waste incineration plant, built in 1971, solidified its commitment to resource conservation with practices like waste-to-energy, especially when the debate of 'sustainability' was at its nascent stage. While incineration has its limitations, it demonstrates Vienna's willingness to explore alternative resource

[9] Smart Climate City Strategy, Vienna (*website*)

management strategies. These historical initiatives have laid a strong foundation for Vienna's current embrace of CE principles. The city's existing infrastructure and ingrained culture of resource efficiency situate it in an advantageous position.

<u>Pressure on Resources and Incentives for CE:</u>

Furthermore, Vienna's population dynamics add another layer of intrigue to studying CE in construction. With a continuously growing population and a high density (over 4,600 people per square kilometre), Vienna faces pressure on resources (ICLEI, 2023). This situation creates a strong incentive for exploring circular construction practices as a means to conserve resources and minimize waste.

<u>A City-wide Approach:</u>

The most distinctive aspect of selecting Vienna as a case lies in its city-wide embrace of CE. Unlike many cities where CE initiatives might be fragmented, Vienna adopted a comprehensive initiative led by the Municipal Directorate for Building and Technology as the DO-TANK program-Circular City Wien 2020-2030 (DTCC30). Also, Vienna's progressive stance is further bolstered by The Climate Lab, a collaborative platform specifically for accelerating the circular transition in key sectors like construction and housing. This initiative, co-funded by the Austrian Climate and Energy Fund alongside key players like Wien Energie and EIT Climate-KIC, fosters innovation and collaboration to achieve a more circular future.

<u>Vienna: The Case for a Multi-level Lens on CE Transition in CI</u>

The research methodology adopts an MLP informed by Parsons' cybernetic hierarchy and Ababio & Lu's (2023) integrated framework. This approach will explore the specific barriers faced by various actors within the CI, along with the enablers that empower them to overcome these challenges and contribute to a more Circular Construction Supply Chain (CCSC). Vienna's established legacy of CE principles, collaborative platforms like the Climate Lab, its city-wide CE initiatives through DTCC30, and its focus on the cultural and socio-economic aspects of CE adoption creates an ideal real-world setting for this research. By delving into Vienna's experience, the research aims to extract valuable insights and best practices applicable to other urban environments seeking to transition towards a more resource-efficient and sustainable construction.

3.2.2. Case Selection: The Climate Lab (Meso System study)

While the transition towards CE in CI holds immense promise, challenges in market creation and siloed collaboration across the supply chain can hinder its progress. Vienna's Climate Lab emerges as an ideal meso-system case for studying the major network barriers. The collaborative platform, co-funded by a powerful consortium encompassing government agencies, energy providers, research institutions, and impact investors, embodies the spirit of public-private partnership. It fosters collaboration between companies, policymakers, researchers, and financiers. The Lab develops targeted programs, builds a cross-sector community, and measures success beyond partnerships, focusing on environmental and economic impact. Even the physical space offering co-working space is designed to spark connection and creativity, making it an ideal environment to study network barriers.

3.2.3. Case Selection: Companies (Micro System study)

Post macro and meso-system study, the research delves deeper by examining the micro-system. It specifically focuses on an in-depth analysis of the specific barriers, enablers, motivations, impacts, and actors' position on societal readiness level and within the phases of the building life-cycle. By understanding the experiences of individual actors of micro-systems, valuable insights are gained into the practical realities within CE implementation in CI.

3.3. Research Methods and Techniques

Investigating the barriers in practical implementation of CE in CI necessitates a deep understanding of actor's attitudes and motivations through employment of interpretivist approach. The present research undertakes a qualitative survey research method to unearth the underlying reasons of complexities and anxieties within the CSCs. Survey Research is the foundational research approach for this thesis study. It is defined as "*the collection of information from a sample of individual through their responses to questions*"(Ponto, 2015).

Exploring the practicality of CE in CI through qualitative data collection and application of various quantitative analysis techniques and tools, help to explain the complex issues. Thud interpreting the qualitative data into a quantifiable understanding (Saldaña, 2013). Drawing from Gary Gardner's analogy of cities as a system of systems, we can see the city as ideal case study for research of a macro system (Gardner, 2016). Analogous to living organisms, cities ingest resources, process materials, and expel waste. Just as biological entities adapt for survival, cities, with impetus to informed personals (citizens and leadership), can evolve towards sustainability. Cities, covering 7% of the earth's surface, are the centers of waste production and consumption and have great economic weight, generating 70% of the global Gross Domestic Product (GDP) (Campbell-Johnston et al., 2019; Paiho et al., 2020). They rely heavily on the imported food, water, materials, and energy, which are injected into the urban system and consumed, while the resulting waste streams are mostly sent out of the city for treatment, disposal, or landfill, bolstering the linear model, that terribly contaminates the environment (Horn & Proksch, 2022). This linear model has triggered urban areas to leave environmental footprints that are larger than their inherent bio-capacities, rendering them to be more vulnerable to environmental risks and become less resilient. While case studies can utilize various data sources like direct observation or physical artifacts, considering limitations, documentation, interviews, and questionnaires are the most practical options for this study (Saldaña, 2013). Relevant documents and content on public domain highlighting CE policies have been examined. Moreover, actor-based interviews and questionnaire responses from the selected actors, are the foundational base for this research in understanding the barriers in practical implementation of CE practices in CI at multi-systemic levels with Cybernetics' hierarchical systems approach.

3.3.1. Data Collection

Content for SWOT Analysis of Macro System

The study analyses content from various sources to conduct a SWOT analysis (Strength, Weakness, Opportunity, and Threat) Analysis of Vienna's transition to CE in construction. Leveraging a SWOT analysis in relation with Parsons' Cybernetics Hierarchy of Systems, this content analysis delves into Vienna's Construction Industry.

Government reports and policy documents including National Economy Strategy of Austria, the Federal Waste Management Plan 2023, Smart Climate City Vienna Strategy and others to understand the policy hierarchy and directives from supernational to city level. New articles, Eurostat database and blogs, especially *Wien Schauen*, catered to build a critical view on the ongoing practices in Construction Industry and a posit a check on the CE practical implementation in CI.

Municipal websites like (*VIE.CYCLE – zirkuläres Bauen - Stadt Wien*), academic research and various reports, for example from Federal Environment Agency in Austria paint a comprehensive picture of Vienna's internal capabilities and the external environment. For example, data on Vienna's social housing model (strength) and material circularity gap (weakness) is used alongside factors like the government policies are utilized to create a holistic view.

Semi-structured Interviews: Rationale

Qualitative research, particularly using in-depth interviews, offers a valuable contribution to the knowledge production process. It facilitates the deconstruction of dominant theoretical frameworks (Sandberg & Alvesson, 2011). Interviews are a cornerstone technique for social scientists seeking to understand how people construct meaning from their social experiences (Dunwoodie et al., 2023). Unlike quantitative methods focused on testing cause-and-effect relationships, interviews delve into participants' subjective perspectives: feelings, biases, opinions, and desires related to workplace or other social contexts (Denzin, 2009). This qualitative approach is crucial for exploring uncharted phenomena as interviewing acknowledges the interconnectedness of human experience. It allows to develop a hermeneutic relationship with interview participants throughout the process. This means both the participant's views and the researcher's interpretations are central to the approach.

The present thesis utilizes the technique of semi-structured interviews for understanding the case of Vienna from the multi-level lens of systemic approach. This method strikes a balance between a pre-defined interview guide and the flexibility to explore emergent topics on the subject. By allowing the actors to share their lived experiences with CE implementation, underlying barriers are uncovered and interpreted beyond those captured by the quantitative data, allowing foe a deeper understanding of the root causes.

Semi-structured Interviews: Procedure

To grasp the complexities of Vienna's Construction Industry as a whole (macro system), its crucial to examine the inner workings of its smaller components (meso and micro systems). This necessitates interviewing actors in capacity of their roles at different systemic levels (as defined by Ababio & Lu (2023)). By doing so, a comprehensive picture of the entire construction industry emerges. Using the 'public domain search tool' and snowballing approach, several actors within the Construction Industry of Vienna, were contacted via Email or LinkedIn. 13 actors were identified as interview partners and have been classified according to the Ababio & Lu's (2023) systemic categorization of actors as presented in figure 5. For this study, 'in-depth interviews' or 'intensive interviews' were conducted, which centered on the meanings of lived experiences that individual hold in the quest for a practical implementation of CE in CI. The duration of interview session ranged from 30 mins to 3.5 hours, with an average of 1 hour/ interview. Both online and offline mode-based 12 interview sessions took place based on the preference of the interviewee. The 13th actor, provided the answers via written document. The questions for each interview can be referred to at the end of this document in the section of Annexures. The questions for the interview were framed based on the role of actors in the systemic levels to have a holistic understanding of the meanings and motivations behind their experiences, perceptions, and actions. The whole session was audio recorded with a prior verbal consent of the interviewee for developing the transcripts. The transcripts were then produced with the help of AI based tool in Microsoft Office- online version of MS Word. Further, the transcripts were also refined manually with the support of recorded audio.

Figure 5: Interview Partners for the Research Study

Name of the Interview Partners	Organization/ Companies	Systemic Level	Role as actors
Klaus Kodydek	Project staff member for resource conservation and sustainability in the construction industry, City of Vienna, working on " DoTank Circular City Wien 2020-2030 (DTCC30)" - Kreislaufwirtschaft in der gebauten Umwelt	Macro	Government
Stefan Watzke and Kilian Rießbeck	Parastruct	Micro	Professionals across value chains
Maria Wirth	Alchemia Nova	Meso	Research and Collaboration
Birgit Gahleitner	Quality Austria	Micro	Professionals across value chains
Andreas Ellenberger	Circonnact	Micro	Collaboration
Jakob Ledrer	TU Wien	Meso	Research and Collaboration
Helene Patternmann	The Climate Lab	Meso	Market Creation and Collaboration
Gaetano Bertino	Alchemia Nova *	Micro	Professionals across value chains
Karin Huber Heim	Circular Economy Forum Austria	Macro	Civil Society
Peter Kneidinger	Materialnomadden	Micro	Professionals across value chains
Markus Zilker	Einszueins	Micro	Professionals across value chains
Anna Ver Deinhamer	FHWien der WKW (University of Applied Sciences for Management & Communication), Circular Economy Forum Austria, Austrian Sustainable Building Council (ÖGNI)	Macro	Government** and Civil Society
Michaela Gebesroither	Digital Findet Stadt	Meso	Government and Collaboration
* Alchemia Nova, the organisation, also works on individual construction-based projects along with Research and Collaboration (Two partners were selected from different departments within the organization and categorized as Micro and Meso respectively)			
** Previous capacity as Co-ordinator of DTCC30			

Source: 5- Compiled by author according to Ababio & Lu, 2023

Online Surveys: Rationale

Online questionnaire-based surveys are a powerful tool to explore Vienna's construction industry's shift towards a circular economy at both meso and micro system levels. This approach offers flexibility for actors to participate at their convenience and take their time answering their questions. The ability to use diverse question types, including open ended ones, allows researchers to gather rich data on both perceptions and experiences (Regmi et al., 2016). This versatility of answers gives a deeper understanding of the barriers in practical implementation of CE in CI, capturing not just the "what" but also the "why" behind the industry behavior. This method of data collection, boasts features that significantly improve response rates. Unlike paper surveys with potentially lost or forgotten responses, online questionnaires can be designed with mandatory fields to ensure valuable data is collected for each question. Additionally, reminder emails can nudge hesitant respondents to participate.

Online Surveys: Procedure

Meso system: To gain an insider's perspective and understand the network barriers hindering the collaboration within Vienna's construction industry's transition to CE, a targeted online survey was conducted amongst the members of 'The Climate Lab.' This meso-system case study focuses on the collaborative platform's potential roadblocks. Thus, to achieve this insider learner's stance, a paid membership was secured at 'The Climate Lab' from January to June 2023, allowing for active participation in their community events and fostering deeper understanding of their approach. The questionnaire-based survey was distributed through a dedicated LinkedIn group, "*Friends of Climate Lab*," and garnered 24 responses. Sogolytics, an online survey platform, facilitated both questionnaire development and data analysis. Its user-friendly interface ensured a professional survey even for those less familiar with the tool. Powerful analysis tools within Sogolytics generated comprehensive reports for extracting meaningful insights.

Micro system: The micro-level system study has been conducted using the qualitative method of Questionnaire in Survey research. Here the unit of analysis is a company as a part of micro-level system for CE implementation. The questions have been drawn majorly from two sources: 1) Circular Initiative Mapping platform of Circular Regions[10], and 2) Study published in Building and Environment regarding "*Mapping the barriers to Circular Economy adoption in construction industry: A systemic review, Pareto Analysis, and mitigation strategy map*" (Wuni, 2022).

This questionnaire method allows to gather detailed experiences and perspectives from actors. It is helpful to gain insights into, for examples, existing knowledge and attitudes

[10] Accessibility to the platform - worked as an intern in the organization- Circular Regions from October 2022- February 2023 (*website*)

towards CE in construction, specific strategies companies are using or considering for implementing Circular Practices (e.g., using recycled materials, designing for disassembly), and perceived enablers and barriers associated with CE implementation. Nine(9)[11] taxonomies of the barriers and enablers to CE implementation in the Construction Industry have been articulated following the study conducted by (Wuni, 2022) based on a Systemic Literature Review (SLR) of existing classifications and typologies. The taxonomies are: Cultural, Market, Knowledge, Financial, Management, Regulatory, Technology, Supply chain, and Stakeholder. Each taxonomy, collectively with its associated unit barriers, can enable targeted mitigation strategies, as well as integrated solutions to improve CE implementation in construction.

The questions addressing the impact (environmental, social, and economic) of the company, positionality of the company in the circular business model and societal readiness level, have been adopted from the Mapping platform of Circular regions.

3.3.2. Data Analysis- Methods and Tools

Leveraging the rich data collected, the next stage delves into the analysis methods and tools employed to extract meaningful insights. For the data collected from government reports, new articles, and municipal websites, providing insights into policy, current practices, and internal capabilities, SWOT analysis has been undertaken along with an establishment of inter-relationship from Parsons' cybernetics systems approach. Semi-structured interviews with the actors explored lived experiences and underlying barriers to practical implementation of CE in CI. Online surveys conducted at both meso and micro systems level, enabled to gather rich data on perceptions and practices.

<u>SWOT Analysis of Vienna (Macro System) towards Circular Construction</u>

A multi-layered SWOT analysis has been conducted by dissecting Vienna's construction industry through the insightful lens of Parsons' Cybernetic Hierarchy of Systems Control. This framework categorized factors of the cultural and social systems influencing the industry's CE transition in CI, offering a deeper understanding of their internal and external dynamics. These factors are presented from the various data collected from the public domain database. To further explore the demolition trend, a map of demolition sites has been developed using the data collected from 'Wien Schauen', and ArcMap, a Geographical Information System (GIS) mapping tool. By linking these strengths, weaknesses, opportunities, and threats to specific levels within Parsons' Hierarchy, the analysis goes beyond a simple listing. It reveals the foundational cultural values and social structures

[11] 9/11 taxonomies are incorporated in the present research study

that either propel or hinder Vienna's progress towards adopting the Circular Economy systems in its construction industry.

A visual representation of this analysis is provided with a scoring system (low, medium, and high). This scoring reflects the potential impact of each factor on Vienna's transition to a CE system-based Construction Industry. Crucially, conducting a SWOT analysis is essential to understand the barriers and enablers in translating present status of applications of CE systems in Vienna's construction industry through a macroscopic lens (municipal to global level) to understand the potential scope of gaps between the theory of 'practices' and 'practical implementation' in the quest for transition towards circular construction. This analysis creates a springboard for further empirical investigation.

<u>Empirical Investigation of 3M systems in the city of Vienna and its construction industry</u>

a) *Vienna: The Case for a Multi-level Lens on CE Transition in CI*

To investigate the barriers faced by the actors in implementing circular practices within Vienna's construction industry, this study adopted a qualitative approach centred on semi-structured interviews. The analytical framework employs a multi-level lens, drawing from the cluster of five barriers and associated key enablers of CE transition in construction identified by Ababio & Lu (2023). These barriers and enablers have been operationalised into a coding scheme as shown in figure 7 for the systemic analysis of the interview transcripts.

Atlas.ti software facilitated the quantitative data analysis for the collected qualitative data. This involved a rigorous process of identifying interview segments where actors directly or indirectly referenced the pre-defined barriers and enablers. This subjective interpretation ensured a comprehensive understanding of the actors' perspectives on both barriers and enablers for CE implementation. Further, a heatmap based on quantified coded data has been generated, providing a visual representation of the relative intensity for each sub-categorical barriers and enablers across the three 3M systemic levels outlined by the Ababio & Lu (2023) framework. This multi-level approach offers a multi-faceted understanding of the complex interplay between the individual, organizational and institutional factors influencing the practical implementation of circular practices within Vienna's CI.

Figure 6: Codes for Data Interpretation

Barriers	Sub-categories (CODES)	Associated Enablers	Sub-categories (CODES)
Cultural Barriers	Conservative nature of industry; Inadequate resource availability; Lack of awareness; Lack of expertise; Lack of Interest; Negative social pressures; Old production and consumption practices; Poor environmental perceptions; Resistance to change; Willingness to interact along value chains.	Cultural Enablers	Creating roles in construction firms to champion the transition Incentivising firms and professionals alike to trigger behaviour change Promoting stakeholder awareness through education
Financial and Economic Barriers	Access to funds; Competition; Dysfunctional markets for recyclables; High Financial risks; High upfront cost of CE initiatives; Low cost of virgin materials; Lower cost of disposal than recycling/recovery; Market alternatives for materials; Rapid changes in market; Short Term investment outlook of investors; Uncertainty in material resale value.	Financial and Economic Enablers	Innovative procurement and financing with the sector New market creation for circular services and products Public Private Partnership
Political and Legislative Barriers	Bureaucracies and complex procedure; Challenges in contract development;	Political and Legislative Enablers	Advocating new standards that capture circularity of materials

	Inconsistent regulations in different regions; Lack of circular requirements in public procurement; Lack of Consistent guidance; Lack of environmental regulations and laws; Lack of incentives; Lack of overarching policy; Lack of promotion and education.		Development of national vision and target for national vision and target for CE in the industry Strict policies and guidelines to enforce CE
Technological Barriers	Absence of Material alternatives; Availability of Technology; Challenges with material recovery; Inadequate indicators for holistically assessing CE; Insufficient collaborative and information sharing tools; Lack of circularity in product design; Lack of Information on material quality and properties; Problems with standardisation of materials; Supply chain complexities.	Technological Enablers	Collaborative tools for information transfer enabled by new technology New innovations in materials capabilities and technology advancement Process and product redesign with adoption and promotion of eco efficient products and processes
Framework and Theory related Barriers	Absence of coherent vision; Attention on specific aspects of CE rather than the whole system; Lack of clear definition for the industry; Lack of convincing case studies; Lack of holistic business model; Long standing linear economic regime.	Framework and theory related Enablers	Available funding for CE research Clarity of Definition Develop CE model for specific to CI Strategic research efforts into various aspects of CE within the industry

Source: 6 Ababio & Lu (2023)

b) The Climate Lab (Meso System study on network barriers)

This research considers into the meso systems to gain insights regarding the network barriers, as this system level deals with market creation, network and collaboration (Ababio & Lu, 2023). The research method of online-questionnaire based survey has been employed, to gather data from actors (member of 'The Climate Lab').

To bridge the gap between qualitative data and quantitative analysis, the platform of Sogolytics was utilised.

Question 1: Ranking challenges in Value Network Formation

For the first question, which asked the participants to rank the main challenges in building a value network and collaborative system (using pre-defined options from Wuni (2022)'s identified network barriers), a weighted score method was employed. Each answer choice received a weight based on its ranking (1 for the highest challenge, 5 for lowest). These weights were then multiplied by the frequency of each answer at each rank and summed across all ranks. The answer option with the highest overall score was designated the most significant challenge, followed by the second highest score, and so on. This method provided a quantitative ranking system for the qualitative data.

Question 2: The Climate Lab's role in Network building

The second question focused on how The Climate Lab facilitated value network creation. Here, a thematic analysis was conducted using Sogolytics. Actors' statements were analysed to generate a word cloud, visually highlighting the key themes and concepts emerged regarding the importance of network creation by institutions like The Climate Lab. This word cloud provides a qualitative insight into the perceived benefits of the Climate Lab's role in fostering collaboration.

Question 3: Membership Utilization at the Climate Lab

The third question employed a multiple-choice format, allowing participants to select various ways they utilise their membership at The Climate Lab. The data from this question provided a straightforward quantitative analysis of how actors leverage the physical space and resources offered by The Climate Lab.

c) *Companies (Micro System Study)*

After the semi-structured interview, four Companies/Organisations were sent an online questionnaire of 29 questions, via Typeform. 4/4 responses were received in the period from *21-08-2023* to *31-08-2023*. In case of barriers, only some of them are mentioned in the document, for example in case of financial barriers, top 5/10 are stated based on the rankings by the actors. The lower ranked barriers are not included for the analysis. The data has been published in this research with their prior consent of answering 'Yes' at the end of the online survey. The detailed questionnaire has been presented in the 'annexures.' The analysis has been done with the support of Microsoft Excel, where the top ranked entities have been highlighted by each participant.

Question 1-8: Categorization and Impacts

These questions analyze various aspects of each company through a ranking and categorization approach.

- ✓ <u>Scope of Business/Work Outreach</u>: Categorizes the company's operational scale (National, Global, etc.).
- ✓ <u>Business Transaction Model</u>: Categorizes the type of business transactions the company engages in (B2B, B2C, B2G).
- ✓ <u>Facet of Circular Economy</u>: Categorizes the specific areas of circular economy the company focuses on (Built Environment, Material Flows, etc.).
- ✓ <u>Addressing SDGs</u>: Categorizes the Sustainable Development Goals (SDGs) that the company's activities contribute to (SDG 9, SDG 11, etc.).
- ✓ <u>Social Impacts</u>: Categorizes the social impacts created by the company's operations (Developing Social Capital, Increased Human Capital, etc.).
- ✓ <u>Environmental Impacts</u>: Categorizes the environmental benefits associated with the company's activities (Increased Resource Utilization, Preserving Natural Capital, etc.).
- ✓ <u>Economic Impacts</u>: Categorizes the economic benefits created by the company (Alternative Revenue Streams, Increased Value Creation, etc.).

Question 9-22: Barriers and Enablers

Barriers: For example- About the Cultural barriers- This question asks participants to rank the most significant cultural barriers (out of 5 options) hindering circular economy implementation in construction. An analysis based on the top barrier by each company has been perceived as most critical. Similar Ranking Analysis is used for the following barriers:

- ✓ Market Barriers
- ✓ Knowledge Barriers
- ✓ Financial Barriers
- ✓ Management Barriers
- ✓ Regulatory Barriers
- ✓ Technology Barriers
- ✓ Supply Chain Barriers
- ✓ Stakeholder Barriers

Social Enablers & Market Enablers (and others): These questions identify factors that can facilitate the transition towards a circular economy. They likely use a categorization approach to group these enablers (e.g., Competitive Advantage for Early Adopters under Market Enablers).

Question 23 -29: Positionality of Companies in CSCs

Position of the Company in the Circular Construction (Phase): This question categorizes the specific phases of circular construction (Material, Design, Production/Distribution, Consumption/Stock, Waste) that the company's activities focus on to understand the CE practices.

Societal Readiness Level: This question categorizes the level of societal readiness for the solutions offered by each company based on a pre-defined scale (SRL 1-9).

Ch 4 Case Introduction: The City of Vienna

4.1. Positionality of Vienna in the Austrian Context

"Österreich droht an Klimazielen krachend zu scheitern" (Pramer, 2023)

"*Translated- Austria is in danger of failing miserably when it comes to climate targets*"

Austria's federal government (Turquoise-Green coalition, indicating collaboration between center-right Austrian People's Party (ÖVP) and an environmentalist party, The Greens) boasts a seemingly impressive target: achieving climate neutrality by 2040, a full decade ahead of the EU's goal. This ambitious pledge has gathered attention, but a recent report by the Federal Environment Agency[12] paints a concerning picture. It says that the current policies are insufficient to even meet the EU's less stringent target of net-zero emissions by 2050. The report predicts a troubling scenario: Austria's CO_2 emissions could still be around 55 Mt CO_2e by mid-century, well above zero, and only managing a 30% reduction from 1990 levels. This significant gap between Austria's ambitious goals and its current trajectory exposes a critical need for the government to enact stronger and more effective policies if it hopes to achieve its self-imposed deadline.

This trend is likely to be accentuated due to the construction industry being a major culprit. The 2021 final report on the circular construction industry published by the Federal Environment Agency in Austria reveals that construction consumes well over 50% of the nation's resources (Achatz et al., 2021).

Austria's CI faces a pressing challenge regarding waste management, as evidenced by the substantial proportion of national waste it generated (72% equating to 60 million tonnes annually). This waste stream is primarily composed of excavated materials (33 million tonnes/ year), with a concerningly high landfilling rate of 70% (Kasper, 2018). Even the seemingly positive recycling rate of 80% of mineral construction and demolition debris presents a discrepancy, with the actual recycled quantity falling short. Despite Austria's position as a European leader in recycling, the construction sector exhibits a significant circularity gap (62.6%) indicating a substantial portion of materials remains outside efficient reuse or recycling loops (Kasper, 2018). This confluence of factors- overflowing landfills, unmet targets, and a high circularity gap- underscores a reality check on the Circular Economy Implementation in the Construction Industry and hence, research on the barriers and enablers.

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[12] Pramer, P. (2023). Österreich droht an Klimazielen krachend zu scheitern. DerStandard. Retrieved 28 April 2024, from (*website*)

A key point to note, in crafting Austria's 2050 circular economy strategy, extensive stakeholder participation ensured a comprehensive approach. Through workshops and online surveys, over 250 participants representing businesses, government, academia, and civil society identified key areas for CE implementation. The construction industry emerged as a top priority, with nearly half of survey respondents acknowledging its high potential for circularity (Moser et al., 2021).

Vienna, the capital city of Austria, is the center of the Social Democratic Party (SPÖ). SPÖ in its coalition agreement 2020 with The New Austria and Liberal Forum (NEOS), presented the first program of a social-liberal government in Austria. Their plan involves reducing GHGs to zero and promoting recycling and resource conservation in construction. They intend to achieve this partly by tracking building materials to make sure they are reused or recycled effectively (City of Vienna, 2022). On June 3rd 2022, around 100 experts from various disciplines took part in "CIRCULAR VIENNA!" or "Zirkuläres Wien!" at the city hall envisioning Vienna as a "*social climate model city, securing affordable housing for the Viennese and future generations by reducing* CO_2*, relying on renewable energies and thinking about the circular use of raw materials in residential construction right from the start*," where the emphasis was given on the planning of buildings, taking in an account where materials can be reused and recycled in the event of demolition and or dismantling and to address, how the waste can be reduced by using secondary materials productively again and again. Deputy Mayor Kathrin Gaál[13] highlighted the dimensions related to the concept, "*In a circular city, the principles of the circular economy are applied for the benefit of citizens. Sustainability and resource conservation go hand in hand with climate protection and quality of life*" [14]

Vienna, is generally considered the capital 'social housing' since approximately 60% of its residents live in flats rehabilitated or constructed through housing subsidies. This is especially looked after by the municipal and limited-profit providers, ensuring the aid to approximately 220,000 municipal flats and around 185,000 flats owned by the later association (Glaser, 2022). Vienna Model of Social Housing is a true example of social solidarity, however, the capital city is no different from the ever-growing fast cities around the globe, experiencing climate change, which has become quite apparent in the city, for example, an increase in extreme heat events (Holzer & Tschannett, 2022). Vienna's high percentage of social housing presents a golden opportunity for a smooth transition to a CE. Centralized management allows for an opportunity of coordinated retrofits that can improve resource use and energy efficiency. Social housing providers can be incentivized to extend building lifespans, aligning with CE's focus on keeping resources in use. Moreover,

[13] Kathrin Gaál, Deputy Mayor and Executive City Councillor Business Group Housing, Urban Renewal, and Women, 2022

[14] City of Vienna. (2022, June 10). Kathrin Gaál, Deputy Mayor and Executive City Councilor Business Group Housing, Housing, Urban Renewal and Women. Retrieved from Stadt Wien: (*website*)

the direct connection with the residents allows for CE education and engagement, fostering a sustainable community.

4.2. Hierarchy of Policy Instruments for enabling CE systems

A range of policies at global, EU, federal and municipal level has been presented that promoted resource efficiency and circularity in construction. These include bans on landfilling certain materials and directives on priority to renovations etc.

Level	Timeline	Policy	Description
Global	2015	Agenda 2030 Sustainable Development Goals (SDGs)	Promote waste prevention sustainable consumption and production (SDG 12)
EU	2008	EU Waste Framework Directive (Directive 2008/98/EC)	Efficient use of resources and the best possible use of natural resources covering the entire life cycle of the product from repairing to recycling and dismantling.
	2011	EU construction products regulation (Regulation (EU) 305/2011)	Encourages sustainable use of natural resources in construction. Promoting reuse and recycling after demolition, structural durability, and eco-friendly raw and secondary materials as a must.
	2015	EU Circular Economy Package	Promoting repairability and recyclability of products
	2020	A Renovation Wave Strategy for Europe	Increase energy and resource efficiency in building renovations. The renovation rate is to be doubled by 2030
	2020	The 2ND edition of the EU Circular Economy Action Plan as a central element of the European Green Deal	Construction as one of the seven key product areas for circularity
	2020	EU Taxonomy regulation and non-financial reporting directive in 2022 (Directive 2014/95/EU)	Defining environmentally sustainable economic activities and limiting the risks of "greenwashing"

	2023	Delegated regulation to EU taxonomy (Regulation (EU) 2023/2139) as a supplement to the EU Taxonomy Regulation (Regulation (EU) 2020/852)	Technical assessment criteria for sustainable construction activities: “new construction”, “renovation of existing buildings” and “acquisition and ownership of buildings”
Federal (Austria)	2002	Waste Management Act 2002 “*Abfallwirtschaftsgesetz 2002*”	Prioritize waste prevention and resource efficiency
	2016	Recycling building materials ordinance “*Recycling-Baustoffverordnung*” (BGBl. II Nr. 181/2015)	Promote recycling-oriented demolition with the associated standard ÖN B3151
	2016	Landfill ordinance 2008 and The amendment (Federal Law Gazette II No. 291/2016)	Bans on specific materials to landfill. For example, it stipulates that from January 1, 2024, bricks from production, concrete demolition, or road demolition may no longer be deposited in landfills. From January 1, 2026, there will be a landfill ban for plasterboard.
	2022	National Circular Economy Strategy	Promote resource-saving and circular construction methods
	2023	Federal Waste Management Plan 2023 “*Bundesabfallwirtschaftsplan 2023*” (presented every 6 years)	Increase circularity rate to 18% by 2030
Municipal (Vienna)	2020	Govt agreement 2020 the Progressive Coalition for Vienna	Net zero GHGs emissions by 2040
	2020-2030	Strategy Vienna 2030 Economy and Innovation	Life cycle and CE oriented planning and construction
	2020-2030	Do Tank Circular City Vienna 2020-2030" (DTCC30) program	A flagship project of the Vienna 2030 economic and innovation strategy and sees itself as a cross-municipal hub for the topic of circular economy in the construction industry and the built environment.

	2022	Smart Climate City Vienna Strategy	Standard for Circular construction and planning in new buildings and renovations from 2030

4.3. SWOT Analysis of Vienna (Macro System) towards Circular Construction

Strength and weaknesses are internal factors to Vienna. Opportunities and Threats are external factors that can influence the Circular Economy transition in Construction Industry. Relating a SWOT (Strength, Weakness, Opportunity, and Threat) analysis with Parsons' Cybernetic Hierarchy provides a more nuanced understanding of the factors influencing the flow of information and energy. *(The list of factors is inexhaustive and can be expanded as per the availability of various data and information related to the macro system)*

Flow of Information in Cultural System (Values and Norms): Overall societal values and norms that influence construction practices.

Flow of information in Social System (Economic system, Political system, Socialization, Social Control): This system considers various aspects including economic conditions, government policies, level of awareness within society, and established norms within the CI.

A summary for the details has been depicted in Figure 11, highlighting the inter-relation of SWOT Analysis with the Cybernetics Hierarchy with a scoring. The scoring is based on the potential impact on Vienna's transition to a CE system in construction. The SWOT analysis offers a robust foundation for the empirical research to understand the lower hierarchy-based systems that interconnects the flow of energy.

It is important to note that the scoring is subjective and the goal is to prioritize the focus based on the relative importance of each factor. A high score indicates a significant factor, while medium score suggests a moderate influence. A low score reflects a less critical influence, but can be still relevant.

Factors	Parsons' Cybernetics Hierarchy of Control	Status of Vienna/Austria	Implications on CE transition	Category of SWOT
Culture in Cities (Strong Social Cohesion) (Figure 7) Source of data: Eurostat[15]	Cultural system (Values and Norms)	According to Perception survey results, the Austrian Capital, Vienna has been ranked first since 2019 till the latest survey in 2023.	Vienna's longstanding position in Perception surveys hints at the city's emphasis on social harmony. As suggested by Parsons' cultural system, this social cohesion might translate to a willingness to embrace resource sharing and waste reduction. Additionally, a high perception ranking indicates a potential strong infrastructure supporting circularity, such as waste management systems.	STRENGTH
Culture of 'Demolition' (Figure 9)	Cultural System (Attitudes and Values) – Preference of newness over old Social System (Norms and Roles)- Economic pressures by developers	Since 2016, there has been an increase in the number of demolished buildings in Vienna.	According to Scherer (2023), "the bypassing of the MA 19 via "demolition" has often been observed in recent months" (reducing the potential for reuse of high-quality materials, forcing them to be downcycled into lower-grade applications)	WEAKNESS

[15] Eurostat Database (*website*)

Network and Collaboration (Figure 10)	Cultural system (Value sharing and exchange of knowledge) Social System (Socialization)	DTCC30 has collaborations with Austrian Standards, Circonnact, CIRCUIT, Climate Lab, Digital findet Stadt, EIB/Circle Economy, ICLEI, IG Lebenszyklus Bau, Impact Hub Vienna, OIB, Thinkport Vienna, Thinkubator, BOKU, Vienna Business Agency	Extensive engagement with research institutions, NGOs, and government bodies fosters knowledge exchange and innovation. Strong Social System for collaboration and knowledge sharing on circular construction.	OPPORTUNITY
Global Liveability Index Source: Economist Intelligence Unit (EIU)[16]	Social System (Economic System)	The Austrian Capital, Vienna has secured the top position in eight out of the ten times, over the past decade. This sustained success can be attributed to the city's ability to provide an exceptional quality of life characterized by a confluence of factors: political stability, well-developed infrastructure, robust educational and	However, Vienna is facing a growing heat stress problem due to urban development and climate change. This is causing health issues, with heat-related deaths reaching as high as 1283 during extreme summers. Simulations predict that this problem will worsen in the coming decades. The current building materials in the city trap heat, exacerbating the issue. Embracing CE, with its focus on reusing existing structures and buildings with secondary materials, offers a viable path	STRENGTH

[16] The Global Liveability Index (*website*)

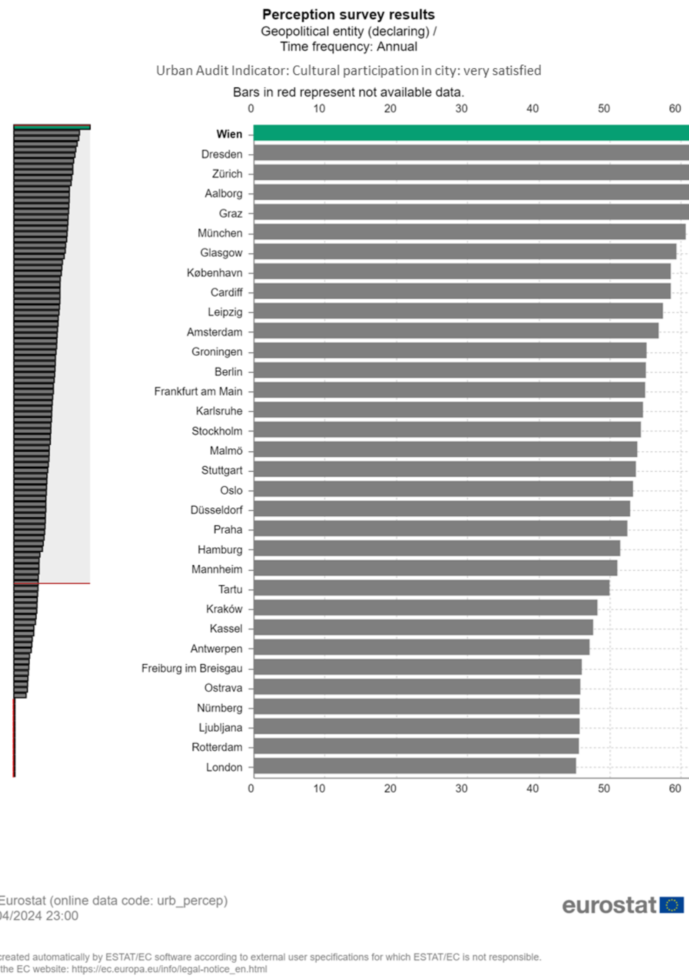
		healthcare systems, and a vibrant cultural landscape.	towards a cooler and healthier Vienna. [17]	
Construction Confidence Indicator Source of data: Eurostat	Social system (Economic system)	The monthly data suggests that the sentiments of construction industry professionals in Austria are quite pessimistic, as it has been in the negative quarter for 10 months. This translates to a negative outlook on future prospects, potentially manifesting in reduced project volumes, anticipated profit contraction, and workforce shrinkage.	Positive Impact: If the pessimism stems from economic slowdown or high material costs, it can lead to a decrease in new construction projects (Less demand for virgin materials) Negative Impact: Financial anxieties associated with low confidence can discourage upfront investments in circular construction practices.	OPPORTUNITY/ WEAKNESS
Industrial Confidence Indicator (Figure 8)	Social System (Economic system)	The monthly data reveals that Austria has been floating at the base in the negative quarter of the indicator, gauging declining production and rising inventories.	Can be a boon for the CE. Lower production reduces raw material strain, aligning with CE's focus on conservation. Additionally, with fewer new orders, a culture of reuse or recycling is fostered, core principles of CE.	OPPORTUNITY

[17] Vienna Environmental Protection Department- MA22. (2018). *Urban Heat Island Strategy: City of Vienna*. Vienna: Municipality of Vienna, Vienna Environmental Protection Department – Municipal Department 22.

Source of data: Eurostat				
Material Flow Accounts Unit of Analysis: Tonne per capita Source of data: Eurostat	Social System (Economic System)	Austria stands at 11/37, highlighting high material flows from fossil energy materials, biomass, metal ores, etc.	This implies a large amount of raw material being extracted and used within the country's economy. It also indicated high levels of economic activity and potential environmental impacts. This indicates a need to transition their economy towards a circular model.	THREAT
Material Import Dependency Source of data: Eurostat	Social System (Economic System)	Austria has high fossil energy materials import dependency at 96.5% (2022)	A high reliance on fossil fuel imports creates vulnerability to price fluctuations and environmental concerns. Promoting local sustainable materials and transitioning to CE can reduce its dependence.	THREAT
Material Circularity Rate Source of data: Eurostat	Social System (Economic System)	Austria ranks at 7/37 among other European countries in 2022 with a material circularity rate of 13.6% up from 9.2% in 2013.	Austria shows a positive movement towards CE. However, this ranking alongside its high reliance on fossil fuel imports (~97%) underscores the need for further progress in resource conservation and a	WEAKNESS

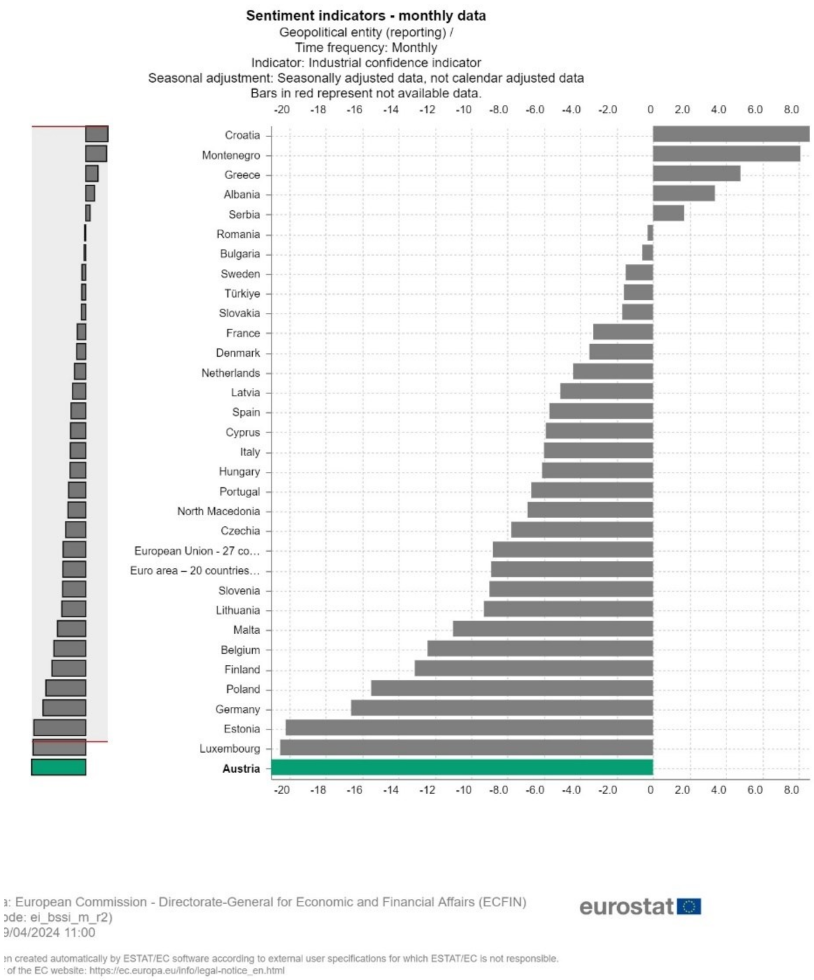
			potential shift towards more local, sustainable materials.	
Government Targets for CE at national and city level	Social System (Political system)	National CE Strategy, Smart Climate City Vienna Strategy, DTCC30 etc.	Policy direction creates a supportive environment for circular construction	OPPORTUNITY
Different Political Ideologies	Social System (Political System)	Different ideologies of coalition government at federal level (Austria) (conservatives- green) and at provincial level (Vienna) (social-liberal)	Gap Between Policy & Action due to different ideological preferences	THREAT
Vienna's Social Housing Model	Social System (Social Control)	A quarter of housing in the city belongs to this category	Central management – Co-ordinated retrofits, resident education	STRENGTH
Existing Legal Framework	Social system (Political system)	EU directives, Recycling building materials ordinance Federal Waste Management Plan 2023 etc.	Regulations promoting recycling and stringent bans on landfilling certain materials	STRENGTH

Figure 7: Culture in Cities (Participation)



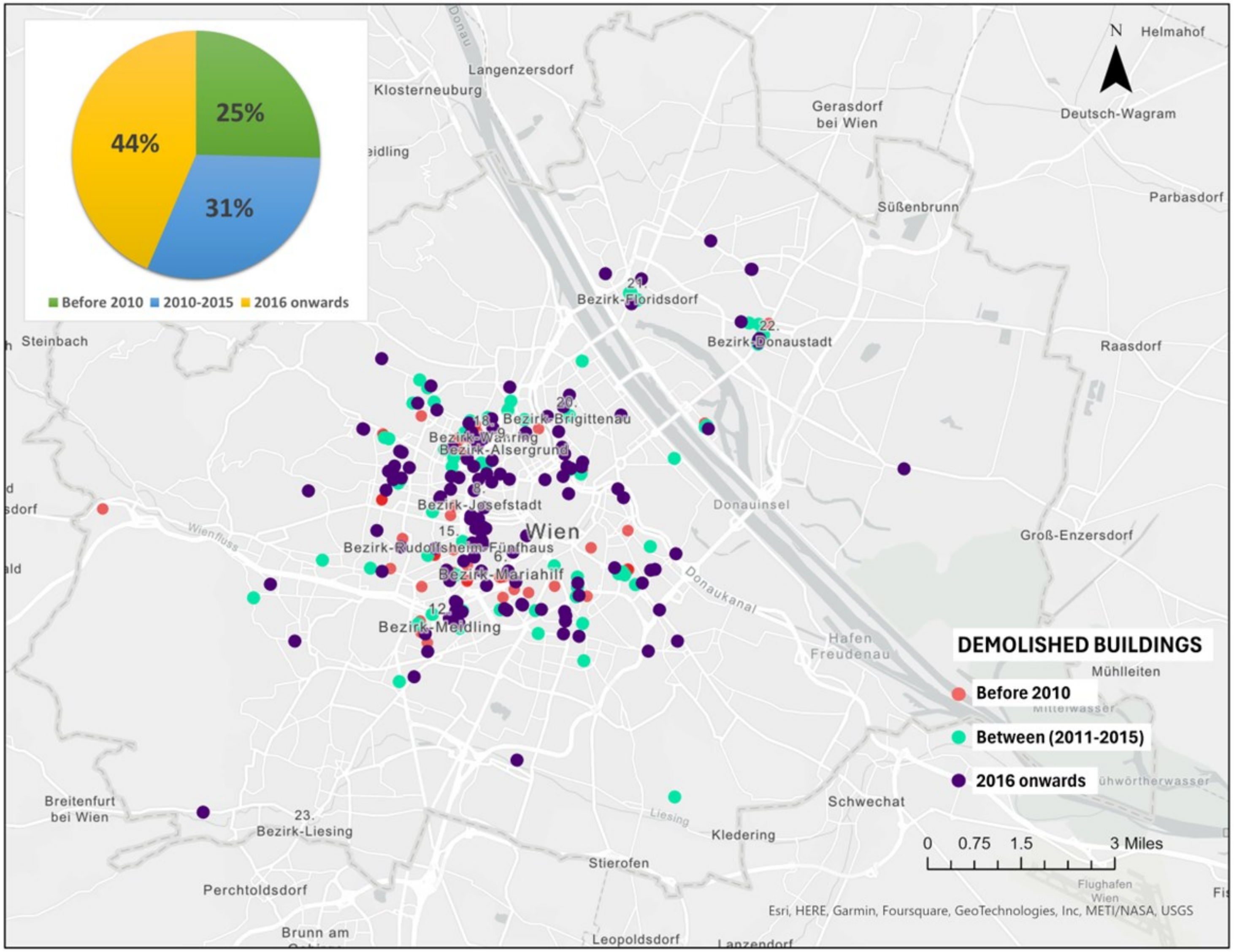
Source: 7- Eurostat database

Figure 8: Industrial Confidence Indicator



Source: 8- Eurostat Database

Figure 9: Culture of 'Demolition' in Vienna



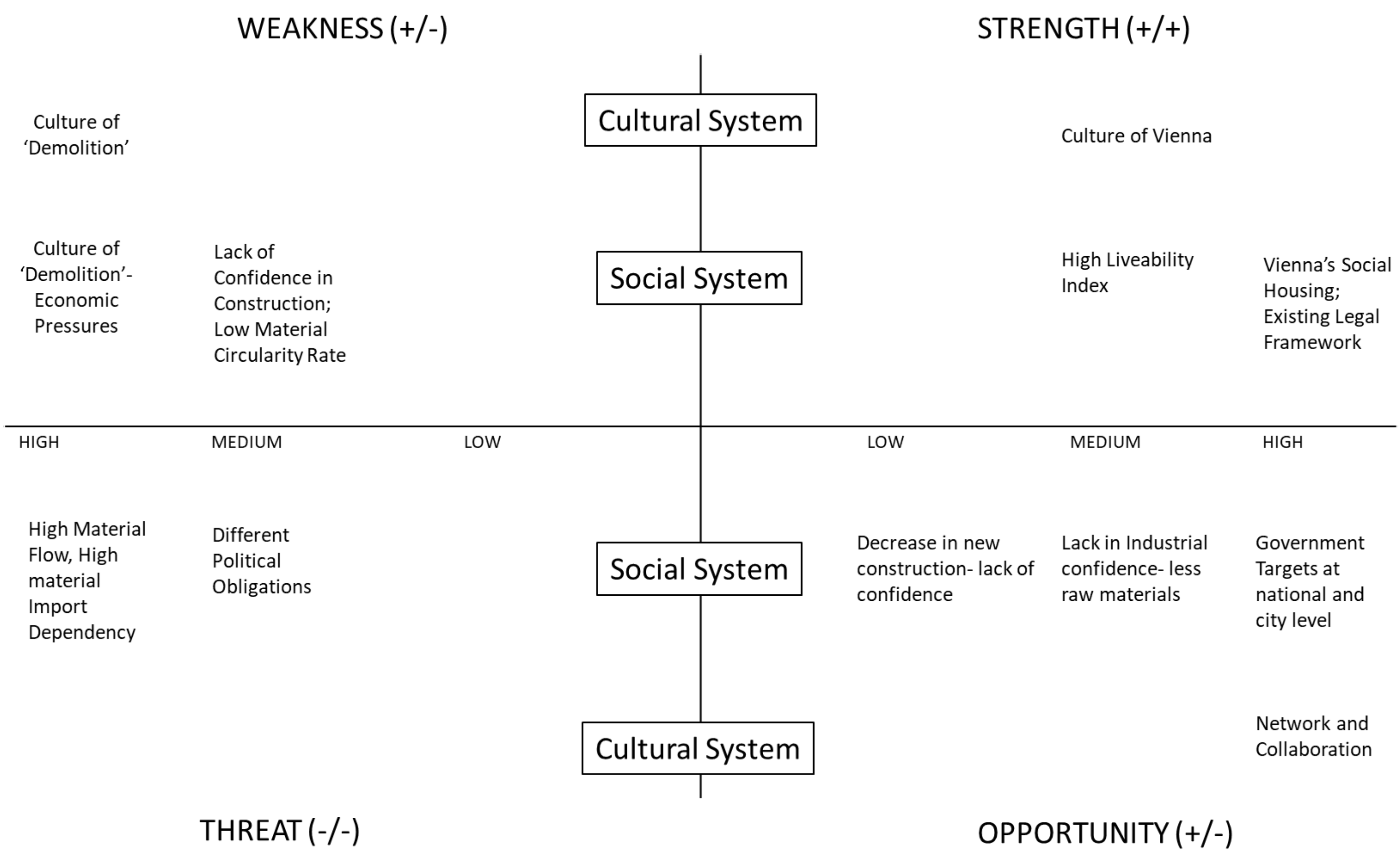
Source: 9: Compiled by author, data from ([Wien Schauen]())

Figure 10: Network and Collaboration of DTCC30 program of the city of Vienna

Color Coding	Topic
	Norms and Regulations
	Circular Economy in Construction, Sustainable Building
	Digitalization and circular procurement
	Roadmap, Strategy, Governance
	Knowledge Transfer, Accessibility of the Topic and Logistics
	Funding opportunities

Source: 10- Compiled by Author

Figure 11: SWOT Analysis for Vienna and its relation with Cybernetics' hierarchy of Control



Source: 11- Compiled by Author

Ch 5 Empirical Investigation- Results and Interpretations

4.1. Vienna: The Case for a Multi-level Lens on CE Transition in CI

Pomponi et al. (2021) while conducting a study to answer, "*where will circular economy take us*?" reported that the concept of a circular economy (CE) involves developing new technologies, sustainable business models, and regulatory measures to address the environmental challenges. However, there are complexities and challenges associated with implementing a CE, including the need for impact assessment and measurability.

With the help of classified cluster of five barriers by Ababio & Lu (2023), the study examines the barriers to practical implementation of CE in Vienna's CI. The cluster of barriers has been be categorized by their impact within the construction system(Ababio & Lu, 2023). The systemic analysis of the semi-structured interviews based on the cluster of five barriers are as follows:

Barriers	Sub-category of Barriers	Micro	Meso	Macro	Total
Cultural Barriers	Conservative nature of industry and *political system*[18]	2	2	1	5
	Inadequate resource availability				
	Lack of awareness	1	1	4	6
	Lack of expertise	1		1	2
	Lack of Interest		1	3	4
	Negative social pressures	1	1	2	4
	Old production and consumption practices	1		1	2
	Poor environmental perceptions				
	Resistance to change		3	3	6
	Willingness to interact along value chains	2		2	4
Total		8	8	17	33
Barriers	**Sub-category of Barriers**	**Micro**	**Meso**	**Macro**	**Total**
	Access to funds	2	4	2	8
	Competition		2	1	3

[18] The reiteration of conservative nature of the government, this addition of the political system has been made.

Financial and Economic Barriers	Dysfunctional markets for recyclables	3	1	1	5
	High Financial risks	1			1
	High upfront cost of CE initiatives	2			2
	Low cost of virgin materials	2			2
	Lower cost of disposal than recycling/recovery	2	1		3
	Market alternatives for materials for materials		1		1
	Rapid changes in market	1			1
	Short Term investment outlook of investors	2			2
	Uncertainty in material resale value	2			2
Total		15	5	2	30
Barriers	**Sub-category of Barriers**	**Micro**	**Meso**	**Macro**	**Total**
Framework and Theory related	Absence of coherent vision	1	1	3	5
	Attention on specific aspects of CE rather than the whole system	5	4	6	15
	Lack of clear definition for the industry	3	3	1	7
	Lack of convincing case studies	1		1	2
	Lack of holistic business model	1		2	3
	Long standing linear economic regime		2	4	6
Total		11	10	17	38
Barriers	**Sub-category of Barriers**	**Micro**	**Meso**	**Macro**	**Total**
Political and Legislative barriers	Bureaucracies and complex procedure	3	5	4	12
	Inconsistent regulations in different regions	4	1		5
	Lack of Consistent guidance		1		1
	Lack of environmental regulations and laws		3	1	4
	Lack of incentives	4	1		5
	Lack of overarching policy		1		1

	Lack of promotion and education			1	1
Total		11	12	6	29
Barriers	**Sub-category of Barriers**	**Micro**	**Meso**	**Macro**	**Total**
Technological Barriers	Absence of Material alternatives			1	1
	Availability of Technology	1		1	2
	Challenges with material recovery		1		1
	Insufficient collaborative and information sharing tools	1	1		2
	Lack of circularity in product design	1	2	0	3
	Lack of Information on material quality and properties		1	1	2
	Problems with standardization of materials	1		1	2
	Supply chain complexities	2	4	3	9
Total		6	9	7	22

Legends for the color codes:

Intensity of Barrier		**Codes**
Low	1-2	
Medium	3-4	
High	5 above	
Barrier (amongst 3M Systemic Level)- Highest		
Overall Top Barriers		
Total frequency of a barrier		

In the above analysis, the number entails the frequency of each barrier mentioned in the Transcript of the semi-structured interview i.e. by the actors at different systemic levels. Overall, the highest frequency of barriers is related to framework and theory of circular economy in construction *(38)*, followed by the cultural barriers within the 3M systemic levels *(30)*. Moreover, the intensity of each barrier faced by actors at each systemic level can be perceived with the help of the heatmap.

4.1.1. Barriers: Framework and Theory

The result exposes a lack of clear vision for circular economy in construction, with a focus on narrow aspects like recycling instead of a comprehensive approach. This along with lack of clarity with the definitions and concepts of CE in construction and a dominant linear economic mindset hinders the transition.

For example, an actor at meso level argues about the absence of coherent vision,

> "There is a plan behind this. but you create fuss…A haze and people do not know where to start or what to do."

Whereas, an actor at macro level directly points to the lack of clarity,

> "We're still confronted with it, as a new topic. A lot of stakeholders in the construction sectors are not fully aware of the circular economy or are aware that it is important, but do not really fully understand at the moment how to implement it in their daily business."

Another actor at micro level pinpoints the overemphasis on recycling within CE for construction,

> "...and not just recycling. What we do? No, we do not downgrade stuff, we create things up. We bring them to what they are or what they could be in a positive way...."

It criticizes the idea of simply downgrading materials through recycling. In fact, this barrier related to "*Attention on specific aspects of CE rather than the whole system*" a sub-part of the barrier- Framework and Theory, is the most frequent barrier (*15*), more or less, acknowledged equally at all systemic levels.

Few examples of its iteration and the attached meanings have been elaborated below:

> "We have more than 80% of all demolished buildings. More than 80% of the material is recycled. As long as we call landfill, recycling, there is a need for bigger transition with that, but that's no solution. I mean to build streets with demolished concrete. That's not answering anything apart from some tracks less on our streets because we don't need a new gravel, but it's not really an answer for anything to crush it and to use it for landfill for streets." *(Actor at Micro level)*

The above quote criticizes the narrow focus on one aspect of CE, "recycling" in construction. It highlights how crushing and reusing concrete for applications like roadbeds might be counted as recycling statistically, but it doesn't represent the true spirit of CE.

> "Circular Economy Transition is cited as a goal everywhere, there is quite a bit of awareness, but there is quite a lack of what circular economy means. I think that's actually also a pretty big barrier. The concept is not clear. There are so many different strategies, for example with climate change and mitigation, it is much more clear... this is one of the big misunderstandings of circular economy, it is not just about recycling." *(Actor at Meso level)*

The above quote emphasizes not only the confusion surrounding CE but also how some might see it solely as "recycling everything" and highlights a need for a clearer understanding that CE goes beyond just recycling.

> "I mean, it's really a good strategy but and this is one of the big misunderstandings of circular economy, it is not just about recycling. I really also hear the professor on resource management saying why is your project here named recycling-based circular economy. Circular economy is always recycling based, he said. And if he would be a student. He would fail the exam." *(Actor at Meso level)*

The above quote underscores a common misconception about CE in construction, being synonymous with recycling. This interviewee stresses that CE is a broader strategy and suggests that prioritizing recycling over the entire lifecycle of resources would be a failing approach in understanding CE as a concept.

> "Circular Washing. It is in the literal point of view, because still so many people in Vienna to think the circular economy is recycling and this is circular washing as well as the heat supply in Vienna. The heat supply in Vienna, the waste to recovery is also called circular economy too." *(Actor at Macro level)*

The above quote reveals a critical issue in Vienna: the misuse of the term "Circular Economy." The actor criticizes a phenomenon calling it as "Circular Washing," where initiatives like waste incineration for heat supply are labeled as CE, despite not aligning with its core principles. This misuse can further augment the confusion and potentially hinder Vienna's progress towards a genuine implementation of CE systems.

The lack of convincing case studies and holistic business models are also seen as major barriers in the practical implementation of CE in CI.

> "And traditional SME's are struggling to deal with the whole topic, I think in many cases they don't not where to start and they are not forced to because there are not enough regulatory frameworks and they are also not Incentivized or motivated with benefits like tax incentives or subsidies

> and so on. And so at the moment, I think most of them are just waiting "what comes and let'see approach." *(Actor at micro level)*

> "And in combination with this, another major challenge is that the construction sector is absolutely inefficient in material, for example, and too robust. There are not innovation in processes, innovation in material, not a problem. But we need to innovate the processes and to get... I don't know how to say it in another in, in more elegant words, but you know the construction sector, it functions like shit only flows downwards."
> *(Actor at macro level)*

According to the actors, traditional Small and Medium Enterprises (SMEs) are particularly hindered in adopting Circular practices in construction. They lack clear case studies and holistic business models that demonstrates the financial viability and practical steps involved. This, coupled with a general absence of convincing success stories, leaves them unsure of where to begin. Additionally, the construction industry itself struggles with a long-standing linear economic mentality, prioritizing established, inefficient processes over innovation needed for circularity. This ingrained resistance to change creates a system where problems are passed down in line, further discouraging collaboration and hindering the transition towards CE systems. As a result, most SMEs are stuck in a "*wait and see*" approach, waiting for external pressures to push them towards adopting CE practices.

> "They now start building buildings for their disassembly in 50 years with primary resources. This is a fail!! They want to keep the linear because all the developers push money into projects where new material is used."*(Actor at micro level)*

The above quote criticizes the flawed approach in construction that hinders CE. Designing new buildings for disassembly with brand new materials is seen as a failure. This focus on using virgin materials undermines the circular concept of reusing existing resources. This preference seems to lie with the traditional linear economic model, where developers prioritize projects that use new materials, perhaps due to financial incentives or a lack of understanding of circularity. This approach creates a wasteful system that prioritizes short-term gains over long term sustainability.

4.1.2. Barriers: Cultural

The result unveils several significant hurdles to implementing CE practices in construction. These barriers stem primarily from the cultural factors, particularly the conservation nature of industry and the political system.

The stakeholders are accustomed to "business as usual" and hesitant to embrace new approaches. This is evident in quotes like:

> "And the biggest enemy of change is convenience… We are so saturated and so used to having everything everywhere…" *(Actor at macro level)*

The above quote points to a societal preference for convenience and the "status quo." This also highlights societal resistance to change.

> "They don't want to 'I' am changing, there! And this is something very Austrian...We don't like change." *(Actor at macro level)*

The above quote specifically mentions the Austrian cultural aversion to change. It suggests a general reluctance to embrace new ideas and a preference for sticking with established practices. This cultural mindset tends to discourage innovation.

> "They try to control everything and this is the downside of the Viennese municipality… Why so many things are going very, very slowly..."
> *(Actor at macro level)*

The above quote takes aim at the Viennese municipality's bureaucratic approach, suggesting it acts as a brake on progress. The slow decision-making and need for complete control stifle innovation, making it difficult to implement new ideas related to CE practices. This bureaucratic red tapism may throw up roadblocks that impedes any attempt to move forward with the transition.

> "The know-how of the people is sometimes, may be a bit antiquated, then the innovative things are not taken on and being locked into a certain path." *(Actor at meso level)*

This bureaucratic red tapism may throw up roadblocks that impedes any attempt to move forward with the transition. In this quote, the actor highlights a lack of awareness and points out that some people in the construction industry might be resistant to adopting new, innovative approaches due to their outdated knowledge. This may lead to 'status quo' of being locked in the traditional linear economic system.

> "we're (Viennese) very proud of that we have a very good recycling system. And our waste management plan is quite good, but this is not circular economy and it took me from 2017 to 2019. Yeah, quite long period awareness raising in the sectors of the municipality itself and of course in the sector of politics" *(Actor at macro level)*

This quote provides a personal anecdote about the lengthy process of raising awareness within the municipality itself. This suggests a broader lack of understanding about the concept, even with resource recovery. While Austria boasts a good recycling system, the actor stresses that this alone does not constitute a circular economy.

A lack of collaboration or willingness to interact amongst different players in the construction value chain is another major hurdle.

> "It is still the silo thinking that even in the technical disciplines… the interdisciplinary advances disciplinary work have not evolved..." *(Actor at macro level)*

The above quote suggests that different departments and specializations, like architects, engineers, developers, and others seem to operate independently with limited communication.

> "And there is no talk. There is no information flow to…the handcrafted people standing on site...The only way you can involve them is with the product development..." *(Actor at meso level)*

The above quote further consolidates on the lack of information sharing and stakeholder involvement. There seems to be a communication gap between project managers and the skilled workers who build the structures. Crucial information doesn't reach them, and their expertise is only tapped during the initial design phase. This exclusion of the on-site workers, who possess valuable experience, creates a barrier. Their potential contribution to implementing circular practices in construction is limited by this cultural norm.

> "When you have a design mistake…the one in the chain after you will be the one who will have to deal with it…" *(Actor at macro level)*

The above quote highlights a cultural barrier of blame-shifting and a lack of shared responsibility within the construction industry. It reveals that if a mistake is made during design, the blame falls on those further down the line (builders) to fix it, rather than working together to address the issue. The clash between the 'end of life' building harvesters and architectural firms, also augments this barrier. The architectural firms, seem wedded to pre-designed plans and focus on creating unique aesthetics rather than creating designs based on reusing the available harvested materials. Thus, a *'pick and choose'* culture may not apply in order to prioritize functionality and resource conservation over established design practices.

> "You have to go to the Starting point…Because that are to be harvested in 2024, April, and they have these dimensions and these functionalities. Out from this you can plan or design your new building…They get the workshop... then three or 4-5 weeks yet later you get from the same office... 'Do you have any parts that would fit into my building?'… They are used to design something very special, very beautiful, for example,

> Zaha Hadid the Great. But it's not more than like your statue. That's nice for you but for no body else. It doesn't have the functionality."
> *(Actor at micro level)*

Difficulty in building trust and sharing information across the construction industry is another cultural barrier.

> "Also, like a colleague of mine... Professor Erik G Hansen... He says that there are many barriers in this collaboration and networking, mostly because of trust and transparency." *(Actor at micro level)*

> "You have to give a lot of information to the partners in your business ecosystem and you have to inform them about substances... you use during the production process."*(Actor at micro level)*

The above quote presents a prominent barrier of the tenuous nature of the trust between the stakeholders. This lack of trust impedes effective collaboration, as successful implementation of CE in CI hinges on the foundation of sense of security in sharing information and resource. Furthermore, there is also an emphasis on the role of transparency and necessity of openly sharing details concerning materials and production process within the networks.

A crucial barrier lies in the inherent conservatism of the construction industry and the political system.

> "We are so conservative in the dark region that innovative building materials are always like something like an art project. You are not allowed to live in, you can do it in an artistic way. But until you have the proof that this is a building material, it is a long way."
> *(Actor at micro level)*

The above quote exposes a major hurdle for innovative building materials: extreme conservatism. The actor reports that innovative materials are seen as akin to "*art projects*"- impractical and unfit for real-world use. This resistance is further emphasized by the lengthy approval process for new materials.

> "The first time I did this, you know, because I started all those things all by my own, you know. There was 10 steps back. No, no, no, no. We are the sort of fear. No, we don't like experiments because there could be something coming out what we cannot control." *(Actor at macro level)*

The above quote reveals a fear of experimentation within the political system as the actor speaks about a personal experience where trying something new resulted in "*10 steps back.*" This negative outcome seems to have instilled a general aversion to taking risks. The actor underlying, “We are the sort of fear,” suggesting a cultural norm of avoiding experimentation due to potential unforeseen consequences that can’t be controlled.

4.1.3. Barriers: Financial and Economic

Finances: a stubborn reality baring the economic hurdles stand in a way for implementation of CE practices in CI. “*Access to funding*” has been amongst the high frequent barrier within the semi-structured interview, highlighting how the financial factor can determine the fate of this transition.

> "Our way was before through the City, but the city doesn't have money. They are in debt." *(Actor at micro level)*

The above quote suggests that traditional funding sources, like government grants or city budgets, might be limited due to debt or other financial constraints. This lack of public funding makes it difficult to support innovative circular practices.

> As of now we track all our materials manually, but with the help of technology, we will know... You need money for that to implement it into a program." *(Actor at micro level)*

Implementing circular practices often requires digital solutions like material tracking software. However, these technologies require investment, creating a barrier for smaller companies or those with limited resources.

> “The money goes not to us. The money goes to them because they are sitting on the money. It's like gravity. So, we don't have any chance to come with our approach. In no level, we will enter these financial potentials. Never ever. Never, ever.” *(Actor at micro level)*

The above quote suggests a sense of frustration because the developers, who hold significant financial resources, prioritize projects that use new materials and traditional linear construction methods. This focus on the ‘them’ (implies) that funding opportunities are limited for circular practices for the approach *(Re-use of materials)*.

> “We are not seen as partner yet, so we aint part of something that is not existing yet, like a circular supply chain. We call us as a Micro level business, and we will not be respected in an eye to eye level way with the biggest stakeholders like Lafarge or Holcim, the big concrete companies, and we are not striving for that honestly.”*(Actor at micro level)*

The above quote exposes a sentiment of disappointment from a construction company regarding competition. They feel excluded from the ongoing development of circular practices in the construction industry, particularly when it comes to supply chains. The statement about *"circular supply chain…not existing yet"* indicates there is a significant gap to be bridged between the theory of practices to practical implementation of CE in CI. Additionally, they acknowledge the dominance of large companies and aren't necessarily seeking equal footing. However, the lack of recognition might be hindering their ability to contribute their expertise and potentially accelerate the transition of theory of practices to practical implementation.

> "you can also charge more for a higher quality product with a longer lifespan. However, the challenge lies in convincing clients to look beyond the initial price tag and consider the total life-cycle cost. There's a need to educate them about the potential savings in maintenance, repairs, and even potential resale value associated with using high-quality, potentially recycled, materials in construction" *(Actor at Meso level)*

The high initial cost of circular construction practices and methods, which often involve high-quality recycled materials can be a hurdle. However, the actor proposes a strategy to bridge this gap: educating clients about life-cycle costs. Looking beyond the upfront price tag, clients should consider the potential savings on maintenance and repairs associated with these durable materials. By educating clients about these long-term cost benefits, circular construction practices can become more financially attractive.

> " The main is the economic barrier…waste control or monitoring (which is crucial for circular practices) can be expensive... achieve some environmental good levels, but... losses or more expensive than traditional practices in the short term. However, these initial investments can translate into significant cost savings down the line. By properly deconstructing buildings and capturing valuable materials, we can potentially avoid expensive virgin material acquisition and disposal fees in the future." *(Actor at micro level)*

In the above quote, the actor argues that the main barrier is the cost. Traditional methods, while wasteful, are portrayed as being *"very cheap"* and *"very fast."* These methods generate a "*very big amount of waste,*" but disposal seems to be quicker and less expensive solution compared to deconstruction. Deconstruction, on the other hand, offers less environmental benefits by minimizing waste. However, it requires a significant investment in skilled labor, safety measures, and potentially specialized tools or machinery. This focus on skilled labor and additional resources can make deconstruction (CE practices), a slower and potentially more expensive process in the short-term.

> "I mean, this is a matter of pricing and today if you take a building down. What happens actually is that all the materials will be picked up in the very early hours of the morning by Hungarian or Romanian organizations

> who come and take everything away that would be reusable and only the rest like the gravel then is going to be put to a waste disposal, but everything that reusable doors, windows handles, sinks, every everything has been taken away by unofficial, actually illegal organizations. And why? Because it's less expensive. It costs less than if you would officially take care of it.!" *(Actor at macro level)*

> "The demolition industry. They have their streams. They really know where to put the stuff. And they know where it's easy for them to get rid of it without need to pay off waste tax, whatever they exactly know how to, hyper connected with the global waste streams to different countries." *(Actor at micro level)*

Here, the actors expose a surprising consequence of the current economic system in construction. It highlights a situation where demolishing a building is cheaper than carefully deconstructing it to recover reusable materials. The actors respectively mention "*Hungarian or Romanian organizations*" who collect these materials in the demolition process, and *"have their streams… know where to put the stuff"* suggesting a potential unofficial market for such practices. However, the informality and potentially illegal nature of these activities raise concerns about safety, regulation, and lost economic opportunities. The underlying point is that the *'current pricing system'* incentivizes cheap demolition, highlighting the culture of demolition over sustainable practices.

4.1.4. Barriers: Political and legislative

Political and legislative hurdles are one of the major roadblocks for circular construction. Complex bureaucracies *(second highest frequent barrier mentioned),* inconsistent regulations, and a lack of incentives create a challenging environment for practical implementation of circular practices.

> "For example, each time, we hand in our newest combination of material with our binder, We also then have to prove that the product is fire safe and stable enough, etc. This is something upfront, which we will be facing to enable the use of the product in common buildings for commercial purposes will also demand the certificate from the building code." *(Actor at micro level)*

> "The concern is that getting a certification system is a long and difficult process." *(Actor at micro level)*

These quotes highlight the complex and time-consuming process of obtaining certifications for innovative circular construction materials. Companies need to navigate a bureaucratic maze to prove the safety and stability of their products, even for common building applications. This creates a significant hurdle for businesses trying to introduce new circular materials into the market.

“Yes, we are facing a lot of barriers, which we have to look at with the regulatory agencies to enable even using waste as a primary material”

> “there are funding opportunities, but in the case of subsidies it's quite big Administrative Process you have to fill in Lots and lots of forms and papers and I think for small businesses, it's really exhausting and difficult to do this administration..." *(Actor at Meso level)*

The actor suggests that while funding opportunities might exist, the application process itself can be a major barrier. The quote emphasizes the extensive paperwork and bureaucracy involved in accessing financial support, particularly for small businesses. This complexity may discourage potential participants and hinder the broader adoption of circular construction practices.

> “… I really could understand the politicians that it is not so easy for them just to start this new topic, which is beyond recycling. This was another very, very big challenge for me to make all my colleagues in the municipality too, because of course this is a very rigid system, because bureaucracy is made for stability and when you want some changes just to reassure this stability, you really need good reasonings.” *(Actor at macro level)*

The above quote underlines the entrenched nature of the current system and the difficulty of implementing change. The actor expresses empathy for the politicians who hesitate to introduce new ideas or practices, which go beyond the established recycling practices. The rigid bureaucratic structure prioritizes stability, and introducing new regulations requires strong justification to overcome resistance from those comfortable with the status quo.

> “There are really strong hierarchies in Vienna and there are a lot of people in Vienna who are in the city that have understood that's the biggest potential for them (referring to Vienna’s social housing and its role in implementation of CE) But the concrete steps are missing.” *(Actor at micro level)*

The above excerpt reveals Vienna’s strong hierarchical decision-making process creates a major barrier for implementing CE via utilizing its own strength of being the social housing capital of the world. While some within the city government recognize the immense potential of social housing of CE, translating that understanding into concrete actions seems to be a challenge.

> “You know it's (The Climate Lab) funded by the Ministry of Climate, which is currently the Green Party. The city of Vienna is not the Green Party,

> but is very is strongly related to Wien Energie. Wien Energie, is one of the key funding parties also of the that so through that I think this this process could if it was if it was wanted either happened in something like the climate lab or our institution."*(Actor at meso level)*

The above quote highlights the complex political landscape between city-national government. While the Climate Ministry (Green Party) funds initiatives like The Climate Lab, Vienna's city government holds a different political affiliation. However, Wien Energie *(the energy provider),* a key funding source is linked to the city. The actor suggests bridging these political divides could be achieved by channeling efforts through a neutral body like The Climate Lab, implying that political maneuvering might be necessary to overcome these bureaucratic hurdles.

> "I, myself, I'm a trained architect and also I studied social science at University of Applied Arts but during my architectural studies at the Technical University of Vienna, we didn't tackle the topic of circular economy..."*(Actor at macro level)*

The actor underlines the gap in current architectural education, highlighting the need for integrating circular economy principles into the curriculum.

> "The regulatory fiscal incentive system, definitely does not incentivize to a larger sale. That's a missing driver."*(Actor at micro level)*

The actor explicitly points towards a lack of incentives for circular construction practices. Actors also report about lack of standardized tools and enforceable regulations crucial for driving CE transitions.

> "It is a difficult topic because we are dealing with waste and especially if you are going international to drive waste over borders is very difficult." *(Actor at micro level)*

The above quote raises concerns about the international transportation of construction waste, highlighting the inconsistent definition of waste across regions. Regulations and logistical hurdles make it difficult to move used materials across borders. It is interpreted that official movement of waste is much complex than moving waste unofficially.

4.1.5. Barriers: Technological

Insufficient collaboration tools, absence of material alternatives and data, complexities in the supply chain, and the lack of digitalization in the construction, are overall mentioned barriers for technological change within CE systems.

> "And another major challenge and this is I think one of the biggest. It's just the lack of digitalization. We need to know when or which part of a building in which quality is free to harvest. And we need to know this in a database so that everybody can be free of the timeline of anybody else." *(Actor at macro level)*

The absence of a centralized digital record keeping system for existing buildings makes it difficult to assess the potential for renovation and reuse of materials.

> "Renovation of existing buildings – hardly any current planning data"*(Actor at macro level)*

> "..assurance of reused building products – missing data and regulations"*(Actor at macro level)*

The above quotes reveal that extracting and processing certain building materials for reuse can be challenging. Additionally, there is a lack of readily available information on the quality and properties of existing building materials, making it difficult to determine their suitability for reuse.

Another barrier identified by the actor is problems with standardization and circularity in Design.

> "On the down side, It's still, as I said, we do have some problems with some materials, especially fine fractions." *(Actor at meso level)*

> "The value of the material over the cycles gets lower. For example: with concrete, you have to put the materials in an oven at a high temperature, it is an active binder. But you can't recycle it properly. The only possible recycling method is to crush it and then use it again, but only as a filler. So, we have to add new primary raw materials to get proper concrete again. Thus, the concrete always gets downgraded..." *(Actor at micro level)*

The above quote highlights the specific challenge of downcycling concrete. While it can be crushed and used as a filler material in new construction, this process downgrades the material's quality. Concrete loses it binding properties and requires the addition of virgin materials to function properly.

> "You need a lot of logistics...where do you find it? It's not there where you need it"*(Actor at meso level)*

Finding suitable secondary materials often requires extensive searching, as they might not be readily available near the construction site. This makes logistics a major hurdle.

> "you need to set up a different network of people where you're working together"*(Actor at meso level)*

An established network of stakeholders is crucial for connecting those with the secondary materials via digital and technological collaborative tools to those who need them. One of the actors gave a suggestion of "Circular Tinder." Currently, such a network seems to be lacking.

> "Also is not clear, I think there is a big lack of responsibilities... and this is also reflecting on the responsibilities of the different actors" *(Actor at micro level)*

The above quote identified a lack of clear roles and responsibilities for different actors in the Construction Supply Chains for implementing CE systems.

> "But for building up a new house, it's completely meaningless because they also have such a bad thermal insulation property that when you use these bricks you have to use so much of like mineral wool or plastic polystyrene. We don't want to use this material, so you end up with tiles you end up with wooden frames would be possible to be reused, beside that also some historical building elements very very important to be reused. Although in my opinion these old buildings should not be demolished anyway." *(Actor at meso level)*

> "obviously the framework conditions are made rather for demolition than for renovation." *(Actor at macro level)*

While some older building materials might have limitations, these above quotes reveal a potential disconnect between environmental benefits and economic realities in the construction industry. Renovating existing structures offers significant environmental advantages. It reduced construction waste, lowers the embodied energy required for new materials, and can even preserve valuable historical elements. With the emerging technologies available as suggested by another actor:

> "There are several technologies that can support building renovation. Modern laser devices, drones and robots create the basis for a digital building model. AI based modelling tools can classify and identify geometric patterns and could help to faster design a digital model. However, it is not yet possible to survey the physical building stock without laboratory tests." *(Actor at macro level)*

However, the current system seems to favor demolition. And more importantly, the economic framework, as one of the actors suggests, incentivizes demolition over renovation.

> "16,000 living units were renovated in Vienna in the year 2006. Last year it was 2000. So it was reduced by a factor of eight. Greenhouse gas

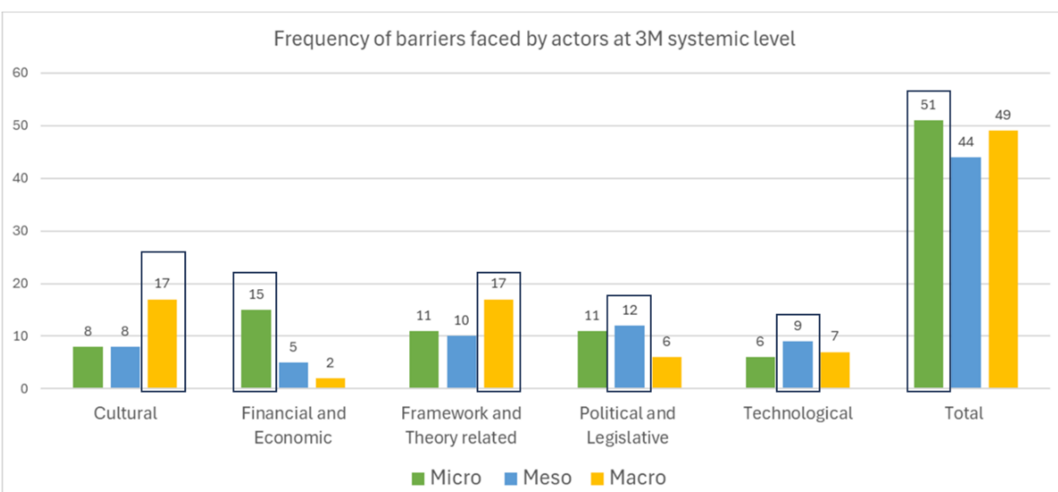
emissions are increasing. Greenhouse gas emission reduction targets are increasing even more city of Vienna, every smart City Vienna strategy sets the target higher, higher, higher meanwhile, thermal renovation targets are going down. So talking v/s practice is really in despair and its getting bigger and bigger….therefore we can achieve circular economy by avoiding the demolition of buildings. Old buildings, for example, that would produce waste which is hardly recyclable. Because if it would demolish these buildings, which is happening unfortunately too much in my opinion." *(Actor at meso level)*

In the above quote, the actor criticizes Vienna's decreasing focus on building renovation. The number of renovated units dropped significantly, from 16,000 in 2006 to only 2,000 recently. This decline contradicts Vienna's increasingly ambitious GHGs reduction goals. The actor highlights a gap between Vienna's stated environmental commitments and its actions regarding building renovations and argues that avoiding demolition is a key to a circular economy, since it reduces waste from difficult-to-recycle materials in older buildings.

4.1.6. 3M Systems Perspective of Barriers

The highest frequency of overall barriers has been witnessed by actors at micro level system mainly facing financial and economic barriers. The actors at macro level elucidated and emphasized more on the cultural and framework and theory related barriers, whereas actors at meso level, they were focusing more on the political and legislative barriers. A summary of 3M systemic barriers has been presented in figure 12.

Figure 12: Barriers faced by actors at 3M systemic level



Source: 12- Semi-structured interviews

4.1.7. Enablers for practical implementation of CE in Vienna's Construction Industry

Ababio & Lu (2023) has identified key factors that can enable a CE in construction. Enablers of circular economy in construction are a set of factors that can help create a more conducive environment and act as catalyst for the transition towards CE systems. These enablers include for examples: financial and economic incentives, technological advancements, cultural policy changes, and research and development. The systemic analysis for enablers suggested by actors have been presented in figure 13.

Enablers	Sub-category of Enablers	Micro	Meso	Macro	Total
Cultural Enablers according to actors at the System(s) level	Creating roles in construction firms to champion the transition	1		2	3
	Incentivizing firms and professionals alike to trigger behavior change		1		1
	Promoting stakeholder awareness through education			4	4
Total		1	1	6	8
Enablers	**Sub-category of Enablers**	**Micro**	**Meso**	**Macro**	**Total**
Financial and economic Enablers according to actors at the System(s) level	Innovative procurement and financing with the sector			1	1
	New market creation for circular services and products	1	2	1	4
	Public Private Partnership			1	1
Total		1	2	3	6
Enablers	**Sub-category of Enablers**	**Micro**	**Meso**	**Macro**	**Total**
Framework and theory related Enablers	Available funding for CE research		2		2
	Clarity of Definition			1	1
	Develop CE model for specific to CI			2	2
	Strategic research efforts into various aspects of CE within the industry	1	3	3	7
Total		1	5	6	12
Enablers	**Sub-category of Enablers**	**Micro**	**Meso**	**Macro**	**Total**
Political and Legislative Enablers	Advocating new standards that capture circularity of materials	1		2	3

according to actors at the System(s) level	Development of national vision and target for national vision and target for CE in the industry			3	3
	Strict policies and guidelines to enforce CE			4	4
Total		1		9	10
Enablers	**Sub-category of Enablers**	**Micro**	**Meso**	**Macro**	**Total**
Technological Enablers according to actors at the System(s) level	Collaborative tools for information transfer enabled by new technology		4	2	6
	New innovations in materials capabilities and technology advancement	1		2	3
	Process and product redesign with adoption and promotion of eco efficient products and processes		1	3	4
Total		1	5	7	13

Legends for the color codes are:

Intensity of Enabler		**Codes**
Low	1-2	
Medium	3-4	
High	5 above	
Enabler (amongst 3M Systemic Level)- Highest		
Total frequency of an Enabler		

Technological Enablers:

The highest frequency of enablers mentioned are related to technology and innovation. Vienna's construction industry is embracing digital tools to improve collaboration and information sharing. BIM is a key enabler, allowing for precise tracking of materials and centralizing data. Digital platforms like Open BIM for Wien and Digital Findet Stadt further connect stakeholders and facilitate collaboration on circular construction projects.

> "Digitization in the building sector is a huge topic and also acknowledged within the executive group of construction and technology. This is why there's a program called OpenBIM for Wien led by Claudia Schrenk. It is another program focusing on the opportunities for implementing BIM in the construction sector. Ofcourse, BIM is a huge opportunity because it

> allows one to have precise knowledge of what kind of data, materials, and quality of the building materials. But it is very easy to implement in the new buildings." *(Actor at macro level)*

> "Digital Findet Stadt is a Network for digital Innovation in the Construction an Real Estate industry. DFS bundles industry representatives, initiatives and research activities from the fields of design, construction and operation to support promising innovation projects with relevant resources and know-how." *(Actor at macro level)*

New innovations both in the material capabilities and technology advancement, are emerging to improve material use as well as streamline the renovation processes. Innovation binder systems are being developed to enable complete material reuse without compromising quality. Additionally, legal changes are under way to simplify the use of recycled materials in construction.

> "For example, you take materials from old buildings and crush them and then use the product as a filler. But you need a binder and the binder has to be primary raw materials. So, this is no complete circular process, but here I think we can come in with our binder system, which is fully circular so that you have absolutely no waste……"*(Actor at micro level)*

The actor while explaining their innovative technology, argues that crushing old building materials for reuse as fillers is a step towards a circular construction process, but it's not perfect. Traditional binders used with this recycled filler are often made from new resources. Here, when a new innovation system by actor's company comes in: a fully circular binder system. This novel binder allows for complete recycling of the entire material mix, including the binder itself. After a product using this binder reaches its end-of life, the binder can be reactivated and reused without losing its effectiveness. This eliminates waste and create a true circular process for construction materials. Moreover, this binder can be used with other recycled materials, further expanding its potential for sustainable creation.

> "I think now I mean a lot of them taken up the whole circularity thing, even before the city started, what they're doing now, which is very good there, I have to underline this Vienna is doing very good in this direction. But we have, like, companies producing Construction materials and they took up the whole circularity thing like more than 10 years ago. And they also invested in plant and also willing to invest in future plants like I have to mention, Wopfinger Transportbeton which is also one of our project partners, they started together with Deisel Beton in Salzburg, were the first to produce recycling concrete."*(Actor at meso level)*

In the above quote, the actor emphasizes on construction material companies, like Wopfinger Transportbeton, that have been independently implementing circular practices for over a decade. Their commitment is evident in their investments in recycling plants and development of new methods. This highlight pre-existing industrial system focusing on circularity, creating a strong foundation upon which Vienna's city-wide efforts can build. The actor also mentions about the collaborative research projects with such companies.

> "Because only because they digged 20 years into sustainability, it was possible for me to find a field, you know. Just to do a little bit more and yes, Political Bureau, they are responsible for ÖkoKauf and of course they were very, very pleased to hear that the construction sector with this big material footprint" *(Actor at macro level)*

ÖkoKauf Wien, programme for sustainable procurement, and is led by the sustainability co-ordination office (MA-22). It presented a crucial established groundwork for the actor at the macro-level to promote the concept of circularity in construction sector. These already functional processes are legacies of Vienna and marks as perfect building blocks enabling the transition towards circular construction.

<u>Framework and Theory related enablers:</u>

> "Once we in the DO–TANK realize there is a need to tackle this issue. With good research questions we reach out to several universities, and they need collaborations which are on an international level." *(Actor at macro level)*

DO-TANK identifies important issues in construction, and uses well defined research questions to initiate collaboration with universities. They prioritize various aspects of CE, with a focus on adaptive reuse and renovation related to demolition. This is evident in their collaboration with the University of Natural Resources on assessing circularity in buildings. They are developing methods to compare the circular potential of new and existing buildings. It is understood from the following:

> "With the cumulative indicators for understanding the circular potential of a new building or of an existing building, we will have the chance to assess the circularity of a building project. We will have a transparent comparison, is it more circular to keep the building, maybe add two or more storeys to the building, or is it more circular to deconstruct and build a new building altogether? Because, there is the demand for new apartments and when it comes to the waste hierarchy, the best is to reduce and refuse and keep the city as it is." *(Actor at macro level)*

The actor highlights the importance of assessment of circularity. By developing comprehensive indicators, researchers can compare the environmental impact of renovating an existing building versus constructing a new one. This transparent comparison will allow for informed decisions about whether to add onto an existing building or deconstruct and rebuild entirely, considering both the need for housing and the CE hierarchy principle of prioritizing reduction and reuse.

> "We do a lot of Research projects and like to demonstrate technologies (physical technologies)….and we're also conducting a study for the city of Vienna that will feed into the new 10-year Urban Development plan... And we're kind of advising them on like what kind of spatial or infrastructure requirements, they should consider in this plan like what they should sort of plan for basically." *(Actor at meso level)*

The above represented actor demonstrates a commitment to both research and real-world application. Their current research project with the City of Vienna, exemplifies this approach. They are using research to inform the city's upcoming urban development plan, specifically focusing on how to integrate CE principles into city's spatial layout and infrastructure needs.

> "But, It's not possible within BIM to Create a catalogue of the components for real. You can so you need Communication between them. We're working on that with TU Wien. DiCYCLE Project with the help of BIM and Blockchain." *(Actor at micro level)*

In the above quote, the actor discusses challenges in managing components of existing buildings for a CE. While BIM is a valuable tool, it cannot create catalog of building components on their own. The actor underlines the need for a separate component catolog that can communicate with BIM. To address this gap, the actor mentioned the DiCYCLE project, a collaboration with TU Wien, which explores using both BIM and Blockchain technology to develop system for tracking and managing building components.

<u>Political and Legislative Enablers:</u>

There are policy instruments in line that will support CE systems in CI, including strict regulations on landfilling and the development of new standards that promote circular design and material use.

> "With the huge milestone of the European Green Deal 2019, the City of Vienna acknowledged the principles of the Circular Economy and tried to implement it in the existing strategies and updated the SMART CITY Strategy in 2019...where targets for CE in construction industry were implemented."*(Actor at macro level)*

The actor highlights Vienna's proactive approach to CE, leveraging the EGD as a catalyst and integrate CE principles into the urban development strategies, setting clear targets for the CI.

> "Strict policies and guidelines to enforce CE… Waste Management Act, a national legislation that envisions raising the current circularity rate of 12% by 18%. Also, Recycling Building Material Ordinance is a game changer… It affects the whole bunch of stakeholders." *(Actor at macro level)*

The actor in the above quote emphasizes the importance of strict regulations. The Waste Management Act and Recycling Building Material Ordinance demonstrate Austria's commitment to increasing circularity rates by setting ambitious targets and involving all stakeholders in the construction process.

> "Advocating new standards that capture circularity of materials… New Circular Economy Action Plan, European Green Deal, EU taxonomy regulation… ÖNORM B 3151 (dismantling of buildings as a standard method for demolition)."*(Actor at macro level)*

The development of new standards is in place to promote CE. Initiatives like the EU taxonomy regulation and national standards like ÖNORM B 3151 establish clear guidelines for deconstruction and material reuse, enabling circularity within the building lifecycle.

> "Landfill ordinance regulating basically what is not allowed to landfill…bricks from Concrete and demolition waste may no longer be landfilled…This is a huge game-changer…"*(Actor at meso level)*

The actor signals the role of landfill bans as a driver for CE in the above quote. By restricting landfilling of certain materials like concrete and bricks, these ordinances incentivize innovation in recycling technologies and promote the reuse of construction materials.

> "Now yes, but this will change. Yeah, this will change because when you are not allowed to landfill mineral wool, then you have to let it as it is.
>
> Until the technical Scientists know how to deal with this material, and they don't know this now. There are ongoing research. And of course EU Taxonomy regulation fosters renovation. Absolutely. Yeah. I think the most the biggest lever is landfill ordinance." *(Actor at meso level)*

The actor acknowledges landfill bans as a double-edged sword. While obliging innovation for materials like mineral wool due to limited disposal options, it is also recognised there is ongoing research to develop effective recycling or reuse technique for the same, which is not yet ready with alternatives. However, the actor remains optimistic with *"this will change."*

<u>Cultural Enablers:</u>

Cultural enablers are the building blocks for a circular CI. They include educating stakeholders, fostering collaboration across disciplines, creation of new roles and the high involvement of public participation.

> "To give these goals power, there is a staff unit with the Executive group and a DOTANK Circular City Vienna program- a 10-year program that tries to foster circular change and the transition towards circular Vienna in the built environment, where a roadmap will be developed within the program." *(Actor at macro level)*

There are roles being created and also promotion of stakeholder awareness through education. For example, dedicated staff positions were created under DTCC30 to tackle the topic of Circular Construction.

> "...with the professor of TU-Wien at the Department of Construction, we are designing an interdisciplinary course where the real estate management students of the like university have to make a project... with the architectural students." *(Actor at macro level)*

Educational programs bridge communication gaps between various stakeholders. This interdisciplinary course fosters collaboration between architects and real estate developers, equipping them with a shared understanding of circular construction projects.

> "they're rebuilding the train station and they realized actually involuntarily because there was a lot of discussion around taking down the whole building. And the citizens who lived around the residents were strongly opposing to take down the building because it's so close to reset to the residential area around and because of the noise, because of the dirt, because of the emissions and they didn't want it. So what happened is they kept the cement core of the building and they just took off, ..They just had the core there and took off everything from the core, so the cement build, the cement core remained and around this, the new building is being built and through that, they realized that they took down their CO2 emissions majorly" *(Actor at macro level)*

In the above quote, the actor showcases the unexpected influence of public participation in Vienna's approach to construction. While residents voiced their opposition to the train station's demolition due to noise, dirt, and emissions (civic activism), their concerns inadvertently steered the projects towards adopting a circular solution. By forcing a shift to deconstruction, which kept the existing cement core, the project significantly reduced CO_2 emissions compared to complete rebuilding. This highlights the power of civic participation, where public engagement can influence outcomes in unforeseen ways, even pushing projects in a more environmentally friendly direction.

Financial and economic Enablers:

The frequency of financial and economic enablers is the lowest. The enablers include: new funding models like lifecycle costing and green bonds reward resource efficiency, while the rise of deconstruction services, recycled materials, and innovative products creates a thriving market. Public-Private Partnerships, where governments incentivize and private companies bring expertise, further accelerate this transformation.

> "The Climate Lab, where people are brought together... we collaborate... and then we have the specific stakeholders that tackle on the issue" *(Actor at meso level)*

Climate Lab act as a facilitator for new market creation. By bringing together relevant stakeholders, they spark collaboration and tackle issues that hinder the development of circular services and products.

> "We are collaborating with think tanks from universities, for example, Thinkubator, a student-led think tank, that is raising awareness in the university sector and amongst young professionals." *(Actor at macro level)*

The actor highlights Public-Private Partnerships (PPP) as a driver for market creation. Collaboration between established institutions and young, innovative groups like Thinkubator raising awareness and attracting new talent to the circular economy, foster the development of new markets.

> "It can be defined as a regional hub, a central point where there is a lot of exchange of resources and the residues being reused, basically between different actors/companies/ businesses... a network of exchanging resources and a physical type of facility..." *(Actor at meso level)*

The actor describes a circular hub as a key economic enabler. By creating a central point for exchanging resources and processing waste into usable products, circular hubs will facilitate the development of new markets for deconstruction, recycled materials, and innovative products.

> "For example, those colleagues who were building up an internal programme of the municipality. It's called "ÖkoKauf". It's procurement, everything well, what the city of Vienna procures for herself is rooted in this programme." *(Actor at macro-level)*

The actor advocates "ÖkoKauf" as a financial enabler because it creates guaranteed customer (the City of Vienna) for potential circular construction products. This guaranteed demand incentivizes businesses to enter the circular market, knowing they have a reliable buyer for their offerings.

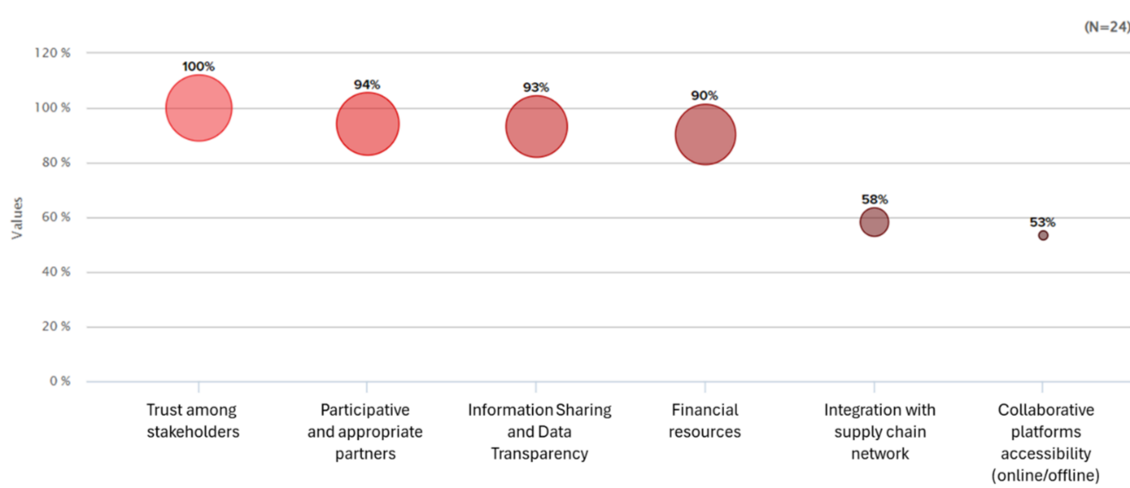
4.2. The Climate Lab (Meso System study on network barriers)

By investigating the perceived challenges in network building (Q1), The Climate Lab's specific contributions to collaboration (Q2), and membership utilization patters (Q3), the meso-level system analysis offers valuable insights into the practical implementation of circular practices within Vienna's construction industry. This multi-faceted approach helps identify potential roadblocks and facilitators for industry actors as they navigate the transition towards a more circular economy.

Question 1(Q1): What is the main challenge that is faced in building a value network and collaborative system? Please rank the challenges.

Result: Trust among the stakeholders is ranked highest by the 24 respondents, showcasing collaboration across construction supply chains, from architects to recyclers/harvesters, hinges on trust to openly share information and innovate. Figure 14 is the analysis of the Q1. It also entails that the actors face barriers in finding participative and appropriate partners with the CSCs with challenges of data transparency and availing or assessing financial resources.

Figure 13: Analysis for Q1 (Challenges in network building and collaboration)



Source: 13 Online survey via Sogolytics

Question 2(Q2): How (in what ways) is "The Climate Lab" helping you to build a value network system?

Result[19]: 24 respondents shared their experiences through statements. A word cloud of the statements shown in figure 14 gives a compact version of actor's perception and their experience as a member of The Climate Lab.

The Climate Lab acts a crucial facilitator for building a value network and collaboration within the construction industry., driving CE transition. By providing a space for knowledge sharing and connection, the Lab brings together diverse stakeholders- "people from various companies with different experiences," "actors" and "companies that face similar issues." These interactions foster "synergy," "collaboration," and "co-creation" through "theme-centered learning sessions" and "open space" events. The lab's network extends online and offline, creating valuable connections with "likeminded people" and the "public sector." This collaborative environment allows participants to gain "insights in different topics related to SDGs" establish "valuable contacts," make "visible" the key players in the industry. Members speak of "increased visibility and credibility," the ability to "talk to stakeholders actively working on transforming the system," and the generation of "ideas through coffee chats and learning sessions." The Climate Lab serves as a "patchwork" that gathers knowledge and expertise, fostering a community around a shared goal: a circular construction industry. This combined initiative of public-private partnership and public-public partnership (Austrian climate ministry and Vienna's energy provider) at the meso-level, exemplifies the power of collaboration in accelerating a practical shift towards a CE system, by "plowing the field for constructive discussions" and "bringing diverse stakeholders together."

Figure 14: Word-Cloud for relevance of meso-systems- The Climate Lab

Source: 14- Analysis in Sogolytics

[19] The statements by 24 respondents have been provided in the annexures.

Question 3(Q3): How have you utilized your membership at The Climate Lab?

Result: Strikingly, 92% of the members reported utilizing co-working space provided by The Climate Lab. This finding aligns with the “consumption/stock phase” principles of a circular economy, promoting resource efficiency by maximizing space utilization and potentially minimizing the need for individual offices. Furthermore, an impressive 79% of the participants leverage community events for knowledge sharing, while an equally high proportion (88%) actively engage in the networking events. This robust collaborative spirit fostered by Climate Lab creates a platform for stakeholders across the construction industry to exchange best practices and facilitate the dissemination of knowledge on circular construction methods.

The Climate Lab’s success in fostering collaboration hinges on building trust among diverse stakeholders within the construction sector. By providing a platform for knowledge exchange, networking, and co-creation, the Lab acts as a crucial facilitator for overcoming network barriers and accelerating transition towards a circular economy-based construction industry in Vienna. This innovative public-private partnership is an example of the power of collaboration in driving systemic change.

4.3. Companies (Micro System Study)

At the micro-level of the construction industry, a shift towards circular practices can generate significant environmental, social, and economic impact on the systemic level of Circular Transitions in CI. This can be seen through innovations in material selection and design. For instance, used recycled aggregates or bio-based materials can dramatically reduce the demand for virgin resources and lower the impact the environmental impact of construction projects. Similarly, designing buildings for disassembly allows for the recovery of valuable materials at the end of a structure’s lifespan, minimizing landfilled waste. Socially, a circular CI can create new jobs opportunities like deconstruction, material refurbishment, and reverse logistics. This can revitalize local economies. Economically, circular practices can lead to cost savings through reduced reliance on virgin materials and more efficient use of resources.

The present study conducted an in-depth online survey of four companies at micro-system level and their recorded responses, on their impact, barriers faced by them and the associated enablers, paves a path of understanding the practical implementation of CE in CI from the microscopic lens. The four companies for convenience of the analysis are represented as Company A for *Materialnomadden*, Company B for *Parastruct*, Company C for *Alchemia Nova*, and Company D for *Einszueins*. The result[20] of the survey is as follows:

The scope of business/work outreach transcends from national to global level. The companies have primarily B2B business transaction model, i.e. working with other businesses. However, 2/4 also engage with consumers (B2C) and government agencies (B2G).

Facet of CE: Company A offers a comprehensive CE solution for the built environment, encompassing everything from design and deconstruction to material recovery and reuse through networks and hubs. Company B focusses on optimizing material flows within the construction sector, specializing in areas like material sourcing. Company C operated across multiple industries, promoting circular practices in construction alongside agriculture, manufacturing, and other sectors. Company D focuses on the social aspect of circularity in construction, facilitating the sharing of resources or spaces within the built environment to promote community and efficient resource efficiency.

Addressing SDGs: Company A focusses on sustainable construction practices (SDG 9 & 11) that reduce resource consumption (SDG 12). Company B promotes innovation and responsible production in construction (SDG 8,9,11 and 12). Company C integrated circular practices across various sectors to ensure resource efficiency (SDG 6,7,9 & 11). Company D encourages resource sharing models in construction to minimize environmental impact (SDG 7,11 & 13). Thus, understanding how companies address SDGs is crucial for CE systems because it reveals their commitment to resource efficiency, reduced environmental impact, and long- term sustainability, all core principles of circularity.

Social Impacts created by the Company: Based on the survey data, Company A, C and D, all share a focus on fostering social capital, which involves strengthening relationships and networks within communities. Company A goes a step further by highlighting its contribution to human capital development, by improving job skills and education within communities. Company C emphasizes improved well-being and increased contact among people, which fosters a stronger sense of community. Company D stands outs for its emphasis on reducing hierarchy within communities and creating community spaces, promoting shares resources and collaborative living arrangements. While Company B does not explicitly mention social impact creation beyond “circular material flows,” their focus on resource efficiency within construction could indirectly contribute to social benefits, potentially affordable housing options.

[20] The detailed result has been provided in the ‘annexures.

Environmental Impact created by the Company: The environmental impacts highlighted by Company A, B, and D all center around core principles of a CE in construction. All three companies emphasize increased resource utilization, signifying a shift away from virgin materials and towards efficient use of existing resources. This focus on resource efficiency goes hand-in-hand with reduced emissions and reduced waste, indicating a potential positive impact on air and soil quality. Company C stands out for mentioning increased biodiversity, which could be linked to their focus on sectors beyond construction, such as agriculture. While Company D does not explicitly mention same range of impact, their focus on "environmental awareness" suggests they are involved in educational initiatives that promote sustainable construction practices. It's important to note that while "increased resource utilization" is generally positive in circular economy, its crucial to ensure those resources are responsibly sources and managed to avoid unintended consequences.

Economic Impacts created by the Company: Three companies, A, B and C highlight the emergence of "alternative revenue streams," suggesting new business opportunities through activities like material recovery, repair, and reuse. This, coupled with "*increased value creation*," indicates circular practices can be economically viable and potentially generated greater value compared to traditional linear models. Company A and Company C take it a step further by mentioning "*job creation*" and "*stimulating innovation*," suggesting to drive job growth and encouraging the development of innovative technologies and processes. Company B emphasizes "new markets," indicating involvement in expanding the market for recycled or reused materials within construction industry. Company D's focus on "*reduced economic pressure*" and "*reduced spending*" suggests that they might be involved in initiatives that make sustainable construction practices more affordable, potentially benefitting consumers and businesses alike.

Cultural Barriers ranked by the company: The data reveals a consistent ranking of cultural barriers across all four companies (Company A, B, C, and D). The biggest hurdle identified is hesitant culture and resistance to change within the CI, suggesting a preference for traditional practices. This closely followed by reluctance and risk aversion among construction stakeholders, likely referring to adopt new, unproven methods. Finally, all companies acknowledge poor quality of refurbished and recycled products as a barrier. This indicates a potential lack of awareness or trust in quality and performance of recycled materials within the CI.

Market Barriers ranked by the Company: Company A marks "*lack of market for secondary/second hand materials and products*" as its top barrier. This suggests Company A faces difficulty in selling or integrating secondary materials into construction projects due to limited established markets. Company B marks *"lack of market mechanism for waste recovery"* as its top barrier. It emphasizes the absence of proper systems for collecting, processing, and redistributing construction waste, hindering their ability to source secondary materials. For Company C, the biggest barrier is ensuring consistent quality in recycled materials, potentially due to lack of standardized processing. Similar to Company C, Company D identifies the inconsistency in quality of recycled materials as a major hurdle in promoting their use within construction projects.

Knowledge Barriers ranked by the Company: Company A highlights a general lack of knowledge of understanding about CE practices and principles among various players within CI as a top knowledge barrier. For Company B, lack of CE knowledge, technical capabilities, and expertise in construction, is the top barrier. This suggests a more specific knowledge gap within Company B's focus area. Construction professionals and their potential partners might lack the technical know-how to implement circular practices effectively. Company C emphasizes the lack of readily available information on the types, performance, and benefits of circular construction materials and services. Similar to Company C, Company D, a lack of accessible data and information about circular options is a significant barrier.

Financial Barriers ranked by the Company: Company A identifies the initial costs associated with implementing circular practices, such as material processing, deconstruction or hiring skilled labour as a major financial obstacle. Company B highlights the economic advantage of readily available of readily available virgin materials compared to potentially more expensive recycled alternatives. For Company C, unclear financial business case for CE in construction is the top barrier. This advocates the lack of readily available data and clear financial models demonstrating the long-term economic benefits of circular construction presents a significant barrier. Company D echoes the concern about the initial investment costs hindering the adoption of circular practices, similar to Company A.

Management Barriers ranked by the Company: Company A, C and D stress on the need for strong leadership buy-in senior management to drive the adoption of circular practices within the organisational system as well as industrial system. They rank lack of top management, commitment, support, and leadership as a top management barrier. Company B highlights the absence of woven and replicable models for implementing circular construction projects, creating uncertainty for businesses considering circular approach.

Regulatory Barriers ranked by the Company: Company A views the absence of clear regulations and policies as a major hurdle for implementing circular practices. Company B and Company C, accentuate the lack of incentives to design for end-of life products. This can disincentivize the upfront planning crucial for circular practices. Company D ranks lack of regulatory framework, appropriate policies, and sound legislations of CE in construction, as a top barrier.

Technological Barriers ranked by the Company: Company A and Company B, rank *"lack of technological and eco-innovation capacity"* as top technological barrier. This implies that the CI currently struggles to implement new technologies that would enable CE in CI. On the other hand, Company C and Company D, marks "*lack of technology and infrastructure readiness"* as the top technological barrier. This translates to the lack of efficient methods for processing circular methods, for example, the limitations in collecting and sorting used components.

Supply chain Barriers ranked by the Company: Company A and Company B, rank *"lack of producer-based responsibility system in production of construction materials"* as the top supply-chain barrier. This emphasizes the need for manufacturers to take responsibility for the end-of-life stage of their materials, potentially by facilitating the circular practice of deconstruction to promote the circular principles of reuse and recycle. Company C and Company D, rank *"fragmentation and complexity of the CE supply chain network in construction"* as the top supply chain barrier. This suggests that the current supply chain is fragmented and complex, making it difficult to source and manage circular materials efficiently.

Stakeholder Barriers ranked by the Company: Company A, B and D calls for an attention towards the *"poor co-operation, collaboration, and communication among stakeholders in CE Value chain,"* as they rank it as a top stakeholder barrier. This emphasizes the lack of effective communication and collaboration between all parties involved in a circular construction project. Company C identifies lack of trust among stakeholders as a major hurdle, potentially due to concerns about the reliability or quality of circular materials and processes.

Social Enablers for Circular Construction (Can be): Company A, B and D acknowledge the importance of user behaviour in promoting circular construction. *"Change in the choices made by Users"* highlights the potential impact of consumer preferences shifting towards circular practices like a café owner preferring elements like reclaimed wood, recycled steel, or salvaged bricks. Company A, C, and D specifically mention *"Civic engagement and voluntary activities,"* indicating a belief that participation in initiatives like community gardens or repair workshops can foster a more circular mindset. Interestingly, Companies B and C highlight the potential for a social shift in status associated with using circular materials. *"Increased status related to secondary materials and circular products"* suggests that promoting the environmental and economic benefits of circular construction could lead to a cultural shift where using recycled or reused materials become desirable.

Market Enablers for Circular Construction (Can be): The data reveals a shared focus on collaboration and long-term vision as key market enablers for circular construction across all four companies (A, B, C, and D). *"Competitive advantage for early adopters"* is a common theme, suggesting that companies believe that there's a first mover advantage to be gained, especially for those whose DNA is based on circular practices. New alliances and collaborations are seen as crucial for navigating the complexities of a CE, potentially requiring partnerships between construction companies, waste management firms, and material processing specialists. Company A, B, and D emphasize "Valuing the services, not only the products- provided by nature," indicating a recognition of the inherent value in ecosystem services and the importance of a regenerative approach. Company B goes a further step by mentioning "Functional service economy (XaaS)", suggesting they see potential in transitioning from selling products (building materials) to offering services (long-term building performance or material maintenance). Company B and Company D highlight the potential for "*a long-term vision by businesses*" and Company C suggest that "*access to regional/global supply of secondary materials or by products*" can enhance feasibility of a circular project.

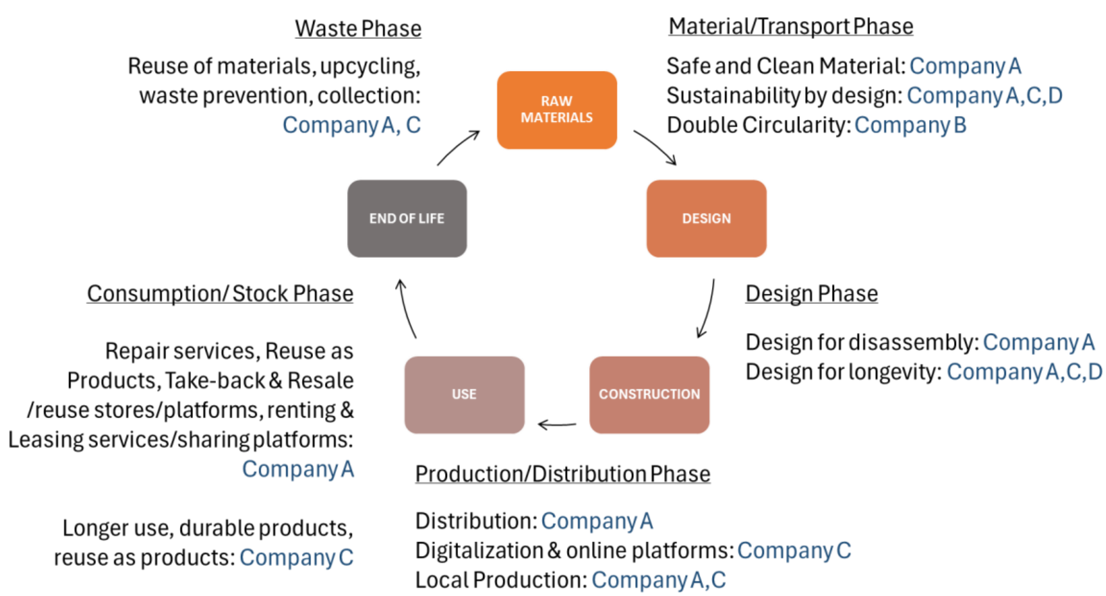
Regulatory Enablers for Circular Construction (Can be): A strong consensus among companies (A, B, and C) on the importance of "*Extended Producer Responsibility (EPR)*" and "*Green & Circular Procurement*" as regulatory enablers for circular construction. EPR policies hold manufacturers accountable for the EOL stage of their products, potentially incentivizing them to design for disassembly and recyclability. Green & Circular Procurement policies encourage government agencies and businesses to prioritize sustainable and recycled materials in their construction projects. Additionally, Company A and Company B, highlight a *"Tax shift from Labour to Resources."* This suggests a policy prospects where taxes on materials and resource extraction are increased, while taxes on labour are decreased. This could incentivize companies to use fewer virgin materials and explore more circular solutions. Company D differs slightly, focusing solely on Green & Circular Procurement, suggesting a view on this policy as the most impactful regulatory mechanism for circular construction.

Cultural Enablers for Circular Construction (Can be): All the four companies (A, B, C, and D) share a focus on workforce development as a key cultural enabler for circular construction. All the companies underline the importance of a creative and skilled problem-solving resource, suggesting a need for workforce equipped to innovate and adapt to the challenges and opportunities presented by circular practices. Company A, B, and C, specifically mentions the need for "*integration of CE concept into training and educational programs*". This signifies the importance of educating current and future generations of architects, engineers, developers, and construction workers about the principles and methods of circular construction. Company D emphasizes "*Preparation of future professional practices and understanding*," suggesting they view broader industry-wide adaptation and cultural shift as crucial for successful implementation.

Technological Enablers for Circular Construction (Can be): Company A, B and D acknowledge the importance of "Increased productivity, cost reductions." This suggests that advancement in technology is seen as a way to optimize resource use and achieve cost savings within circular construction projects. "*Digital technologies and engineering to support business models*" is a common theme for Company A and Company B, highlighting the potential for technology to facilitate new circular business models, involving efficient logistics or data-driven material management. Company A emphasizes "*increased* *efficiency with innovation*," suggesting they see broader technological advancements as key to overcoming challenges. Company B prioritizes "*better waste processing*" and "*high quality of recycled materials*," indicating a focus on technologies that improve the efficiency and quality of material recovery processes. Company C stands out with its emphasis on "*Biomimicry innovation*," suggesting a potential in emulating nature's resource efficiency within the CI.

Position of the Company in the Circular Construction Process (Phases): Company A and Company C considers all five phases: Material, Design, Production/Distribution, Consumption/Stock, and Waste. This suggests a comprehensive approach encompassing the entire lifecycle of building materials. Company B and Company D are engaged in the early stages of the lifecycle. Company B emphasizes the Material phase, focusing on sourcing and processing recycling materials. Company D involvement in the Design phase, suggest that they view design for disassembly and reusability as crucial for circular construction. Figure 15 is an illustration of the position of the four companies within the five phases with their circular practices.

Figure 15: Position of the Company in the Circular Construction Process



Source: 15- Compiled by author and online survey

Societal Readiness Level (SRL) of the Company: Company A and Company C indicate they are at SRL 6, which means their solutions have been demonstrated in a relevant environment and in co-operation with stakeholders. This suggests they have progressed beyond the initial testing and are gathering feedback on the potential impact of their solutions in a real world. Company B, they are at early stage, at SRL 3. This means they are still in the initial testing phase of their proposed solutions, likely collaborating with relevant stakeholders to gather feedback and refine their ideas. Company D, they are at SRL 5, which means their proposed solutions have been validated by relevant stakeholders in the sector. This suggests their solutions have been reviewed and approved by the industrial system, but they may not yet have been demonstrated in a real world- setting.

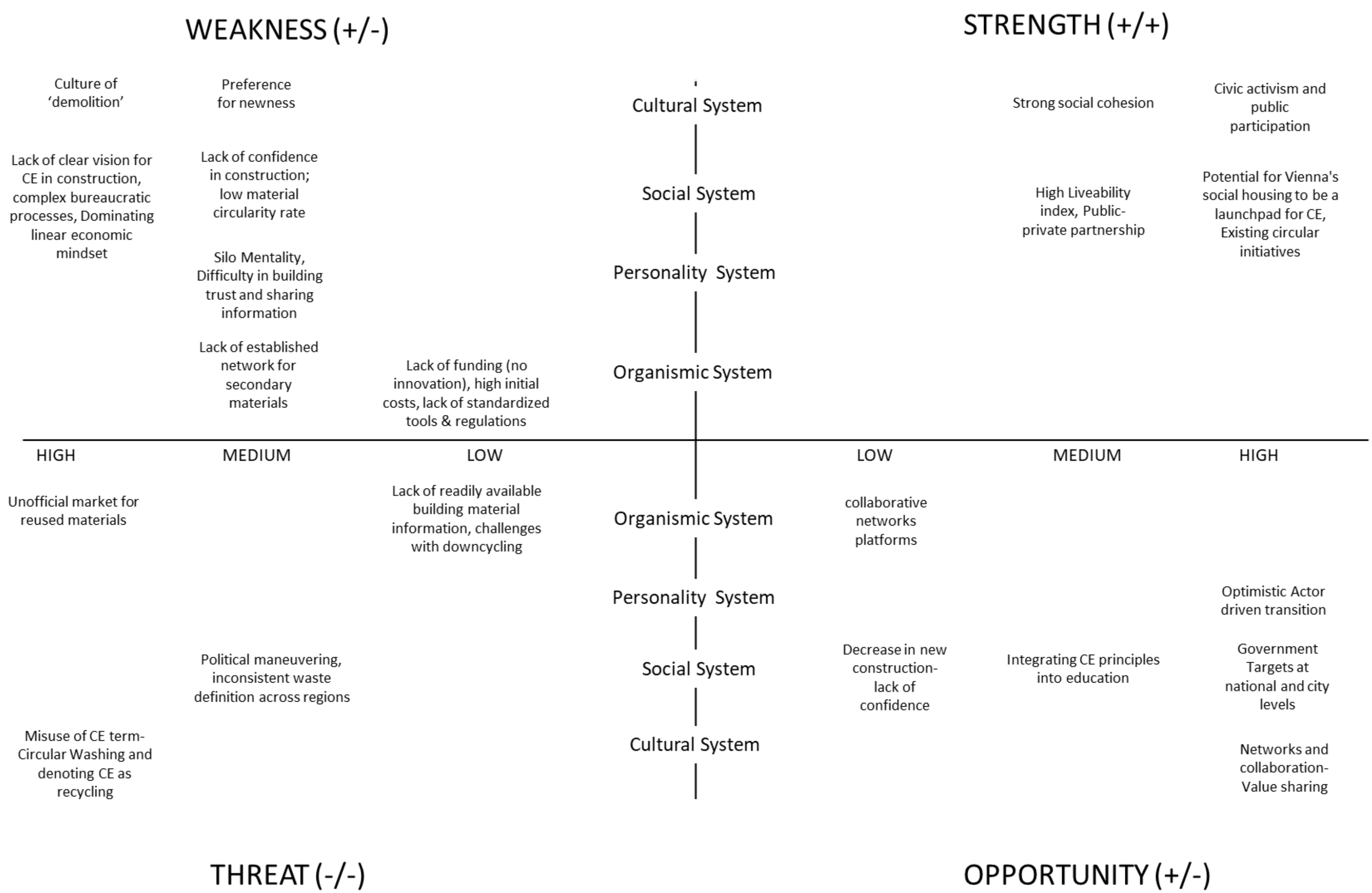
4.4. Remodeling of SWOT Analysis of Vienna (Macro System) towards Circular Construction

The figure 16 suggests Vienna's SWOT analysis in relation with the Parson's cybernetics hierarchical systems of control. It has been remodelled after the in-depth empirical investigation of 3M systems. The remodelled SWOT analysis has been expanded to include the organismic and personality system, where the flow of energy is greater. Vienna's macroscopic view of systems present a complex intermix of factors. While strong cohesion and civic activism remains its strength. A key drawback within cultural systems is the "culture of demolition," facilitated by economic pressures as well as illegal market streams. The prevailing linear economic mindset further hinders the progress. However, opportunities exist through educating clients about the long-term cost benefits of circular construction. Though, overcoming the threat of political hurdles is crucial to capitalise the opportunities and move the transition in a faster pace.

4.5. Limitations, and future research prospects

Limitations on Ababio & Lu's (2023) framework were experienced, related to direct barrier related to 'lack of collaborative platform', 'conservative nature of political systems', and barriers on regulation can be expanded from only environmental laws to other legislations. It also does not address the issue with 'scalability' or 'lack of trust or transparency.' Further this research only focuses on Vienna from 3M systems perspective (micro-meso-macro) and the results may not be generalizable due to its unique characteristics. However, the approach to this study is replicable. Due to the small sample size of the micro-level study, the analysis has been done in MS-EXCEL. A future research may apply to the same approach and then when dealing with larger sample size, 'Analytical Hierarchy Process' may be used by employing multi-criteria weighted method for the analysis (Sipahi & Timor, 2010). A network analysis of actors within meso-systems level in the future will provide a powerful insight for the ongoing transition within CSCs.

Figure 16: Remodelling of SWOT-Analysis for Vienna and its relation with Cybernetics' hierarchy of Control



Source: 16- Compiled by author

Ch 7 Conclusion

The Circular Economy (CE)- viewed as a concept by some, and as a framework by others- is actively being promoted as an alternative to the traditional 'take-make-dispose' linear economy which is associated with mass production and resource consumption (Hossain et al., 2020; Jacobi et al., 2018). The concept of CE has no single definition but focuses on extending the lifecycle of products and materials through reuse and recycling, aiming to reduce waste. (Schöggl et al., 2022). The transition towards CE, demands a 'systems thinking' beyond just waste management. This included designing products, optimizing production processes, encouraging extended product use, maximizing a product's lifespan, and ensuring material recovery at the end of its life cycle.

The holistic understanding of CE systems via Construction Industry of Vienna, entails that there is huge implementation gap that needs to bridged. Despite Austria's promising national strategy and Vienna's innovative social housing programs, achieving climate neutrality hinges on bridging the gap between policy and action. The construction sector in particular, necessitates a drastic systemic transformation for a transition towards circular practices.

Vienna's aspirations for a circular construction industry are hampered by a web of barriers as stated by actors at different systemic levels. A cultural preference for new buildings and a lack of clear information on how circular construction works in practice discourages actors from adopting it. This reinforces a "business as usual" mentality within the already rigid construction industry, ultimately hindering social acceptance of circular practices in CI. Additionally, the economic viability of CE remains unclear due to absence of robust business-case or models and a focus on short-term costs. Fragmented collaboration between the stakeholders, coupled with complex bureaucracy and a lack of standardized regulations, further complicates the practical implementation of circular practices in CI. On the ground, high upfront costs associated with circular construction, limited data on existing building materials, and a weak network for secondary materials pose operational hurdles. These factors, combined with the potential for 'circular washing'- superficial efforts lacking true circularity, to appear sustainable without implementing meaningful changes. A deeply ingrained weakness of "culture of demolition" may persist, fueled by a perverse economic reality: in many cases, demolishing a building is currently cheaper than carefully deconstructing it to recover reusable materials. This economic incentive creates a loophole that stakeholders exploit. Hungarian or Romanian organizations, known for their established "streams" and ability to handle these materials, swoop in to collect debris from demolition sites, suggesting a potential, and likely informal or even illegal, market for such practices.

Building trust among actors across the CI supply chain is the biggest barrier in establishing a network for circular construction practices in Vienna. This lack of trust hinders open information sharing and collaboration, which is essential for not only innovation in products but also in processes. Other barriers include finding suitable partners and navigating issues around data transparency and financial resources. Institutions like 'The Climate Lab' at the meso-system level, can play a critical role in overcoming these network barriers. By providing a platform for knowledge sharing and connection, 'The Climate Lab' brings together diverse stakeholders and fosters a collaborative environment. These interactions allow members to learn from each other, establish valuable contacts, and gain insights into circular construction practices. The Lab's co-working space further promotes resource efficiency and collaboration. Overall, The Climate Lab offers to "plow the field" for constructive discussions and build community around the shared goal of a circular construction industry in Vienna.

There are several barriers that hinder companies from implementing circular construction practices at the micro-level. These barriers fall into nine categories: cultural, market, knowledge, financial, management, regulatory, technological, supply chain, and stakeholder barriers.

Cultural barriers include a preference for traditional practices, resistance to change, and a perception of poor quality in recycled materials. Market barriers include a lack of established markets for secondary materials and a lack of economic incentives for using recycled materials. Knowledge barriers include a general lack of awareness of circular construction principles and a lack of information on available circular materials and methods. This highlights the inadequacies in the flow of information from the higher systems- cultural and social – political systems, for example, from policy makers to construction workers via developers or architectural firms. Financial barriers include the high initial costs associated with implementing circular practices and the unclear financial benefits. Often the long-term financial gains of circular construction aren't always clear, as there is a lack of incentive programs or financial support offered by the broader economic system at macro level. Management barriers include lack of leadership buy-in and a lack of established models for implementing circular practices. This can be attributed to the fragmented nature of organizations due to 'silo mentality' that could otherwise collaborate and share best practices at meso level. Regulatory barriers include a lack of clear regulations and policies supporting CE. The absence of clear government regulations and policies supporting circular construction practices creates a significant hurdle. Without a strong framework established by the broader economic and political systems, companies are hesitant to invest in circular construction due to uncertainty. Technological barriers include lack of technology for implementing circular practices and a lack of efficient methods for processing secondary materials. Supply chain barriers include a lack of producer responsibility for the EOL phase of waste materials and a fragmented and complex supply chain for circular materials. Stakeholder barriers include poor collaboration and communication among stakeholders involved in CSCs.

There is Hope! And, as one of the actors says, "*This will change*," Vienna's emerging circular construction industry, fueled by a combination of enablers. Technological advancements like BIM and digital platforms are streamlining collaboration and information sharing. Companies, whose DNA is 'Circular Economy' are fostering innovation in material science and binders, making complete material reuse a reality. The plethora of ongoing research projects are golden opportunities for Vienna's successful transition; however, its timely and regular funding remains critical. Vienna is taking a proactive stance by leveraging the EGD and setting strict regulations and new standards for promoting circular design and material use. Culturally, new roles are being created to promote circularity, inter-disciplinary education programs for fostering collaboration are in action, and even benefitting from unexpected public participation that steers projects towards deconstruction and reuse. Financially, new funding models and public-private partnerships are creating a market for deconstruction services, recycled materials, and innovative products. Circular hubs are emerging as central points for resource exchange, and initiatives like ÖkoKauf are providing a guaranteed customer base for circular construction products.

Vienna's CI is on the cusp of a remarkable transformation. While gap exists between the theory of circular practices and their practical implementation, the city possesses the necessary tools and unwavering determination to bridge this gap. The collaborative efforts of stakeholders across all the 3M levels (micro-meso-macro)- coupled with the ongoing advancements in technology, policy, and public awareness, are building a strong foundation for a thriving circular construction industry.

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Annexures

Interview Guidelines and Interview Details

Interview: Mr. Klaus Kodydek DOTANK-Circular City Vienna program 2020-2030 (Projektmitarbeiter Stabsstelle Ressourcenschonung und Nachhaltigkeit im Bauwesen, Department of Resource Conservation and Sustainability in Construction (SRN),Municipal Directorate for Buildings and Technology)

a. Introduction of the interviewee and interviewer: How long has the interviewee been associated with the circular economy in general, and is associated with the City of Vienna in particular? And a brief introduction about DO-TANK Strategy and what it focuses on.

b. What is circular city? How can it be defined for Vienna?

c. DO-TANK Strategy 2030: Why construction sector has been prioritized and what does circular economy mean in the construction sector? Will Circular Strategy for other sectors be in place in the future? What are the main challenges in circular construction, especially while drafting the strategy at the city scale for a full-fledged implementation framework?

d. Is there any regulatory framework for the implementation of circular economy in construction, can you shed light on some policies/ regulations or legislations for CE in construction? Do you think these regulations are stringent enough, to make pressure on the companies to abide by the rules?

e. Are there any financial support mechanisms like tax incentives to support circular business models as low prices of raw materials and higher costs of recycled materials may be a concern to move toward circular business models?

f. Are there any networks/platforms for construction companies in Vienna or Austria, where they can collaborate with each other? (in general or with DO TANK in particular)

g. What are the ways through which information sharing and data transparency between stakeholders, can be increased for minimizing the fragmentation within the construction supply chain?

h. Taking the case of City Loop as a collaborative project, per se, How are the pilot projects in City Loop being replicated in the Viennese context? Your recent visit to Bodø, Norway, a pilot project where citizens are also involved by the City Lab? What were the insights that can be implemented in Vienna? Are citizens involved in the DO Tank Circular city Strategy of Vienna?

i. What are the other collaborative projects which the city of Vienna is partnering with, like City Loops?

j. How many stakeholders have been involved with the Do Tank strategy, (how can it be known who was involved to understand the network- possibility for a list of stakeholders), especially in the 4 round table discussions- Tra-TraP Design in Phase 1?

k. What are the ways or approaches to spread CE knowledge and awareness, transfer technical know-how and specially promote expertise in construction?

l. Building Information Modelling can be a breakthrough for the implementation of CE in the construction sector, what are the opportunities and challenges in the adoption of BIM in the supply chain?

m. A major challenge in the materials' end-of-the-cycle phase, per se, is the inconsistency in Life cycle assessment standards, for example, i.e. how they are quantified has not been well unified because of multi-life cycles. How this challenge can be overcome? Is there any standardized building material passport system?

n. Can the extended producer responsibility be also applicable in the construction sector, if yes, can you give any example if there is any practice regarding the same?

Interview: Mr. Jakob Lederer, Assistant Prof. Dipl.-Ing. Dr.techn., TU Wien

a. Introduction of the interviewee and interviewer

b. What is the project about - The "Christian Doppler Laboratory for the Design and Evaluation of an Efficient, Recycling- based Circular Economy" examines possibilities for a more circular economy together with corporate partners and the University of Leoben. Can you also mention the corporate partners? Or any project related to Circular Economy?

c. How circular economy can be defined? In general and in particular with the construction sector?

d. Why there is so much emphasis suddenly in the last 4-5 years on the circular economy? With the EU circular economy action plan? Why circular economy?

e. What are the MAJOR challenges in achieving a circular economy in the construction sector in general and particular in Austria and Vienna?

f. The case of Vienna, re-use and recycling of CDW is not sufficient to achieve (primary) raw material reduction targets (Lederer et al., 2021)

g. There is no scarcity of primary raw materials, there is less need for secondary raw materials like MIBA (e.g. Austria). Even if there is guidelines present, it is not practiced and the MIBA utilization rate outside landfills for the construction sector is 0% (Blasenbauer et al., 2020)

h. Is much emphasis on the recycling principle? A political and economical point of view? Are there other principles of circular economy- in practice in construction sector?

i. How to integrate the whole supply chain, construction and deconstruction ? Is there any networking system?

j. A major challenge in the materials' end-of-the-cycle phase, per se, is the inconsistency in Life cycle assessment standards, for example, i.e. how they are quantified has not been well unified because of multi-life cycles. How this challenge can be overcome? Is there any standardized building material passport system?

k. In Vienna, demolition is preferred to renovation? How to encourage the protection of older buildings?

l. Is there any elitist or capitalist concern/political interest that is revolving around Circular Economy?

Interview: Ms Helene Patternmann, Circularity and Community Director, Climate Lab

a. How long has the interviewee been associated with the circular economy in general, and a brief introduction about Climate Lab and its role in Circular Transition in Vienna?

b. How circular economy can be defined? What does it mean for Vienna as a city?

c. Why there is so much emphasis suddenly in the last 4-5 years on the circular economy? With the EU circular economy action plan? Why circular economy?

d. What are the MAJOR challenges in achieving a circular economy in general and particularly in Austria and Vienna?

e. Do you think, achieving a circular economy in construction has higher upfront costs at the initial stage and can the higher costs, be a reason for resistance or ignorance of the clients/even supply chain members to not be a part of a circular economy?

f. Are there any financial support mechanisms like tax incentives to support circular business models as low prices of raw materials and higher costs of recycled materials may be a concern to move toward circular business models?

g. How to integrate most of the businesses into the circular network?

h. Is there any elitist or capitalist concern/political interest that is revolving around Circular Economy?

Interview: Mr. Gaetano Bertino, Project Manager / Architectural Engineer, Alchemia-nova

a. Introduction of the interviewee- about their role in AlchemiaNova and how the org. is contributing in the circular construction or circular transition in Vienna? How to identify the projects and partners Alchemia Nova is involved to conceptualise the networking system.

b. How circular economy can be defined? In general and in particular with the construction sector?

c. Why there is so much emphasis suddenly in the last 4-5 years on the circular economy? With the EU circular economy action plan? Why circular economy?

d. What are the MAJOR challenges in achieving a circular economy in the construction sector in general and particular in Austria and Vienna? Also, emphasizing the challenges phase-wise life-cycle:Design, manufacturing (production), construction, maintenance, EOL (deconstruction)

e. How to promote secondary raw material circulation as a building material? Are there enough regulatory measures/legislation towards this practice in Vienna?

f. How to integrate the whole supply chain, construction, and deconstruction? Is there any networking system?

g. A major challenge in the materials' end-of-the-cycle phase, per se, is the inconsistency in Life cycle assessment standards, for example, i.e. how they are quantified has not been well unified because of multi-life cycles. How this challenge can be overcome? Is there any standardized building material passport system?

h. In Vienna, demolition is preferred to renovation? How to encourage the protection of older buildings? If the development plan allows for more space - i.e. higher buildings and more floors - and there is no protection zone for the site, then demolition becomes more likely.

i. There are so many certifications and labels, and standards, how to understand, which one needs to be followed? Is there any specific standard or certification system for circular construction?

j. How can we identify whether an architecture firm/construction company is working towards circular construction? Possibility of Circular Washing?

k. Is there any elitist or capitalist concern/political interest that is revolving around Circular Economy?

Interview: Ms Karin Huber-Heim, Executive Director, Circular Economy Forum Austria

a. Introduction of the interviewee- about their role in Circular Economy Forum Austria and how the org. is contributing to the circular construction or circular transition in Austria/Vienna?

b. What is Circular Economy? How it can be defined from the sustainability dimension? How it can be implemented in Construction Sector?

c. What is Circular Vienna, launched in June 2022?

d. Talking about system change? How Vienna is leading/incorporating a shift to this systemic change through a circular economy?

e. CCRI/City Loops, many EU-pan initiatives are developing numerous matrices/standards, how to have a successful transition? What do you think of –

f. Pilot v/s upscaling

g. Repetition of documented roadmaps/strategies, are they overwhelming?

h. What are the MAJOR challenges in achieving a circular economy in the construction sector in general and particular in Austria and Vienna? (may also point out in general for circular economy transitions)

i. In Vienna, demolition is preferred to renovation? How to encourage the protection of older buildings? If the development plan allows for more space - i.e. higher buildings and more floors - and there is no protection zone for the site, then demolition becomes more likely. Talking about the policy challenges.

j. How to ease this whole transition, what are the key ingredients for Austria/Vienna? Can you SWOT (Strength, Weakness, Opportunity and Threat)?

k. How to integrate the whole supply chain, construction, and deconstruction? Is there any networking system? Talking about MSMEs. Mainly in the collaboration, there is the dominance of big players.

l. Despite the good intentions of many construction stakeholders, legal, economic and policy barriers, create an uneven playfield that favors virgin/raw materials.

m. Example/Role model of successful implementation in construction sector like- Vauban Freiburg, Barcelona (cited by Systemiq at WCEF '23)?

n. Is there any elitist or capitalist concern/political interest that is revolving around Circular Economy?

Interview: Ms Anna-Vera Deinhammer; Endowed Chair / Stiftungsprofessur Sustainable Real Estate Development, FHWien der WKW (University of Applied Sciences for Management & Communication); Director for Circular Cities & Regions, Circular Economy Forum Austria

a. Introduction of the interviewee- about the various roles in OGNI, FHWien, Circular Economy Forum Austria and how these orgs. are contributing to the circular construction or circular transition in Austria/Vienna? Can you also briefly talk about your journey with CE? How it all started?

b. What is Circular Economy? How it can be defined from the sustainability dimension? How it can be implemented in Construction Sector?

c. What is Circular Vienna, launched in June 2022? And the DO TANK PROGRAM- which kicked off because of you (can you highlight the challenges/ difficulties?)

d. Talking about system change? How Vienna is leading/incorporating a shift to this systemic change through a circular economy? Any legal back up?

e. Why city of Vienna is not in any other projects like CCRI or Circular Cities Declaration?

f. What are the MAJOR challenges in achieving a circular economy in the construction sector in general and particular in Austria and Vienna? (may also point out in general for circular economy transitions)

g. In Vienna, demolition is preferred to renovation? How to encourage the protection of older buildings? If the development plan allows for more space - i.e. higher buildings and more floors - and there is no protection zone for the site, then demolition becomes more likely. Talking about the policy challenges.

h. How to ease this whole transition, what are the key ingredients for Austria/Vienna? Can you SWOT (Strength, Weakness, Opportunity and Threat)?

i. How to integrate the whole supply chain, construction, and deconstruction? Is there any networking system? Talking about MSMEs. Mainly in the collaboration, there is the dominance of big players.

j. Despite the good intentions of many construction stakeholders, legal, economic and policy barriers, create an uneven playfield that favors virgin/raw materials.

k. Is there any elitist or capitalist concern/political interest that is revolving around Circular Economy?

Results: Meso system level study- Q3- Statements:

a) Meeting likeminded people that work towards a similar goals, learning from each other
b) Providing space, focus on pillars and bringing participants together
c) They are providing a much needed network (online and offline) to reach necessary actors
d) Many different people from various companies with different experiences and knowledge
e) Synergies with other members Industry circles Theme-centered learning sessions Open space
f) Concentration of people working in similar directions. Co-branding with Climate Lab increasing reach.
g) Bringing relevant actors together. Providing processes and frameworks to enhance tangible results
h) Through establishment of personal connections with likeminded people that share a similar path
i) Establish valuable contacts to the public sector and companies that face similar issues
j) Gathering and Idea sharing, coffees, while learning to know topics keep others busy
k) Visibility, Credibility, Cooperations
l) It's more obvious to me who are the players in the field and that I can reach out of them
m) Conversation and Network building between multi-dimensional stakeholder ecosystem
n) A Place where people can meet, some formats
o) I am able to Talk Go stakeholders which also actively working on transforming the system
p) Bringing together different people and companies, exchanging ideas, all willing to contribute
q) By many different curated community formats to bring people together and initiate collaboration
r) Events for specific topics serve as networking and education platform
s) By events that make it easy to get to know new people
t) Providing a platform to meet and share
u) Plowing the field for constructive discussions. Insights in different topics related to SDGs
v) Bringing diverse stakeholders together- publicity on circularity- relevant events
w) The climate Lab is Patchwork that helps gather more knowledge and know how under the same roof.

Results: Micro system level-study

Question	Company A	Company B	Company C	Company D
Scope of Business/ Work Outreach	National	Global	Supranational	National
Business Transaction Model	B2B- Business to Business	B2B- Business to Business	B2B- Business to Business B2C- Business to Consumer B2G- Business to Government	B2B- Business to Business B2C- Business to Consumer B2G- Business to Government
Facet of Circular Economy	Built Environment, Design, Logistics, Material Flows, Networks & Hubs, Remanufacturing, Repair, Reuse, Sharing	Built Environment, Material Flows	Agriculture, Bio-economy, Built Environment, Energy, Food& Drink, Manufacturing, Material Flows, Recycling, Repair, Reuse, Sharing	Built Environment, Community, Sharing
Addressing SDGs	SDG 9 Industry, Innovation & Infrastructure SDG 11 Sustainable Cities and Communities SDG 12 Responsible Consumption and Production	SDG 8 Decent Work & Economic Prosperity SDG 9 Industry, Innovation & Infrastructure SDG 11 Sustainable Cities and Communities	SDG 6 Clean Water & Sanitation SDG 7 Affordable & Clean Energy SDG 9 Industry, Innovation & Infrastructure	SDG 7 Affordable & Clean Energy SDG 11 Sustainable Cities and Communities SDG 13 Climate Action

		SDG 12 Responsible consumption and production	SDG 11 Sustainable Cities and Communities	
Social Impacts created by the Company	Developing Social Capital in partnership with others (ie families, communities, businesses, trade unions, educational, voluntary organisations) Increased Human Capital - people's health, knowledge, skills and motivation Increased local resilience	Circular material flows	Developing Social Capital in partnership with others (ie families, communities, businesses, trade unions, educational, voluntary organisations) Improved wellbeing Increased contacts among people Increased Quality of Life	Developing Social Capital in partnership with others (ie families, communities, businesses, trade unions, educational, voluntary organisations) Increased contacts among people Increased local resilience Increased Quality of Life Less hierarchical organisations

				New community space
Environmental Impacts created by the company	Increased resource utilisation Preserving natural capital-stocks & flows of energy and material Reduced emissions Reduced waste	Increased resource utilization Preserving natural capital-stocks & flows of energy and material Reduced emissions Reduced waste	Increased Biodiversity Increased resource utilisation Reduced waste	Environmental Awareness Increased resource utilisation Reduced emissions Reduced waste
Economic Impacts created by the company	Alternative revenue streams Increased Value creation Job creation Stimulating innovation	Alternative revenue streams Increased Value creation New markets	Alternative revenue streams New markets Stimulating innovation	Increased Value creation Reduced economic pressure Reduced spending
CULTURAL barriers (Ranking- Top 3/5)	**1) Hesitant culture and change resistance**	**1)Hesitant culture and change resistance**	**1) Hesitant culture and change resistance**	**1)Reluctance and risk aversion of construction stakeholders**

	2)Reluctance and risk aversion of construction stakeholders 3)Perceived poor quality of refurbished and recycled products	2)Perceived poor quality of refurbished and recycled products 3)Reluctance and risk aversion of construction stakeholders	2)Reluctance and risk aversion of construction stakeholders 3)Perceived poor quality of refurbished and recycled products	2)Preferences of virgin construction materials over reused and recycled products 3)Perceived poor quality of refurbished and recycled products
MARKET barriers (Ranking- Top 3/6)	**1) Lack of market for secondary/ second-hand materials and products** 2)Lack of market pressure and competition 3)Limited availability of recycled materials and reused products	**1)Lack of market mechanisms for waste recovery** 2)Lack of market pressure and competition 3)Uncertain market demand for refurbished and recycled, remanufactured, and recycled products	**1)Lack of quality of high-quality recycled materials and products** 2)Uncertain market demand for refurbished and recycled, remanufactured, and recycled products 3)Lack of market pressure and competition	**1)Lack of quality of high-quality recycled materials and products** 2)Lack of market mechanisms for waste recovery 3)Lack of market pressure and competition
KNOWLEDGE barriers (Ranking- Top 3/7)		**1)Lack of CE knowledge, technical capabilities**	**1)Lack of data and information of circular**	**1)Lack of data and information**

	1) Limited CE awareness across the construction supply chain network 2)Lack of appropriate CE training, development programs, technical support for supply chain members 3)Limited stakeholder awareness of circular materials, products, services and strategies	**and expertise in construction** 2)Lack of appropriate CE training, development programs, technical support for supply chain members 3)Lack of data and information of circular construction materials, products and services	**construction materials, products and services** 2)Difficulty of measuring CE project and business benefits in construction 3)Lack of appropriate CE training, development programs, technical support for supply chain members	**of circular construction materials, products and services** 2)Limited stakeholder awareness of circular materials, products, services and strategies 3)Client ignorance of CE
FINANCIAL barriers (Ranking- Top 5/10)	**1)Higher upfront investment costs** 2)Low prices of virgin materials 3)Lack of funding on circular business models 4) High cost of establishing eco-industrial chains 5) Lack of capital and financial resources	**1)Low prices of virgin materials** 2)Higher upfront investment costs 3)High cost of establishing eco-industrial chains 4)Lack of funding on circular business models 5)Lack of capital and financial resources	**1)Unclear financial business case for CE in construction** 2)Lack of economic viability of Circular business models 3)Unpredictable financial returns and economic savings 4)Higher upfront investment costs	**1)Higher upfront investment costs** 2)Lack of funding on circular business models 3)Unpredictable financial returns and economic savings 4)Lack of capital and financial resources

			5)Lack of funding on circular business models	5)Low prices of virgin materials
MANAGEMENT barriers (Ranking- Top 3/7)	**1)Lack of top management commitment, support, and leadership** 2)Lack of consideration for end-of-life issues of buildings 3)Lack of standard indicators and systems for data collection and performance assessment of CE in construction	**1)Lack of successful circular business models and frameworks to implement circular construction projects** 2)Limited circular designs for construction projects 3)Lack of standard indicators and systems for data collection and performance assessment of CE in construction	**1)Lack of top management commitment, support, and leadership** 2)Lack of consideration for end-of-life issues of buildings 3)Lack of design tools and strategies for circular business models and circular products	**1)Lack of top management commitment, support, and leadership** 2)Lack of standard indicators and systems for data collection and performance assessment of CE in construction 3)Lack of successful circular business models and frameworks to implement circular construction projects
REGULATORY barriers (Ranking- Top 5/10)	**1)Lack of regulatory pressure and stringent regulations**	**1)Lack of incentives to design for end-of life products**	**1)Lack of incentives to design for end-of life products**	**1) Lack of regulatory framework,**

	2)Lack of regulatory framework, appropriate policies, and sound legislations for CE in construction 3)Lack of incentives to design for end-of life products 4)Lack of government financial support mechanisms and tax incentives for circular business models 5)Poor institutional support and framework for CE in construction	2)Lack of regulatory pressure and stringent regulations 3)Lack of clearly defined national goals, targets, and visions for CE in construction 4)Lack of industry support, standards, and technical guidelines for circular construction projects 5)Lack of promotion and large-scale demonstration projects	2)Lack of regulatory framework, appropriate policies, and sound legislations for CE in construction 3)Lack of CE and environmental management certifications and accreditation systems 4)Lack of government financial support mechanisms and tax incentives for circular business models 5)Lack of regulatory pressure and stringent regulations	**appropriate policies, and sound legislations for CE in construction** 2)Lack of government financial support mechanisms and tax incentives for circular business models 3)Poor institutional support and framework for CE in construction 4)Lack of regulatory pressure and stringent regulations 5)Lack of clearly defined national goals targets, and visions for CE in construction

TECHNOLOGY barriers (Ranking- Top 3/7)	**1)Lack of technological and eco-innovation capacity** 2)Lack of proven technologies and equipment for CE in construction 3)Lack of technology and infrastructure readiness	**1)Lack of technological and eco-innovation capacity** 2)Lack of robust information systems to track recycled materials 3)Lack of proven technologies and equipment for CE in construction	**1)Lack of technology and infrastructure readiness** 2)Lack of proven technologies and equipment for CE in construction 3)Absence of sufficient technologies for waste disposal and recycled materials	**1)Lack of technology and infrastructure readiness** 2)Lack of proven technologies and equipment for CE in construction 3)Lack of technological and eco-innovation capacity,
SUPPLY CHAIN barriers (Ranking- Top 4/8)	**1)Lack of producer-based responsibility system in production of construction materials** 2)Lack of integration and collaboration among supply chain partners in construction 3)Fragmentation and complexity of the CE supply chain network in construction	**1)Lack of producer-based responsibility system in production of construction materials** 2)Lack of integration and collaboration among supply chain partners in construction 3)Fragmentation and complexity of the CE supply chain network in construction	**1)Fragmentation and complexity of the CE supply chain network in construction** 2)Lack of complete supply chain network 3)Lack of producer-based responsibility system in production of construction materials	**1)Fragmentation and complexity of the CE supply chain network in construction** 2)Lack of cohesive reverse logistics network and facilities 3)Lack of integration and collaboration

	4)Lack of cohesive reverse logistics network and facilities	4)Insufficient suppliers of circular materials and products	4)Lack of cohesive reverse logistics network and facilities	among supply chain partners in construction 4)Lack of appropriate supply chain partners 5)Insufficient suppliers of circular materials and products
STAKEHOLDER barriers (Ranking- Top 3/5)	1)**Poor co-operation, collaboration, and communication among stakeholders in CE Value chain** 2)Lack of trust among stakeholders 3)Lack of data transparency and information sharing among stakeholders	1)**Poor co-operation, collaboration, and communication among stakeholders in CE Value chain** 2)Lack of data transparency and information sharing among stakeholders 3)Lack of appropriate partners and participative network	**1)Lack of trust among stakeholders** 2)Lack of support and involvement of stakeholders 3)Lack of appropriate partners and participative network	**1)Poor co-operation, collaboration, and communication among stakeholders in CE Value chain** 2)Lack of data transparency and information sharing among stakeholders 3)Lack of appropriate partners and

				participative network
SOCIAL Enablers	Change in the choices made by Users Civic engagement and voluntary activities Shared norms, values, attitudes, and beliefs	Change in the choices made by Users Civic engagement and voluntary activities Increased status related to secondary materials and circular products	Increased status related to secondary materials and circular products	Civic engagement and voluntary activities Increased status related to secondary materials and circular products Change in the choices made by Users
MARKET Enablers	Competitive advantage for early adopters New alliances and collaborations Valuing the services, not only the products - provided by nature	Competitive advantage for early adopters Functional service economy (XaaS) Need for a long-term vision by businesses New alliances and collaborations	Access to regional / global supply of secondary materials & by products Knowledge of impact Valuing the services, not only the products - provided by nature	Competitive advantage for early adopters Need for a long-term vision by businesses New alliances and collaborations Valuing the services, not only

				the products - provided by nature
REGULATORY Enablers	Extended Producer Responsibility (EPR) Green & Circular Procurement Provide access to funding to encourage experimentation, innovation and redesign Tax shift from Labour to Resources	Assess progress using reliable indicators for imports and local production while accounting for the life cycles of products Extended Producer Responsibility (EPR) Tax shift from Labour to Resources Use of circular performance indicators by governments, investors and businesses can encourage the value chain to become more circular	Extended Producer Responsibility (EPR) Green & Circular Procurement Tax shift from Labour to Resources	Green & Circular Procurement
CULTURAL Enablers	A creative and skilled problem-solving resource	A creative and skilled problem-solving resource	A creative and skilled problem-solving resource	A creative and skilled problem-solving resource

	Better consideration of the labour force Integration of the CE concept into training and educational programs	Integration of the CE concept into training and educational programs Preparation of future professional practices and understanding	Integration of the CE concept into training and educational programs	Preparation of future professional practices and understanding
TECHNOLOGICAL Enablers	Digital technologies and engineering to support business models Increased efficiency with innovation Increased resource productivity, cost reductions	Better waste processing Digital technologies and engineering to support business models Higher quality of recycled materials Increased environmental performance Increased resource productivity, cost reductions	Biomimicry innovation - emulating natures strategies Higher quality of recycled materials Increased environmental performance	Better waste processing Increased environmental performance Increased resource productivity, cost reductions
Position of the Company in the Circular Construction (Phase)	Material Phase, Design Phase, Production/Distribution Phase, Consumption/Stock Phase	Material Phase	Material Phase, Design Phase, Production/Distribution Phase	Design Phase, Material Phase
Material Phase	Safe and clean material Sustainable by design	Double Circularity	Sustainable by design	

	Double Circularity			Sustainable by design
Design Phase	Design for disassembly Design for longevity	-	Design for disassembly	Design for disassembly
Production/Distribution Phase	Distribution Local Production	-	Digitalisation & online platforms Local Production	-
Consumption/ Stock Phase	Repair services Reuse as Products Take-back & resale/reuse stores/platforms Renting & leasing services/sharing platforms	-	Longer use Durable products Reuse as Products	-
Waste Phase	Reuse of materials Upcycling Waste prevention	-	Collection Reuse of materials Upcycling Waste prevention	-
Societal Readiness level	**SRL 6** - solution(s) demonstrated in relevant environment and in co-operation with relevant stakeholders to gain initial feedback on potential impact	**SRL 3** - initial testing of proposed solution(s) together with relevant stakeholders	**SRL 6** - solution(s) demonstrated in relevant environment and in co-operation with relevant stakeholders to gain initial feedback on potential impact	**SRL 5** - proposed solution(s) validated by relevant stakeholders in the sector

Questions for 'Micro-level Systems' Study:

Q no	Questions	Options	Type (Options)
1	Name of the Organisation/ Company you represent?	Blank	Text
2	Scope of the business/work outreach of the organization/company ?	Supranational Global National Regional Local Hyperlocal	Single Choice
3	Can you define the business transaction model?	B2B- Business to Business B2C- Business to Consumer B2G- Business to Government G2B- Government to Business G2C- Government to Consumer G2G- Government to Government P2P- Peer to Peer Other	Multiple Choice
4	What are your facets of Circular Economy?	Built Environment, Material Flows, Sharing, Repair, Reuse, Agriculture, Bio-economy, Community, Design, Energy, Food & Drink, Logistics, Manufacturing, Network & Hubs, Recycling, Remanufacturing, Creative Arts/ Culture, Cultural Heritage, Education, Electronics, Finance, Health & Wellbeing, Indigenous, Maritime, Mobility, Plastic, Procurement, Product-as-service Social Enterprise	Multiple Choice
5	Sustainable Goals you are addressing?	SDG 1 No Poverty SDG 2 Zero Hunger SDG 3 Good Health and Well being SDG 4 Quality Education SDG 5 Gender Equality SDG 6 Clean Water & Sanitation SDG 7 Affordable & Clean Energy SDG 8 Decent Work & Economic Prosperity SDG 9 Industry, Innovation & Infrastructure SDG 10 Reduced inequalities SDG 11 Sustainable Cities and Communities	Multiple Choice

		SDG 12 Responsible consumption and production SDG 13 Climate Action SDG 14 Life Below Water SDG 15 Life on Land SDG 16 Peace, Justice & Strong Institutions SDG 17 Partnership for goals	
6	What are the social impacts that your company is creating?	• Developing Social Capital in partnership with others (ie families, communities, businesses, trade unions, educational, voluntary organizations) • Increased contacts among people • Increased local resilience • Increased Quality of Life • Improved wellbeing • Increased Human Capital - people's health, knowledge, skills and motivation • Less Hierarchial Organisations • New Community space • Increased space • Increased access to service-to-service products • Increased emergency preparedness • Increased employment • Increased inclusion • Increased local pride • Increased physical activity • Reduced gender inequalities • Reduced social pressure • Other	Multiple Choice
7	What are the environmental impacts that your company is creating?	• Increased resource utilisation • Reduced waste • Reduced emissions • Preserving natural capital-stocks & flows of energy and material • Environmental Awareness • Increased Biodiversity • Increased Environmental stewardship • Other	Multiple Choice

8	What are the economic impacts that your company is creating?	• Alternative revenue streams • Increased Value creation • New markets • Stimulating innovation • Job creation • Reduced economic pressure • Reduced spending • Increased competitiveness • Increased financial Capital • Increased manufactured capital- material goods or fixed assets contributing to the process than output • Other	Multiple Choice
9	What are the CULTURAL barriers in the circular economy transition (construction sector in Vienna, Austria Context)?	• Hesitant culture and change resistance • Lack of interest in recycled and remanufactured products • Preferences of virgin construction materials over reused and recycled products • Reluctance and risk aversion of construction stakeholders • Perceived poor quality of refurbished and recycled products	Ranking
10	What are the MARKET barriers in the circular economy transition (construction sector in Vienna, Austria Context)?	• Limited availability of recycled materials and reused products • Lack of market for secondary/ second-hand materials and products • Lack of market pressure and competition • Lack of quality of high-quality recycled materials and products • Uncertain market demand for refurbished and recycled, remanufactured, and recycled products • Lack of market mechanisms for waste recovery	Ranking
11	What are the KNOWLEDGE barriers in the circular economy transition (construction sector in	• Lack of data and information of circular construction materials, products and services • Lack of appropriate CE training, development programs, technical support for supply chain members	Ranking

	Vienna, Austria Context)?	• Limited stakeholder awareness of circular materials, products, services and strategies • Limited CE awareness across the construction supply chain network • Lack of CE knowledge, technical capabilities and expertise in construction • Difficulty of measuring CE project and business benefits in construction • Client ignorance of CE	
12	What are the FINANCIAL barriers in the circular economy transition (construction sector in Vienna, Austria Context)?	• Lack of capital and financial resources • High cost of establishing eco-industrial chains • Unclear financial business case for CE in construction • Higher upfront investment costs • Lack of funding on circular business models • Low prices of virgin materials • Unpredictable financial returns and economic savings • Lack of economic viability of Circular business models • High cost of eco-friendly/recycled materials and products • Higher cost of waste collection and segregation	Ranking
13	What are the MANAGEMENT barriers in the circular economy transition (constructio n sector in Vienna, Austria Context)?	• Lack of successful circular business models and frameworks to implement circular construction projects • Lack of consideration for end-of-life issues of buildings • Lack of top management commitment, support, and leadership • Lack of standard indicators and systems for data collection and performance assessment of CE in construction • Limited circular designs for construction projects • Complex planning requirements and management processes	Ranking

		• Lack of design tools and strategies for circular business models and circular products	
14	What are the REGULATORY barriers in the circular economy transition (construction sector in Vienna, Austria Context)?	• Lack of government financial support mechanisms and tax incentives for circular business models • Lack of CE and environmental management certifications and accreditation systems • Weak enforcement of rules and regulations for environmental protection • Obstructive laws and regulations (eg, low taxes on landfill disposal) • Poor institutional support and framework for CE in construction • Lack of clearly defined national goals, targets, and visions for CE in construction • Lack of industry support, standards, and technical guidelines for circular construction projects • Lack of regulatory framework, appropriate policies, and sound legislations for CE in construction • Lack of regulatory pressure and stringent regulations • Lack of incentives to design for end-of life products • Lack of promotion and large scale demonstration projects	Ranking
15	What are the TECHNOLOGY barriers in the circular economy transition (construction sector in Vienna, Austria Context)?	• Lack of enabling digital technologies and solutions • Absence of sufficient technologies for waste disposal and recycled materials • Lack of technological and eco-innovation capacity • Lack of technology and infrastructure readiness • Lack of proven technologies and equipment for CE in construction • Lack of robust information systems to track recycled materials	Ranking

		• Limited technology to design for end-of-life of products	
16	What are the SUPPLY CHAIN barriers in the circular economy transition (constructio n sector in Vienna, Austria Context)?	• Fragmentation and complexity of the CE supply chain network in construction • Lack of integration and collaboration among supply chain partners in construction • Lack of producer-based responsibility system in production of construction materials • Lack of cohesive reverse logistics network and facilities • Lack of appropriate supply chain partners • Insufficient suppliers of circular materials and products • Lack of complete supply chain network • Lack of green manufacturing processes and logistics in construction	Ranking
17	What are the STAKEHOLDER barriers in the circular economy transition (constructio n sector in Vienna, Austria Context)?	• Lack of data transparency and information sharing among stakeholders • Poor co-operation, collaboration, and communication among stakeholders in CE Value chain • Lack of appropriate partners and participative network • Lack of support and involvement of stakeholders • Lack of trust among stakeholders	Ranking
18	What are the SOCIAL ENABLERS for the circular economy transition (construction sector in Vienna, Austria Context)?	• Change in the choices made by Users • Civic engagement and voluntary activities • Increased status related to secondary materials and circular products • Shared norms, values, attitudes, and beliefs • More inclusive and connected communities • Other	Ranking
19	What are the MARKET ENABLERS for the circular economy transition (construction sector in	• Competitive advantage for early adopters • New alliances and collaborations • Valuing the services, not only the products - provided by nature • Need for a long-term vision by businesses	Ranking

	Vienna, Austria Context)?	• Access to regional / global supply of secondary materials & by products • Functional service economy (XaaS) • Knowledge of impact • Digital infrastructure • Other	
20	What are the REGULATORY ENABLERS for the circular economy transition (construction sector in Vienna, Austria Context)?	• Extended Producer Responsibility (EPR) • Green & Circular Procurement • Tax shift from Labour to Resources • Assess progress using reliable indicators for imports and local production while accounting for the life cycles of products • Provide access to funding to encourage experimentation, innovation and redesign • Use of circular performance indicators by governments, investors and businesses can encourage the value chain to become more circular • Foster the development of new technologies with the support of public authorities • Investment in education and employment services to prepare the market for the next economy • No or low VAT on circular products and services • Promote public-private partnerships to better counter and lift political barriers • Social Procurement • Other	Ranking
21	What are the CULTURAL ENABLERS for the circular economy transition (construction sector in Vienna, Austria Context)?	• A creative and skilled problem-solving resource • Integration of the CE concept into training and educational programs • Preparation of future professional practices and understanding • Better consideration of the labour force • Reduced gender inequality • Supporting an inclusive workforce • Other	Ranking

22	What are the TECHNOLOGICAL ENABLERS for the circular economy transition (construction sector in Vienna, Austria Context)?	• Increased environmental performance • Increased resource productivity, cost reductions • Better waste processing • Digital technologies and engineering to support business models • Higher quality of recycled materials • Biomimicry innovation - emulating natures strategies • Increased efficiency with innovation • Implementing gender and ethnic diversity in technology • Other	Ranking
23	Where do you position your company in the circular phase business model?	• Design Phase • Material Phase • Production/Distribution Phase • Consumption/Stock Phase • Waste Phase • Other	Multiple Choice
23	If material phase, what are you looking at?	• Sustainable by design • Safe and clean material • Enhanced Traceability • Other	Multiple Choice
24	If Design Phase, what are you looking at?	• Design for disassembly • Design for longevity • Personalisation • Pro-sumerism • Other	Multiple Choice
25	If Production/Distribution phase, what you looking at?	• Local Production • Digitalization & online platforms • Distribution • Production on demand • Other	Multiple Choice
26	If consumption/stock phase, what are you looking at?	• Reuse as Products • Durable products • Longer use • Renting & leasing services/sharing platforms	Multiple Choice

		• Repair services • Take-back & resale/reuse stores/platforms • Maintenance services • Other	
27	If waste phase, what are you looking at?	• Reuse of materials • Upcycling • Waste prevention • Collection • Other	Multiple Choice
28	Addressing the societal readiness level. Where will you grade yourself ?	**SRL 1** - identifying problem and identifying potential solutions **SRL 2** - formulation of problem and proposed solution(s) - identifying relevant stakeholders for the project **SRL 3** - initial testing of proposed solution(s) together with relevant stakeholders **SRL 4** - problem validated through pilot testing in relevant environment **SRL 5** - proposed solution(s) validated by relevant stakeholders in the sector **SRL 6** - solution(s) demonstrated in relevant environment and in co-operation with relevant stakeholders to gain initial feedback on potential impact **SRL 7** - refinement of project and/or solution and, if needed, retesting in relevant environment with relevant stakeholders **SRL 8** - proposed solution(s) as well as a plan for societal implementation **SRL 9** - integrated into society	Multiple Choice
29	Confirmation	I confirm that the information submitted via this form is true to the best of my knowledge and will be made publicly available as a use case for accelerating the transition to a Circular Economy and utilized/referenced in a research project.	Yes/No