Integrating the circular economy into construction waste management in NSW, Australia

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Abstract

The construction industry ecosystem comprises multiple actors, stakeholders, agencies, materials, processes, and even different industries. The complexity creates a unique challenge when considering the transition towards circular economy practices, as one process can involve multiple variables and actors that considerably impact the outcome. Approaches that embrace the circular economy through the supply and demand chain of the construction industry permeate through construction waste management. This study aims at understanding how circular economy principles are currently practiced through policy implementation and industry practices. It identifies critical challenges and opportunities in the transition toward circularity in construction waste management.

Using a case study of the construction industry in NSW, Australia, this project aims to understand how current policies support the inclusion of circular practices and to explore the influence level of different actors' practices. A policy review and semi-structured interviews were used as methods to identify the relevant policies and industry practices that promote circular economy principles, including any appointed responsibility to the actors involved in the construction industry.

The research found that current policies lack congruency, clarity, and legislative power to promote circular economy practices or appoint responsibilities to any construction waste management industry participant. Moreover, the interchangeable use of sustainable and circular economy practices creates a challenge in the transition as the practices are not fully developed or understood under one paradigm. On the contrary, practices are being carved to fit either. Finally, the research finds considerable potential to integrate the circular economy into the construction waste management industry by transitioning actors to enablers of circular practices throughout the multiple stages of construction and development of projects.

Author Statement

This work has not previously been submitted for a degree or diploma in any university.

To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

All research reported in this thesis received approval from the Macquarie University Human Research Ethics Committee (Reference number: 520221180240122 – Project ID:11802)

(Signed) _____ Date: **22 February 2023**

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List of Abbreviations

Circular Economy (CE)

Construction Waste Management (CWM)

Construction Industry (CI)

Sustainable Development (SD)

New South Wales (NSW)

1. Introduction

Australia had a major wake-up call in 2017 when China announced the 'ban' on imported waste proceeding from the country, throwing the waste industry into a challenging period, as an oversupply of recycled materials tanked prices making the industry rethink their current practices (Phil Kasker, 2017; Downes, 2018). This prompted the government to create incentives within the sector, integrating circular economy principles that can process and self-sustain the industry adapting to the increasing supply and new challenges. As Australia pursues high-speed economic development, the construction industry follows a projected growth rate of 2.4% p.a. (Anon, 2022), and as the industry grows, the waste produced increases with it. Construction waste represents 16.8% of all the waste produced in Australia, and it has increased by 22%, translating into a $2 Billion expense in the construction industry on waste services between the last quarter of 2017 and 2019 (ABS, 2018-19).

Circular economy (CE) practices can potentially improve industry practices and reduce the environmental impact created by construction activities (Gheewala & Silalertruksa, 2020). Recycling, up-cycling, and re-using materials such as concrete, steel, wood, or plasterboard reduce the amount of required raw material for the manufacturing processes while reducing the amount of waste disposed of in landfills. The importance of transitioning towards a circular economy in the construction waste industry is based on the parallel integration of the social, environmental, and financial benefits distributing the responsibilities amongst all the actors and stakeholders involved in the construction industry.

This research aims to identify the challenges and opportunities outlined previously and integrate them with the professional experience of key participants in the construction industry, seeking to understand how ingrained the circular economy is in their practices. Although the existing knowledge around construction waste management identifies challenges and opportunities, it lacks empirical analysis, which impedes the process of consideration for key stakeholders in the construction industry (CI), such as builders, architects, and engineers. Moreover, the research aims to change the positionality of actors to enablers of circularity, which is critical to implementing circular practices in the construction waste management (CWM) industry. Therefore, the research focuses on the day-to-day circular operations and potentialities explained by professionals involved in

the construction industry throughout the multiple stages of project construction, considering their roles and the existing policies in the construction waste management industry.

1.1 Research aim and questions

The thesis aims to explore how circular economy principles might be embedded into construction waste management in NSW, Australia.

The research questions are as follows:

1. How are principles of the circular economy considered within policies relevant to construction waste management?
2. How does the construction industry put the circular economy into practice in construction waste management?
3. What are the challenges and opportunities of incorporating circular economy principles into construction waste management?

1.2 Structure of Thesis

Chapter 2 reviews the current circular economy, sustainability, and construction waste management literature. Chapter 3 presents the research methodology, including the research approach, methods, and data analysis. Findings from the policy review and the interviews are presented in Chapters 4 and 5, respectively, where research questions 1 and 2 are addressed. Chapter 6 sets out the challenges and opportunities in the transition towards circular economy practices in response to research question 3. The thesis concludes in Chapter 7 with a summary of the findings, study limitations, and future research opportunities.

2. Literature Review

The literature review aims to identify the definitions, challenges, and opportunities identified in the existing literature of circular economy applied to the construction and construction waste management industry. At the same time, the literature review analyses the circular economy practices proposed by the literature understanding the potentials and challenges in the construction industry considering the multiple actors and factors involved in any project. Finally, the review aims to identify key literature differentiating sustainability from the circular economy, as the current practices in the construction industry are more often identified as sustainable practices blurring the lines between the two concepts, which represents a risk in the transition toward circular economy practices in the construction waste management industry.

2.1 Overview of construction waste management systems

The construction industry represents 9% of Australia's GDP and contributes to the country's manufacturing, transport, and many other key industries. The growth rate of exploitation of resources and waste disposal is directly related to the construction industry. Recently, the demand for materials and resources for the delivery of construction projects had an impact due to events such as the global pandemic of 2019 (Anon., 2022) and the war between Russia and Ukraine (Walters & Badshah, 2022). Materials and resources have increased prices, lead times, availability, and even quality, resulting in additional pressure on the industry. The latter situation has prompted conversations around alternative practices that can alleviate the current pressures.

The construction waste management systems use a linear approach in the current processes. Waste is continuously squandered in the construction industry as resources are not accounted for nor appropriately documented. The responsibility to sort, categorize, recycle, or upcycle is transferred to waste management organizations that collect the waste on-site. One of the challenges is maintaining a live database that allows actors to access material data specifics and stock availability information that can be readily distributed across existing projects (Rose & Stegemann, 2018).

Current practices include new technology with the potential to position information as a key component of the transition towards new models (Arts, et al., 2015), influencing the interactions of the multiple stakeholders with the project resources (Alaloul, et al., 2020). For example, the architectural salvage industry allows contractors to salvage building components (Rose & Stegemann, 2018). The ability to maintain real-time information on the available members of a building to upcycle through new technology created a ripple effect in traditional practices (Gheewala & Silalertruksa, 2020) as it uses the resources at least twice.

The use of concepts such as close-loop processes and upcycling resources (Gheewala & Silalertruksa, 2020) provides a material flow that is organic and dynamic, allowing the same resources to participate in multiple production chains throughout its life cycle, extending the life and increasing the capitalization capacities of the resources breaking the linear manufacturing and production practices.

These multi-collaborative relations between the construction stakeholders that can be created with the use of new practices change the relationships between the construction waste with the stakeholder as it has the potential to create financial benefits to the parties involved while still having the benefit of reducing the number of resources required and disposed of material. The economic benefits of circular economy practices have been previously studied, which argued that the financial viability of construction waste management feasibility depends on location, context, and social and economic factors (Ghisellini, et al., 2018). This shows the potential for future research around the interaction of the literature to the practical application of on-site practices that apply to multiple projects understood from the positionality of key stakeholders.

2.2 Concepts in Construction Waste Management

2.2.1 The circular economy

The circular economy's primary objective has been described as to regenerate the resources cycles, i.e., to maintain the material value at each point of its life cycle, minimizing the exploitation of resources, and reducing the generation of waste to close the loop of materials cycles through high-value recycling, upcycling, cradle to cradle or servitization (Salmenpera, et al., 2021; Cui, 2021; Ellen Macarthur Foundation, 2018;

Franco-Garcia & Aguilar, 2018). The thesis adopts the following definition of the circular economy: *"The circular economy can be framed as a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling.* (Geissdoerfer, et al., 2017, p. 759)

The concept definition allows the identification of the circular economy practices in the literature applied to the construction industry waste management practices. For example, hiring equipment to recycle demolished waste on-site reduces waste, transports associated carbon emissions, and reduces raw construction materials, showing that circular economy principles can be achieved using different strategies. Table 1 summarises the main concepts associated with the circular economy.

Concept	Definition
Close-loop	A system where there is no material loss during the production/manufacturing processes. Materials are perceived as resources throughout the whole process.
Servitization	Use of services rather than products. i.e., Renting equipment
Cradle-to-cradle	Mimic of biological metabolism of nature for manufactured products and materials minimizing the end-of-cycle waste.
Sharing economy	Share of assets and services between individuals.
Upcycling	Returning materials to a usable form without degradation to their value. Moving resources back up the supply chain.
Planetary Boundaries	Thresholds for humanity's safe operating survival boundaries. It considers climate change, biodiversity, biogeochemical cycles, land systems, freshwater use, ocean acidification, chemical pollution and novel entities, the ozone layer, and atmospheric aerosol loading.

Table 1 - Concepts around Circular Economy

(Gheewala & Silalertruksa, 2020, pp. 17-34)

The implementation of circular economy principles depends on the specificity of the positionalities of the multiple agencies reducing the leakage of resources throughout the processes. For example, cradle-to-cradle applied to industrial design creates a

responsible design for product components to be upcycled in the manufacturing process of new products, which can be certified by specific institutions (C2C, 2022). This can be extended to the construction industry, creating products that can be used as a new source of materials in the same manufacture chain or a new one.

The circular economy has been used to approach a wide array of problems across multiple industries, for example, business (Bocken, et al., 2019), asset management, resource management (Guldmann & Huulgaard, 2020), goods and services production, manufacturing, construction, tourism (Scheepens, et al., 2016). However, regardless of the industry, CE principles are applied to incentivize sustainable practices that reduce the exploitation of environmental services and increase close-loop production and manufacturing (Gheewala & Silalertruksa, 2020; Liu & Ramakrishna, 2021; Velzing, et al., 2019; Bocken, et al., 2019).

Circular Economy has been appointed and acknowledged as a critical component of sustainable development, including environmental, economic, and social development (Korhonen, et al., 2018; Ghisellini, et al., 2016), changing the flow of materials and allowing the reintroduction of resources to the production processes. The aim is to alter the traditional and current extract-produce-use-dump material flow that has been proven unsustainable and catastrophic to the environment because of the misuse of the available resources (Meadows & Randers, 2004; Wood, et al., 2017; Foundation, 2013).

2.2.2 Sustainability

Another essential concept in the context of the construction industry is sustainability. The construction waste management industry applies sustainable practices through the 3Rs of sustainability, reduce, recycle, and reuse (Mohanty, 2011). Understanding the similarities and differences between sustainability and circular economy will give an insight into how the construction industry integrates the concepts and the degree of application in the industry practices.

Sustainability and sustainable development in the construction industry focuses on the environmental and social pillar and the implementation of changes in consideration of the positionality of the actor (Lima, et al., 2021). This means that the sustainability strategy for the project site is considerably different that the one for the materials or waste, as the latter is only considered a final output of the industry. The underlying ambiguity of the

concept of sustainable development has probably led to a worldwide acceptance of the three key pillar frameworks to address environmental and social action (Seghezzo, 2009).

Sustainability is framed as the balanced and systemic integration of intra and intergenerational economic, social, and environmental performance (Geissdoerfer, et al., 2017). Sustainability has multiple definitions and strategies that apply in different contexts depending on the focus, the organization, or the certification applied to each construction project. It is often represented by three key pillars, economy, environment, and society (Seghezzo, 2009; Oke & Aigbavboa, 2017). Therefore, in the construction industry, sustainable development can be defined as “sustainable activities that harmonize and maintain the balance of achieving developments that are economically profitable and favorable, socially beneficial to people, and environmentally friendly to society at large” (Oke & Aigbavboa, 2017, p. 88). This means that sustainability is a fluid concept that adapts and provides flexibility to address the pillars of sustainability, considering the positionality from where it is used and temporality (Seghezzo, 2009).

Some similarities between sustainability and circular economy found in the existing literature mention that they both share a global perspective focusing on global issues on a global scale, promoting shared responsibilities and accountabilities between multiple actors. They also approach challenges from an intergenerational commitment requiring a multiplicity of coexisting pathways for development and a multi-disciplinary consideration to integrate social and cultural aspects (non-economic aspects) into the development. Both consider new technology and business model innovation key in the transitions towards either, resulting in the opportunity for future research as the available technology lags against the current expectations of both concepts (Geissdoerfer, et al., 2017). The construction industry must come to terms with both concepts' environmental, financial, and social agendas because the construction industry impacts all human activity through multiple generations (Curwell & Cooper, 1998).

It is important to expand on the differences between sustainability and circular economy, as some practices can be sustainable but not necessarily apply the circular economy principles. For example, recycling throughout any process does not necessarily translate to reducing resources in a manufacturing process, as there can be sustainable practices without the obligation of maintaining a close loop (Geissdoerfer, et al., 2017).

Sustainability and circular economy have some differences, such as goals, motivations, system prioritisations, beneficiaries, timeframes, and responsibilities, that allow the understanding of the applicability and integration of the concepts in the construction

industry. CE contemporary understandings share the idea of closed-loops where consumption and production are considered a sink for the waste outputs of the existing industries (Geissdoerfer, et al., 2017), focusing the motivations for implementation of circular economy practices toward the efficient use of resources and waste reduction. On the other hand, sustainability as a concept has outlined clear indicators as part of the Sustainable Development Goals (Anon., n.d.), granting flexibility in implementing sustainable practices responding to different scales, situations, or contexts. However, that flexibility creates ambiguity when outlining the beneficiaries, timeframes, and responsibilities of sustainable practices, as the contexts, goals, and motivations must be clarified, meaning, for example, that sustainable practices in the construction industry will be different in the manufacturing industry.

Nevertheless, the difference between the two is that the circular economy's central idea is reducing the number of resources utilized, being narrow and conditional to the approach of the production and manufacturing process in balance with the financial impact on the process. In contrast, sustainability allows the flexibility required to achieve the sustainability development goals. Additionally, circular economy identifies the government and private stakeholders as the beneficiaries, as they will reap the financial benefits of implementing the closed-loop model. In comparison, CE's social impact is generated from environmental improvement and specific add-ons and assumptions like more manual labor or fairer taxation (Geissdoerfer, et al., 2017).

Moreover, the interest in the applicability of one concept to another varies. Circular economy's principal reason for the interest is the potential financial advantages that can be obtained from the optimization of the economics of the processes (Stahel & Reday, 1976) and the reduction of material consumption for the production and manufacturing processes considering the limits on the capabilities of the earth and supply chain of the required materials. Sustainability reason of interest spreads across multiple dimensions. Therefore, it is classified as non-specific and has the flexibility to align with individual interests. For example, sustainability can be gender equality opportunities in the construction industry or sustainable buildings. In sustainability, the reason for interest and the prioritization strategy depends on the individual goals of the interested actor. The circular economy is the opposite, as the system of prioritization focuses on the economic gains for social aspects, and even though the social aspects can vary between stakeholders, scales, and communities, the priority will always fall on the financial benefit and reduction of material leakage (Geissdoerfer, et al., 2017). Furthermore, a circular economy has to follow timeframes attached to specific indicators that can be translated

into financials, including data such as production efficiencies, waste management costs, and input costs. Conversely, sustainability timeframes are open similarly to the responsibilities as they adapt to the specificity of the context and applicability of the sustainable principles.

The flexibility and openness of the sustainability criteria in construction waste management have allowed the individual adjustment of the concept to suit individual projects aligning the sustainability discourse without impacting the project's economics resulting in challenging barriers that discourage the industry transition (Pitt, et al., 2009). This practice has the risk of leading to greenwashing. On the other hand, circular economy strengths provide a greater focus on the principles that facilitate the coordination between multiple disciplines as the principal objective is reducing waste and amount of resources. Table 2 summarises some of the identified differences between sustainability and circular economy and provides a baseline for the differentiation and identification of the current practices in the construction waste management industry.

	Circular Economy	Sustainability
Goals	Close-Loop, elimination of resource leakages of the system.	Open-ended goals, shifts considering agents, their interests, and positionalities.
Motivations	Efficient use of resources and waste emissions reduction.	Diffuse and diverse, embrace reflexivity and adaptability.
Reason for Interest	Financial advantages and less resource consumption and pollution of the environment.	Non-specific. Interest alignment between stakeholders.
System Prioritisation	Economic systems gains and implicit gains for social aspects.	Balance between the three dimensions. Prioritization according to contextual differences.
Beneficiaries	Governments and companies.	Diffused.
Timeframes	Thresholds for a successful conclusion.	Open-ended.
Responsibilities Perceptions	Private businesses, regulators, and policymakers.	Shared, not clearly defined.

Table 2 - Circular Economy and Sustainability Differences

(Geissdoerfer, et al., 2017)

In the current literature, it is unclear how the lack of differentiation impacts the actors, creating uncertainties around implementation, responsibilities, monitoring, and transition. Moreover, existing literature fails to engage with the social and cultural aspects of the construction industry, showing the gap in information about the existing challenges in the transition towards circular economy practices. The thesis aims to contribute to understanding the challenges and opportunities perceived by the construction waste management industry actors in the transition towards circular economy practices.

Currently, the existing literature is unclear on how actors respond to the lack of differentiation in the current practices in the industry. The practices analyzed in the literature are recycling, reuse, and reduce, applied through the different stages of the construction process (Baloi, 2003; Shooshtarian, et al., 2022), yet they do not explore the application of circular economy from the individual positionality of the actors involved.

This thesis aims to explore the impact of the actors' behaviors and practices due to the interchangeable use of sustainability and circular economy in the construction waste management industry, considering the individual actors' positionality in the construction industry.

The opportunity for future research to further explore the differences between circular economy and sustainability could allow the understanding of how the concepts are being understood in the construction industry and how actors from different disciplines can implement circular economy practices while aiming for the sustainable development goals.

2.3 Circular Economy, waste management, and the construction industry

Current research provides definitions of waste management systems and circular economy; however, they do not consider the applicability of circular economy principles to the construction waste management system (Kirchherr & Van Santen, 2019). 114 definitions of the circular economy were analyzed during the study of conceptualizing circular economy (Kirchherr, et al., 2017), yet, there are no specific definitions for the circular economy in construction waste management. This means that the existing literature provides multiple definitions according to the focus resulting in a multiplicity of definitions that consider the intrinsic characteristics of the context from where it is being

observed. The flexibility of the definition impacts the policies, as the multiplicity of definitions found impacts the implementation throughout the construction waste industry.

Policy regulation is important as the construction industry has one of the highest resource consumption rates (Anon., 2022), putting pressure on the transition to more sustainable practices to reduce the industry's carbon footprint. As the industry is one of the primary waste producers, including CE in the CWM provides a valuable opportunity to optimize the available resources. The adoption of circularity within the CWM provides multiple options for waste transformation into resources (Gheewala & Silalertruksa, 2020), i.e., cradle to cradle, where materials, such as windows, concrete, and wood are designed to be reused after the building is demolished (Nußholz, et al., 2020) or the recycling of wood into high-density panels for joinery.

As the construction industry strives for sustainable practices, the introduction of CE offers unique insights into the application of circularity in large-scale scenarios with high complexity and multi-disciplinary requirements demanding a high level of cooperation from multiple industries. Therefore, the integration of the CE principles in the construction waste management processes can be done across six stages of construction throughout the design, manufacturing, procurement, transport, construction, and demolition by considering the multiple actors, stakeholders, and existing relationships have the potential to provide a unique opportunity to minimize the environmental impact of the construction industry by reducing the amount of material required in the construction processes (Shooshtarian, et al., 2022).

For example, one of the stages is design, where the lack of information, design errors, wrong specification of materials, client’s design brief, and design changes during construction presents some significant challenges. However, the integration of circular economy principles during the design stage allows the development of strategies that focus on the de-constructability of designs, standardization of projects, education, product certifications, and waste design. (Shooshtarian, et al., 2022).

Other literature mentions four construction stages: design, construction, procurement, and demolition (Poelman, 2009). The design stage considers using recycled materials or prefabricated elements, reducing the project’s carbon footprint, and future-proofing the project's components for future disassembly. I.e., windows, joinery, walls. Recycling and reusing of materials must be promoted as much as possible during the construction stage (not considered in the design) (EPA, 2020). Procurement of materials provides an understanding of the supply and demand relation, identifying as a significant challenge

the poor stability of the supply of recycled materials (Rose & Stegemann, 2018; Velzing, et al., 2019). The demolition stage is understood as the activity of destroying existing buildings and producing waste that needs to be sorted and correctly processed to promote debris recycling.

Understanding CE in the CWM context “offers a way to minimize waste’s environmental and economic costs, such as landfill maintenance, extracting virgin materials, landfill levies, transportation costs, and illegal dumping” (Martin, 2019). That understanding provides a strategic approach to the sustainable development of the construction industry using as the central premise the use of waste as a new source of value for a business creating and updating the existing practices in the construction industry. Current practices identify some materials as potential resources, such as concrete, wood, steel, bricks, asphalt, or gypsum; however, the industry still does not recognize them as a resource as some challenges must be addressed in practice, such as the cost, lack of education, quality, benchmark projects, supply and demand challenges, a market of construction waste, storage, transport, contamination, separation, and equipment (Bolde, et al., 2013).

As construction waste is composed of multiple materials, the challenge is to provide accurate information about what material and how much is available for upcycling or recycling (Korhonen, et al., 2018). To understand the efficiency and long-term implications of the repurposing of the materials and rebranding of waste as a new resource, organizations have promoted monitoring the tons of waste created/required by the CI activities (OECD, 2022or example, steel is monitored closely by the OECD and CWM organizations, as reprocessing steel technology is available and provides quantitative information that later can be distributed to the interested parts promoting the exchange of material across industries (OECD, 2020). Additionally, the intrinsic mechanical characteristics allow for close-loop markets where the material is reused and re-manufactured (Broadbent, 2016) that can be easily monitored through current practices. This is not the case for all other materials, information, and data.

CE literature applicable to multiple industries has gaps regarding the impact of social equity and future environmental development as they are rarely mentioned, as well as the roles of the market, business models, and consumers as enablers implementing circular practices (Kirchherr, et al., 2017). This is contradictory as the involvement of all actors and their capacities and responsibilities to link and create an exchange environment has proven successful in the transition towards CE practices (Ghisellini, et al., 2016). From the CWM, it is clear that the actor’s responsibilities within the context of

the construction industry's operational and structural processes must consider all the involved stakeholders as enablers of the CE practices in the CWM industry.

The lack of empirical work on CE in the CWM system creates a gap between the academy and real-world practices constraining the decision-making process to the traditional practices. Even though the existing literature provides a theoretical approach to the inclusion of CE concepts into the CWM system in the CI, there is no clear direction or consensus of recommendations, tools, or practices that can be used to transition, nor sufficient evidence that shows the financial advantage of adopting the CE practices. CI practitioners focus on the applicability and feasibility of circular economy practices (Salmenpera, et al., 2021), aiming to improve the practices while generating the same or higher revenues demanding further research supporting the financial feasibility of the CE practices in the construction waste management industry. For example, the research supporting evidence that its operation can financially support reusing and recycling concrete practices and create additional value for the organization performing them.

Case studies can provide an idea of the expected results; however, as every project has intrinsic characteristics, further research needs to be done to consolidate the conclusions and practices in the CWM from the multiple case studies where circularity has been included in the operational practices and strategies of the planning, development, and execution of a project in a way that can be replicable and scalable though the whole construction industry.

Circular practices within CWM can be included through multiple stages of the development and execution of a construction project, and considering the construction industry practices are directly linked to the construction waste management practices, it is required to include the CE principles since the conception of the project by the client and must continue through all applicable stages until the future demolition of it (Shooshtarian, et al., 2022). This shows that construction waste management should not be considered in isolation, and the literature considers CWM and CI practices inter-dependent.

2.3.1 Circular Economy in construction waste management: Current Practices

Industry practices focus on recycling, reuse, and reduce strategies, allowing the circular economy to integrate its principles into construction and demolition waste management

practices to enhance resource management efficiency (Cardoso da Silva, et al., 2022). Current construction waste management practices that include the circular economy principles focus mainly on the demolition stage of a project despite various literature mentioning practices across multiple stages of project construction (Shooshtarian, et al., 2022). Moreover, despite recycling, reusing, and reducing strategies being implemented in the industry practices as part of the circular economy principles, the complete integration and the monitoring of the process are not thoroughly monitored, and it does not ensure the close loop of materials in the construction process.

Construction circular economy practices are represented in Figure 1. The inner circles represent the hierarchy of approaches in developing a project going from the less invasive (retaining) to the most complex options that aim to create new products or return materials to the biosphere (recycle of materials). Additionally, Figure 1 represents the expected design principles that ought to be considered and applied to follow each type of approach, the degree of complexity and applicability of the design principles depends on the selected approach in the circular economy practices in construction waste management (Mangialardo & Micelli, 2018).

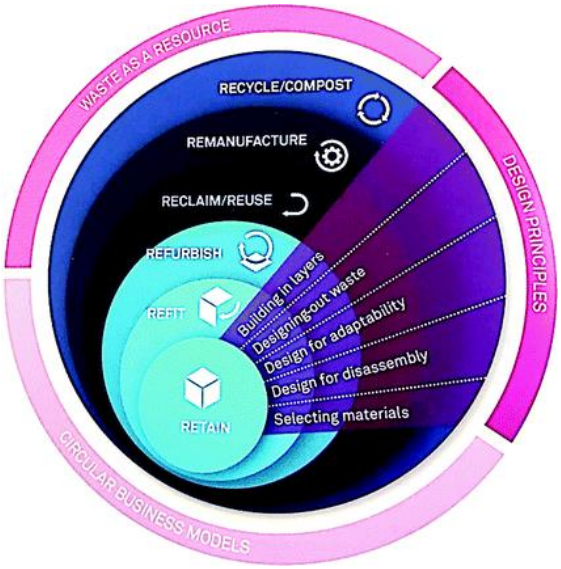

Figure 1- Principles of Circular Economy applied in the construction industry (Mangialardo & Micelli, 2018).

The application of the principles and approaches in Figure 1 support the argument that construction waste management practices should be applied throughout the whole life cycle of a project, moving away from the traditional practices that only focus on the construction and demolition stage (Li & Du, 2015). This creates the need to engage the actors involved in the construction process since the project's conception, causing a shift in the current responsibilities and participation within the construction industry in construction waste management.

Design Principle	Definition
Building in layers	Building by differentiating the various elements and their different lifespans. Layers allow easy maintenance, repairs, and replacements if required.
Designing-out waste	Development of design considering the entire building lifespan, starting with the consideration of waste as a new resource.
Design for adaptability	Buildings are to be designed considering multiple uses, i.e., Building that can be of commercial, educational, or health uses.
Design for disassembly	Buildings that can be dismantled without damaging the construction elements allow the transfer of the elements to a different project.
Selecting materials	Critical consideration of the materials selected for the project. Special attention is to the carbon foot-print, and the ability of the materials to be recycled and repurposed at the end of the life cycle.

Table 3 - Circular economy design principles definitions

(Mangialardo & Micelli, 2018)

The principles above can be implemented across the construction industry depending on factors such as financial viability, skilled labor, available technology, and material integrity in consideration of the project's stage—for example, a development at Circular Quay, Sydney. NSW, Australia, provides an exceptional example of implementing the retention of a building structure and upcycling the structure. The project retained the structural core and adapted it to the new development (MacSmith, 2022). Table 3 defines the principles in Figure 1 in the construction industry.

The defined principles in table 3 can be applied across all the stages of any construction project, as the principles aim to promote a practical design that allows the building to minimize the amount of waste. Therefore, applying the principles must be done through each stage of the design, management, and planning execution.

Current literature focuses on the potentials, challenges, and future research around construction waste management with embedded circular economy principles. Nevertheless, the literature fails to provide an empirical approach where the suggested strategies are applied in the project life cycle. Some case studies (Baloi, 2003) have been developed around specific construction projects, which have identified some “structural barriers that hinder the transition to a circular economy in construction and demolition waste management” (Cardoso da Silva, et al., 2022, p. 2). The structural barriers refer to the operational flow that characterizes the construction industry in consideration of the sequence of works in a project.

As the current practices evolve, it is essential to note that the introduction of new digital technologies is critical to facilitate circular economy practices (Arts, et al., 2015; Gheewala & Silalertruksa, 2020; Geissdoerfer, et al., 2017), and they have slowly become part of the construction industry practices which address critical items of the construction waste management through data analysis such as materials, buildability approaches, material composition and quality, embodied carbon, and supply availability.

Integrating the new technologies with the current practices is done through the construction certification programs that outline a project's sustainability and circular economy objective criteria. For example, suppose a project applies for the LEED Certification (Leadership in Energy and Environmental Design). In that case, it will have to be modeled in a software to verify compliance in the five key areas, energy efficiency, indoor environmental quality, materials selection, sustainable site development, and water savings (Contributor, 2010). The same will apply if the project wants a Green Star Certification; however, the software's compliance criteria (Anon., n.d.). This shows the need for the actors involved in the construction industry to be perceived as enablers in the transition towards circular economy practices.

2.4 Summary

The literature review concurs with the need to introduce circular economy practices into the construction industry as an alternative to the continuous exploitation of resources and inefficient material disposal. The literature outlines the recommended practices, challenges, and opportunities. However, the lack of empirical research on circular economy practices in the construction industry is evident. Moreover, despite recognizing

the multiple stages of the construction process that can be influenced by transitioning towards circular economy practices, the literature requires and expansion on the understanding of the roles and positionality of the actors involved in the multiple stages to promote the transition towards circularity across the multiple disciplines of the various actors involved in the construction process. The application of circularity across the multiple stages of construction allows the distribution of responsibilities to the involved actors, prompting the multiplicity of relationships within the construction waste management industry.

3 Methodology

This chapter outlines the methodological approach that is undertaken for the project. The chapter is divided into three sections: research aims and questions, research approach and research methods, and data analysis.

3.1 Research aim and questions

The thesis aims to explore how circular economy principles might be embedded into construction waste management in NSW, Australia.

The research questions are as follows:

1. How are principles of the circular economy considered within policies relevant to construction waste management?
2. How does the construction industry put the circular economy into practice in construction waste management?
3. What are the challenges and opportunities of incorporating circular economy principles into construction waste management?

3.2 Research approach

The research project focuses on gathering and analyzing qualitative information, providing the flexibility required to understand the data. This means that the key concepts and principles are implemented in various manners that respond to the project's positionality and needs. The qualitative data allows the integration of the theoretical analysis of the theories, literature, and policies. This is later translated into quantitative information that provides a systematic analysis of the information and numerical values that support the conclusions of the data analysis. Moreover, the quantitative data collected aids the argument for construction waste management practices and provides information that can be monitored and analyzed.

Several works of literature use a mixture of quantitative and qualitative data when researching circular economy in the construction industry, as it allows the integration of

the positionality of the concepts with the specificity of the projects and the implementation of the theories, strategies, and principles of the circular economy in the construction industry applied to the multiplicity of variables and characteristics of the construction process. (Bolde, et al., 2013; Cardoso da Silva, et al., 2022; Geissdoerfer, et al., 2017; Ghisellini, et al., 2016; Korhonen, et al., 2018; Velzing, et al., 2019). For example, the analysis of the circular economy through the different stages of the development and construction of a project highlights the circular economy practices. It provides a quantitative analysis of a case study allowing the evaluation of the paradigm of circularity (Mangialardo & Micelli, 2018).

The selection of NSW, Australia, as the case study allows the undertaking of a complex subject such as construction waste management and narrowing it to manageable questions (Heale & Twycross, 2018). At the same time, the case study allows the reduction of the amount of analyzed data, responding to the scope and time of the Master of Research. Finally, the case study as a geographical area allows the generalization of policies and current practices providing a geographical framework for the research.

The research also recognizes the importance of positionality, as only through recognition of our biases do the identities of both researcher and participants have the potential to add value to the research process (Bourke, 2014). The research project has three key positionalities that are relevant and determine the development of the project.

First, the researcher's positionality as an architect with professional background in architecture and project management provides a unique understanding of the construction industry processes, structures, and relationships. The latter creates a bias as there is assumed knowledge of construction practices, materials, workflows, and responsibilities of the actors. Second, the positionality of the theories, principles, and strategies of circular economy practices in the construction waste management industry provides a deeper understanding of the multiple relationships of the various agencies involved in the construction industry. Third, the positionality of the actors and stakeholders in their discipline and scope of work provides insights into the potential challenges and opportunities in the transition toward CE practices.

The recognition of the positionality influences the data gathering as the focus is biased through the professional experience and understanding of the applicable regulation and standards in construction waste management. Moreover, it allowed the structuring and conversation with the participants as there is a level of common knowledge and trends identifications that facilitated the conversations during the semi-structured interviews. At

the same time, the understanding of the positionality of the participants creates a valuable insight into the practical experience in construction waste management in consideration of the construction agencies, such as actors, policies, practices, and considerations.

3.3 Research methods and data analysis

The project uses two methods to explore how circular economy principles are embedded into construction waste management policies and practices: a policy review and semi-structured interviews. These methods are explained in more detail below.

3.3.1 Policy review

As policies may have the strength to shape the practices of any industry, it is imperative to understand the role the current policies have on the adoption of circular economy principles in the construction waste management industry. The policy analysis focused on the existing policies around construction waste management and the impact they have on the existing processes and practices. The policy analysis allowed the gathering of qualitative information that identifies how the existing policies promote and approach the circular economy principles.

A policy review is a suitable method to understand the policy landscape around construction waste management in NSW. It has been used in previous research to examine how organizational decision-makers use the information available when making evaluative judgments (Karren, 2002) to analyze the policies' level of influence and relevance in the construction waste management industry. At the same time, it provided insight into the current practices in the existing policies and how governance interacts with the multiple agencies involved in construction waste management through policies.

For the purposes of this research project, the policy review focuses on how existing policies and legislation around construction waste management shape the industry's practices. The selected policies focused on construction waste management or the circular economy principles implementation through legislative power. The policies selected follow the criteria below:

- Policy current and applicable to NSW Australia.
- Waste management policies that regulate the waste stream of the construction industry.
- Policy that monitors the amount of waste recycled
- Mention of a circular economy or sustainability derivatives with a focus on Construction waste management
- Policy focus on construction waste management practices

Note: Policies regulating operational waste are not included.

Once the multiple levels of responsibilities are understood, it allows the analysis of the policies from the construction industry context. This provides an insight into how targeted the regulations in construction waste management are. Considering the project case study, the policy review will focus on the state policies and regulations to maintain the project scope and understand the influence of the existing policies in construction waste management in NSW. At the same time, some federal regulations are included as they provide the bases for state policies. On the other hand, the review does not include local nor international regulations or Australian standards for CWM. The research aims to identify influential policies that shape the procedures and practices of the construction waste industry in NSW. This research acknowledges the Council Development Control Plan from the local policies; however, it is not included in the review as the focus of the policy is the operational waste of the project, not the construction waste management.

Figure 2 illustrates the policy hierarchy and structural relations where the principal driver is the federal policies determining Australia's aims regarding waste management. On the second level, the state policies determine the desired strategies to achieve the deferral targets. Finally, on the third level, local policies provide the specificities of compliance on a smaller scale but with more detail than the federal. Local and state policies influence the industry's practices most as they have specific goals. For example, the national waste policy is a federal regulation. However, the state has specific obligations and liberty to implement the targets as deemed satisfactory in compliance with the federal targets (Government, 2019). The organizations and companies primarily focus on compliance at a local level and move up depending on the nature, location, and scale of the project.

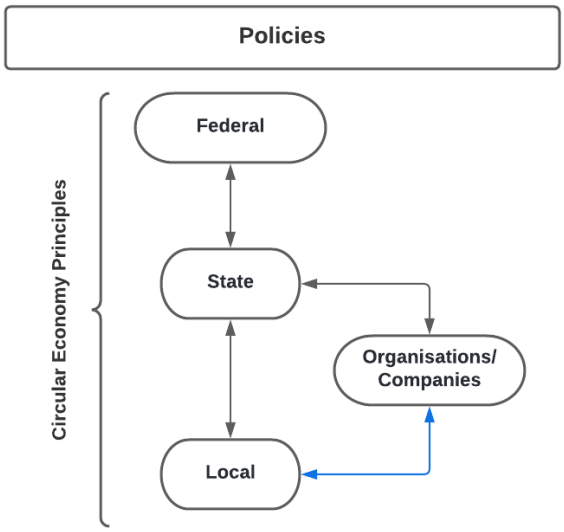

Figure 2 - Policy Structure

Despite several policies that mention sustainability, sustainable development, and environmental protection as a priority, the review focuses on the policies that regulate construction waste as a strategy for sustainable development and circular economy practices. The selection of specific policies is made by comprehending the existing policies and discerning the ones that do not contain relevant information for construction waste management. The policy review did not include all policies that focused on alternative strategies for sustainable development, as the scope of the research project focuses on construction waste.

No.	Year	Policy
1	1979	Environmental Planning and Assessment Act No 203
2	1997	Protection of Environment Operations Act (POEO) and amendment Act 2011
3	1991	Protection of the Environment Administration Act
4	2001	Waste Avoidance and Resource Recovery Act 2001 No 58
5	2014	Waste Classification Guidelines Part 1: Waste Classification
6	2021	NSW Waste and Sustainable Materials Strategy 2041—Stage 1: 2021–2027
7	2014	Protection of the Environment Operations (Waste) Regulation

Table 4 – Policies selected for the policy review.

The acts and regulations included in the policy review were selected to identify key factors that affect the transition of construction waste management toward a circular economy model. The regulations were found on the official NSW portal, and the latest versions and addendums were included when applicable. Table 4 contains the policies that were selected for the policy analysis.

The review of the policies used content analysis to examine the main acts regulating construction waste management in NSW. The policy review aims to understand the landscape and current state of the existing policies; therefore, the content analysis allowed the understanding of how the policies are worded and the policies' objectives and aims. Moreover, content analysis as a method allows the systematic and objective means to describe and quantify specific data using a tailored unit of analysis which is used for the quantification of data through the codification of the information (Downe-Wamboldt, 1992). Even though content analysis varies and does not specify a single set of rules, Downe-Wamboldt outlines the general steps that provide a procedural sequence for the research project.

A framework to analyze the content is developed to understand the objectives, aims, and expected outcomes and determine what words were included within the policies. The key words were selected using the three main concepts identified in the literature review, circular economy, construction waste management, and practices in the industry. As they are broad umbrellas that encompass several concepts, the identification of any word that entails sustainable practices, circular economy concepts or practices, or any practice of the industry was identified and flagged using a matrix that allowed the quantification of the qualitative analysis.

The analysis criteria of the selected policies are composed of three categories, (1) the overall target, aim, and objectives, (2) key words, and (3) operational and/or technological recommendations. Table 5 shows the unit of analysis and the category system for the content analysis process of the policies. The general criteria aimed to understand the policy nature by identifying the target audience, rationale, and expected outcomes. The Keyword selection aims at recognizing the rhetoric of the policies and exploring the mode of communication of the objectives focused on the two main concepts identified in the literature review: circular economy and construction waste. Finally, the policy review tried to pull out any recommendations or requirements for the guidelines or processes that impacted construction waste management.

GENERAL	KEY CONCEPTS		RECOMMENDATIONS
Target Industry	Sustainability	Technology	Operational
Aim	Sustainable Practices	Digital Technology	Practices
Expected Outcome	Circular Economy		
Rationale	Reuse	Construction Waste	
	Recycle	Waste Data Base	
	Closed Loop	Waste Report	
	Shared Economy		

Table 5 - Policy Review Framework

The identification of the concepts mentioned in Table 5 was sought after in a literal and derivative manner, meaning that, for example, the word recycle, could be identified by the use of ‘recycle’ or any other word used in the policy that might imply a recycling practice such as upcycle or upcycling. The rationale behind this approach is identifying what concepts were actively integrated into the policies or were vaguely mentioned and left to interpretation. This means that even though the Waste Avoidance policy aims to reduce the amount of waste disposed of in the landfill using the treatment hierarchy, it leaves to the interpretation of the reader certain practices, such as the mix of waste, to change the classification of the waste stream. Moreover, following the guidelines of the Construction Development Plans, a waste management plan is required; however, the plan's focus is the project's operational waste management, leaving the construction waste management (during the building process) inadequately regulated.

The policies were filtered to identify the key concepts in Table 5 and any derivatives from them. This information is coded using an excel table to quantify the percentage of use of the concepts and definitions. The data is presented in a chart to easily understand how the circular economy is integrated with the current policies.

3.3.2 Semi-structured interviews

Qualitative semi-structured interviews were conducted to understand the current industry practices and available technologies around construction waste management in the

construction process of projects. Interviews provide a unique opportunity to gather information from people who work in the industry and experience first-hand the challenges of construction waste management during project construction. It also provides a picture of the intricacies of the construction industry, allowing the identification of challenges and opportunities for incorporating circular economy principles into the industry. Semi-structured interviews allow the gathering of qualitative information, facilitating the understanding of the construction waste management practices that include and promote the circular economy principles.

The interview structure (Appendix A) allowed the semi-structured interviews to gather data about the participant's professional experience. This is achieved thanks to the flexibility of the phrasing and content of the interview structure that encourages free speech while maintaining a clear structure and focus throughout the interview resulting in an organic discussion and questioning that allows the collection of more in-depth data from the interviewees. The interview structure allowed for follow-up questions that gathered data that could only be obtained through industry experience, exposing the participants' positionalities.

Selecting the participants for the interviews required classifying the project construction process into three stages. The stages, as shown in Figure 3, were selected in consideration of the MRes timeframe and using the proposed stages by Shooshtarian et al.o differentiate the analysis in consideration of the actor's positionalities in consideration of the professional capabilities and involvement in the project (Shooshtarian, et al., 2022).

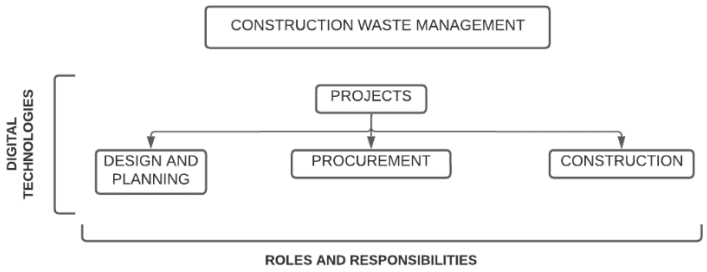

Figure 3- Construction Stages

It is worth noting that the demolition stage is being excluded from the research project as the practices during the demolition stage of circular economy principles are more focused on the processing and recycling materials (Kabirifar, et al., 2021). The thesis aims to focus

on understanding CWM beyond the demolition stage, identifying the roles, responsibilities, challenges, and opportunities in the transition toward CE practices.

It starts with the desire and initiative to develop and commit to the development of a project. The client/property developer will have the land and engage multiple consultants. The architectural consultant is involved in developing the design per the client's requirements and specifications, ensuring compliance with all the Australian construction codes and standards. The design is developed using other consultants' input, such as level of footings, flood levels, zoning compliance, code compliance, environmental compliance, and any other input required depending on the project characteristics and requirements. It is worth noting that some projects might need some and others all the consultants to get involved from the beginning of the project. For the purposes of the research project, the main actors will be consultants, Architecture (Design and Planning stage) and project management (Procurement Stage), and the builder (Construction and Demolition Stage). Suppliers and contractors are necessary secondary actors, yet their responsibilities do not go beyond the contractual obligations to perform and supply a job. Demolition is not included as it will have a close bond with waste management companies which deviates the focus from the selected scope. However, this is identified as a future research opportunity.

For this study, the definitions used for the actors are based on the construction dictionary of the Australian Standards and the Australian Building Codes Board (ABCB, n.d.). Consultants are actors who provide is responsible for the overall planning and coordination of the required documentation of construction work. It can be architectural, waste, environmental, structural, or any other discipline required to ensure the compliance and buildability of a project—a builder undertakes the construction work—a contractor is who arranges the supply of materials or resources to the project, this is typically done for a specific job or duration—suppliers are the ones providing the materials, goods or equipment required over a period of time. It is important to note the difference between the contractor and the supplier. A contractor can supply materials if it is included in the contract or can provide labor and skill resources needed on site. In contrast, the supplier is just providing material and has nothing to do with the work on site.

Across these three phases, participants were selected due to their involvement with selected companies, according to the following selection criteria:

- Companies with project execution in New South Wales, Australia.
- Companies that have involvement in private and public projects.
- Companies with + 500,000m2 designed, planned, or build (depending on the nature of the organization).
- Included in the case study. NSW, Australia.

Seven interviews were conducted, participants had multiple levels of expertise and roles through the development and construction of a project, and all were working on different projects across NSW, Australia. The selection of organizations provided multiple perspectives of construction waste management in the construction industry, as in each stage, the considerations and determinants vary. From these organizations, interview participants were identified in Table 6.

Design and Planning	Procurement	Construction
Sustainability Manager – Architectural Firm	Sustainability Manager – Property Development	Senior Project Manager
Senior Architects x 2	Project Director	

Table 6 - Interview Participants

The interview approach considered the participant's positionality, experience, and role. For the Project manager, the conversation is directed toward the construction waste management plan of the project, if there are company standards that are adjusted to each project, the application of circular economy models, and interaction with other stakeholders. At the same time, the project manager's interview focus is the current practices of CWM in the construction process, from different materials such as wood, concrete, steel, bricks, and plasterboard, starting from the design development stage to the execution of the project. The site manager interview focuses on the preferred practices, waste location, sorting, participants, the responsibility of the builder and contractors, and digital technologies used to monitor the waste disposed of and recycled waste. Lastly, the interview with the procurement manager focuses on the procurement framework, the digital technologies used to find the resources, and the selection criteria of the potential recuperated materials, such as steel (Appendix A).

Potential interviewees were contacted through email initially and by phone, where contact details were available. The interviewees were asked to provide their consent before the

commencement of the interview, depending on the modality. The official interview participant consent form is read in online interviews after starting the audio recording (see Appendices B and C). For face-to-face interviews, consent is signed. The Macquarie University Human Ethics Research Committee approves this protocol and the entire interview process. Furthermore, the confidentiality of this research project, including the guarantee of anonymity of the participants, is communicated before the interview via email to the project participants.

Due to the time and resource restraints of the Master of Research Program, only those who were available to give the interview during the proposed time frame (August 2022) were interviewed. The duration of the interviews ranged between 30 to 70 minutes, and the interviews centered around the current practices of construction waste management, including the actors and responsibilities and potentials and challenges of the applicability of circular economy practices in the construction waste management industry. In addition to defining the key concepts, participants were asked to share their professional experience and reflect on the circular attitude identified in the construction industry. The structure and content of the interview questions are available in Appendix A.

The interviews are quoted in the findings and discussion chapters using a two-letter code and the year that allows the identification of the interview in the data collected while maintaining the anonymity of the participants. This is done following the Ethics Approval to maintain the anonymity of the participants.

Using the Strauss themes data types of conditions, interactions amongst actors, strategies, tactics, and consequences (Strauss, 1987), the interview information is coded through a two-tier structure. The codes were developed through in-depth reading and analysis of the transcripts, aiming to identify the interviews' general themes for later classifying the specific themes from the interviews. The transcripts were coded, identifying trends and using the questions to reflect and explore the interviewee's professional experience. Out of the seven interviews done, only six were transcribed and used for coding, as one of the interviews did not provide new or relevant information.

The conditions are understood as the context of the construction waste management industry and the existing practices. The interaction among actors allows the identification of the known and unknown relations within the multiple systems of the construction

industry that influence and participate in construction waste management. Despite referencing the actions and how people perform in a specific situation, strategies and tactics are coded to explore and identify the challenges and opportunities of the current practices. The last data type, consequences, is applied transversally, meaning that the consequences were identified in each of the abovementioned data types. Table 7 represents the above approach and allows the categorization of the data collected. for example, that answer what are the factors that affect the transition of construction waste management towards a circular model, and information such as the involved actors and responsibilities are required (tier 1). Moreover, information about the actors' interactions or who has the decision-making power provides a unique insight into the existing workflow and industry practices. Therefore, Tier 2 data provides a deeper insight and understanding of the identified main data types.

TIER 1	Actors, Roles, and Responsibilities	Industry Practices	Challenges and Opportunities
TIER 2	**Prior knowledge of the industry** Understanding the key definitions according to the discipline where it is being implemented. Acknowledging professional role in construction waste management. **Involved actors in the process** Identifying key actors that have the greatest influence on the project **Actor's responsibilities** Understanding of the actor's accountability in the process of construction waste management.	**Motive of practice** Understanding and identification of the industry practices. For example, legal, financial, market **Specific practices for the construction waste management** Identification of the current industry practices. Reflection on previous practices **Key materials** Identification of the construction elements that are currently included in circular economy practices **Factors influencing decision-making processes** Identification and understanding of the decision-making process factors and the implication in the current practices **Use of digital technologies** Identification of the tools in the multiple disciplines for construction waste management.	**Waste culture and awareness** Level of understanding and acknowledgment of circular economy construction waste management practices. **Knowledge and practice gap** Applicability of circular economy theory in the current practices **Industry related experience** Reflection on past experiences where the outcome is not the desired **Market sentiment toward circular economy practices** Acceptance, flexibility, and feasibility of circular economy practices.

Table 7 - Interview Coding List

4 Findings from the Policy Review

4.1 Introduction

This chapter addresses the findings of the policy review, aiming to identify how the existing policies consider the principles of the circular economy in the construction industry. The chapter demonstrates that the policy in construction waste management has challenges that must be addressed to facilitate the transition towards circular economy practices through policy implementation.

The chapter begins by identifying how the CE principles and practices are regulated in the selected policies when focusing on construction waste management. The chapter explores the disconnection between existing regulations and construction waste practices, meaning that the current policies do not specify conditions around construction waste. Moreover, the chapter explores the challenges of the current policies in the construction industry context.

4.2 Content of policies

It is clear from the outset that construction waste management is not heavily regulated by the Environmental Protection Authority (EPA). The general guidelines and policies provided by the EPA are unclear. Despite the regulations seeking to cover all of the waste streams per the categorization made by the EPA (EPA, 2014), there are no specific policies for construction waste, such as the Waste Avoidance Act (Goverment, 2001).

Using the approach explained in section 3.3.1, the policies' quantitative data was condensed in Figure 4. The latter shows the low presence that some selected key concepts have in the policies noting that in some instances, the definition included in the policies vary. Recycling, with a 12% presence, is one of the most popular concepts in the policies and is mentioned from time to time as a strategy for sustainability and resource management. The waste database is just mentioned when the requirement for reporting the amount of waste for the bi-annual reports for the policies analysis is stipulated in the Protection of Environment Administration Act 1991. On the other hand, technology is used quite broadly to reference the use of tools that allow the efficient and compliant

management of waste. However, the policies do not mention specific tools or technologies for implementing the policy, as compliance can be achieved through different means.

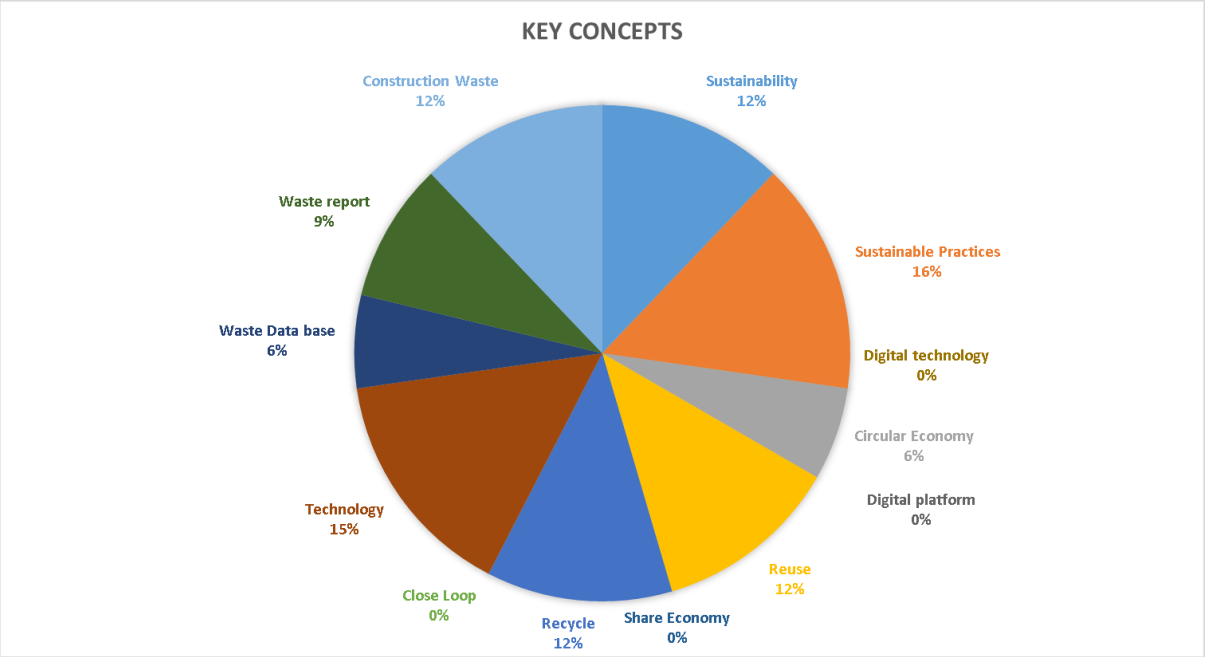

Figure 4 - Policy Review Content Analysis Key Concepts

4.3 The absence of distinct Construction Waste Management policies and definitions of circular economy

One of the research findings is that Construction Waste Management policies could be enhanced in two critical areas as it currently fails to address the circular economy goals and transition strategies. Firstly, there is a need to address construction waste specifically. Out of the eight reviewed policies that aim to preserve, monitor, and rehabilitate the environment, only six mention construction waste management, explicitly referring to construction waste. Furthermore, the structure of regulations that regulate construction waste management is not precisely fit for purpose, as the regulations do not focus on individual waste streams. For example, the Waste Avoidance and Resource Recovery Act 2001 No 58 aims to regulate waste recovery. However, it applies not only

to construction waste but also to organic waste, household waste, and other waste streams.

Secondly, there are no clear definitions of key concepts in the regulations that frame the impacts of construction waste on the environmental and aspirations toward sustainability. One of the common aims of the policies is to reduce the impact on the environment; however, the multiple definitions found create a challenge in the unification of strategies as the definition varies throughout. For example, the environment is defined in the Environmental Planning and Assessment Act 1979 as everything that “includes all aspects of the surroundings of humans, whether affecting any human as an individual or in his or her social groupings.” However, in the Protection of the Environment Administration Act 1991 No 60, the environment is defined “as components of the earth such as (a) land, air, and water, (b) any layer of the atmosphere, (c) any organic or inorganic matter and any living organism, (d) human-made or modified structures and areas, including interaction natural ecosystems that include components referred into (a) to (c).”

Another key concept throughout the policies is the definition of ecological sustainable development found in the definition sections of the policies. It embodies the sustainability principles and aims to articulate economic development with sustainable practices to meet the present needs without compromising future generations' ability to meet their needs (Emmery, 1993). This concept is part of the applicable regulations as it promotes six principles that could be qualified as sustainable, yet are treated as ecological sustainable development to integrate the economic considerations. Even though Environmental Sustainable Development integrates economic and financial considerations with the conservation of the environment, there is not an evident horizontal integration of the circular economy principles in the existing regulations.

There is potential for Circular economy principles to enhance and reorient policy and practice by addressing the manufacturing process's economic and environmental impacts. In contrast to the policies above, the NSW Waste Strategy (Department of Planning, 2021) has directly incorporated circular economy principles into its goals yet still fails to segregate and address the multiple waste streams. Its strategies are non-mandatory to the construction industry. The goal of reducing the waste generated by person and increase to 80% the recovery rate from all waste streams by 2030 involves strategies such as recycling, reusing, and repurposing within the construction waste management industry. Such goals show the potential for sustainable approaches to be

taken into consideration. At the same time, the strategy defines and explains circular economy benefits and integrates the strategies with the principles of reusing and recycling. NSW Waste Strategy establishes the 80% goal for construction and demolition waste reduction and avoidance. However, according to the reports included in the NSW state strategy, by 2019, it was 77%. However, it does not specify the different waste streams included in the percentage given, specifically the construction waste industry tons (Department of Planning, 2021). It is unclear what waste streams are considered besides the putrescible and non-putrescible waste classifications per the Waste Classification Guidelines Part 1: Waste Classification (EPA, 2014).

The Protection of the Environment Operations (Waste) Regulation 2014 does not outline required practices or any of the minimum objectives for waste management. It focuses on how the operational processes of waste collection work. This means the focus is on functioning infrastructure, such as residential and commercial buildings, where waste needs to be disposed of and transported in a certain way. The regulation outlines the contributions and the exemptions as well as the required reports and surveys that must be provided by the Environmental Protection Authority of New South Wales (Goverment, 2014). There is no mention of any special consideration for the construction waste stream putting into evidence the lack of regulation around the industry.

NSW Policies considers the reduction of waste minimization and waste management of the construction activities as part of the core ideal of most of the policies. However, none of the policies mention how to manage, reduced, and recycle construction waste. For example, the Waste Avoidance and Resource Recovery Act 2001 No 58 does mention the preferred outcomes of the waste management processes. It fails to differentiate the construction waste stream from the other non-putrescible waste.

Overall, the policy analysis found that under the Protection of the Environment Administration Act 1991 No. 60, eleven mentioned acts, of which only two mention waste management. However, no specific policies or regulations focus solely on construction waste management. The analyzed policies demonstrate how poorly integrated sustainable practices are with construction waste management as the waste stream is classified with all non-putrescible waste. Integrating key concepts in the policies is subjective, and there are no definitions for the selected strategies, allowing free interpretation of the approaches. Moreover, the Development Control Plan requires a waste management plan for the development application for a project; however, the focus is towards the operations of the project once it is occupied, transferring the responsibility

of the strategies and practices of the construction waste management during the construction of a project to other parties.

The existing policies do not have a unified definition for key concepts that allow the unification of strategies for construction waste management resulting in practices that are circular in theory but not in practice. The multiplicity creates a challenge and allows the positionality of the policy to vary, creating lax regulations around construction waste management. At the same time, the lack of congruency across the reviewed policies exposes a weakness of construction waste management as identified in the existing literature, providing this as a barrier in the transition towards circular economy practices. Finally, the broad categories of the waste streams in the policies impose a challenge in construction waste management as the strategies focus on the general waste (non-putrescible) stream.

There is an evident development lag between current sustainable practices and the acts that regulate them. For example, one of the objects of the Protection of the Environment Operations Act 1997 is the “reduction in the use of materials and the re-use, recovery, and recycling of materials.” Nevertheless, there are no clear strategies for achieving this or considerations for accomplishing the action object meaning that materials can be classified as recycled, but that does not mean that it is the most efficient use. i.e., waste to energy input material.

4.4 Summary

The policy review has provided three key findings. Firstly, circular economy principles are not currently directly embedded in the policies that apply to waste management. However, the concepts that align with the principles are considered part of practices aligning with the principles of ecologically sustainable development. The application of sustainable development principles “requires the effective integration of social, economic and environmental considerations in decision-making processes” (Government, 1991) and provides specific programs and practices such as “minimizing the creation of waste by the use of appropriate technology” (Government, 1991). However, the latter puts into evidence the lack of specificity in waste management practices that apply to the construction industry as part of the policy review findings.

Second, there is a need for clear guidelines with regulations incorporating clear definitions of circular economy principles and practices. The absence of such definitions challenges the empirical application of the regulations in the construction waste management context. Moreover, stakeholders, such as organizations, are not mentioned in any policies or appointed as enablers of circular economy practices. Creating clear definitions and guidelines for the incorporation of circular economy principles in construction waste management would allow more coherent practices or approaches to be implemented by the stakeholders.

Third, all the analyzed policies do not focus on specific waste streams, creating a challenge for construction waste management. There is a need for more specific special considerations to be incorporated into regulations and policies that target the construction industry's waste streams. Incorporating such guidelines into regulation would then ensure industries are required to put circular economy principles into practice.

5. Findings from interviews

This chapter addresses research question 2 and contains the findings gathered from the semi-structured interviews focusing on identifying the existing practices in the construction waste management industry that contain circular economy principles. It uses the data gathered using the methodology described in section 3.3.2. First, the chapter will identify the roles and responsibilities of the actors involved in the current practices in the construction waste management industry. And then, the findings around the industry practices that include the circular economy principles aim to analyze the data collected from the participants focusing on their expertise and previous professional experience. Finally, a summary of the findings will be presented, gathering the key ideas found in the interviews.

5.1 Overview of construction waste management in NSW: actors and responsibilities

The Construction industry is one of the world's biggest industries. It includes an endless combination of resources that are not limited to the materiality of the resources but also involves services provided by different disciplines and actors. The multiple relationships among the actors involved in a construction project vary, impacting the level of responsibility. Figure 5 shows the current practices' interactions during the project construction, as mentioned in chapter 3. The first stage, design, and planning, involves the client/property developer and consultants. During the procurement and construction stage, the builder is the one that hast all the contractual obligations as it is responsible for the execution of the project.

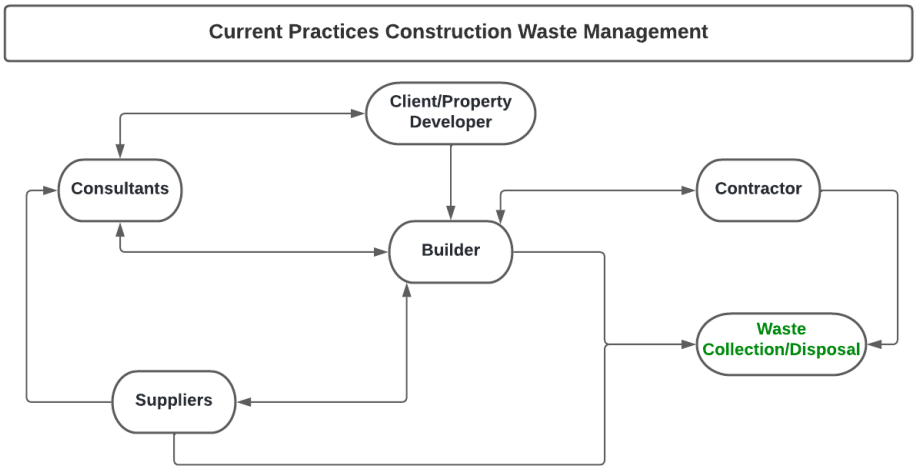

Figure 5 – Actors involved in Construction Waste Management

All interviews started by exploring participants' knowledge about circular economy principles and their applicability throughout their professional experience. Only two participants did not know the principles of the circular economy. However, when explained, they both provided practices that in their field are identified as sustainable practices, such as using recycled brick for aesthetic details in the building of the façade.

Notwithstanding the knowledge of the circular economy practices of all other interviews, the variance of the definition of circular economy and its applicability confirms that "a concept which fails to cohere may ultimately collapse or remain in a deadlock due to permanent conceptual contention, not only in research but also in practice, since cumulative knowledge development on it is impeded" (Kirchherr, et al., 2017). This is corroborated once the interviews continue to explain the practices. Overall, the current construction waste management industry practices do not recognize practices such as recycling or reuse as circular economy practices but more as sustainable practices.

5.2 Who is taking responsibility for construction waste management? Exploring the role of specific actors

This section draws on interviews to explore the various roles of specific actors and discuss the different stages of construction to understand potential opportunities for circular economy principles to be embedded in practice. In particular, it focuses on the role of builders, clients and consultants, and Waste management consultants.

Builders

Builders play a crucial role within construction ecosystems as the enabler of sustainable practices, with other actors situating them as the key to integrating sustainability. The responsibility of the project is to the builders. They transfer specific responsibilities to other consultants as required, meaning that consultants must provide professional advice for which they are responsible under the code of ethics of their discipline. However, that responsibility ends where the builder allows it to. One respondent noted:

> The builder is located at the epicenter of construction. The clients … they all have good intentions, but they do not get out of their own way. Consultants have no authority over the control of materials, demolition, and things like that. Subcontractors they do what you paid them to do. So the one with all the influence is really the builder (ND, 2022).

Builders are situated as the actor in charge of building the project and mediating the communications and responsibilities for addressing waste between all other actors. Several respondents noted that the builder engages the contractors, and the contractual obligation is directly to them. Suppliers relate to consultants, builders, and contractors. However, the first interaction is with the consultant specifying the construction materials, and then the builder can procure the materials directly form the supplier, or the contractor can supply them. It depends on the modality of contractual engagement selected.

Figure 5 shows the multiple interactions that will vary depending on the stage of the project. For example, in the design and planning stage, the communications are between the consultants and the client/property developer until the local council approves the project. After that, the procurement stage starts, and that is when the builder gets involved. The hierarchy of the interaction changes, as the builder is the one engaging the consultants and the contractors. The latter relationship hierarchy also applies to the construction and demolition stages.

Client and Consultants

During the design and planning process, the client/property developer submits a design brief with all the requirements and considerations that must be included in the design for the architect to incorporate in the project proposal. Even though the client holds final

decision-making authority, the consultants must ensure that the design complies with the Australian codes and standards.

Sometimes, a “waste consultant … will sign a waste management plan” (EP, 2022) confirming the compliance with the operational waste management for when the project is occupied. However, the waste management plan does not include the construction waste management generated in the execution of the project. However, because construction waste management does not have a regulation or standard, consultants take responsibility for ensuring that circular economy principles are integrated throughout construction waste management.

Once the project has the Development Application approved and the builder has been appointed, “consultants do not have any authority over the control of materials, demolition, and things like that” (ND, 2022). This creates a shift of responsibilities, as, despite the professional responsibilities, the “decision-making process is driven by costs,” as identified by four interviewees (FT, 2022; CN, 2022; EP, 2022; ND, 2022). This means that the builder has the last say in material selection and sustainable practices allowances; even though consultants want to promote circular practices, if it is not “budget-friendly,” they will not be incorporated into the execution of the project.

Waste management consultants

Interestingly, none of the interviewees felt that their role was responsible for construction waste management; all of them pointed to the waste consultant or the waste contractor as responsible for collecting and disposing of the project's waste.

For example, the construction waste management industry has set practices throughout the three stages of project construction. The interviewees that belonged to the first stage did not know how the process is done, “architects are not involved in waste… is the waste consultant that has to be on top of that” (EP, 2022). In the second and third stages of the construction of a project, the understanding is not different as the three of the interviewees acknowledge the engagement of the waste consultant and a third party to dispose of the waste, resulting in the understanding that none of the actors is utterly accountable of the construction waste. Only the waste consultant and contractor are seen to be responsible.

Such insights further emphasize the expectation that builders be the main enablers of sustainability and the key actor responsible for ensuring that circular economy principles

are integrated. However, to facilitate a broader transition towards circular economy practices, all actors must play a role, as the multiplicity of resources involved in the construction industry cannot be centralized in the builder's practices. This means that consultants, builders, clients, contractors, and suppliers need to be required, through regulations, policies, and guidelines, to implement circular economy principles in their practices, processes, and procedures if the industry is to transition toward becoming a circular economy actor.

The interviews provided critical insights about the actors in the construction waste management process and who is responsible for its disposal. As their professional background varied and belonged to different project stages, it provided insights into how construction waste management is approached. The consensus is that no circular economy practices were embedded in the construction industry or in construction waste management. Some practices were perceived as sustainable practices, such as the "reuse of structure" (CN, 2022), but they are also observed as circular economy practices. For example, one respondent noted:

> … QQ Tower… is the biggest example in the world of re-using the concrete core of an existing asset. So retained 68% of the existing concrete core around 45,000 square meter building, and then it was extended out to create a 90,000 square new office building… (CN, 2022)

The consensus over the key decision-making criterion is the costs, and risk controls, whereas it is a program risk due to delays in the procurement of the materials or the challenge of recertification of materials. The participants' consensus is that any existing or future practice must be budget friendly and have a minimal impact on the industry's current roles and structures. Such insights into the barriers to implementing circular economy principles are further elaborated upon in the following section.

5.3 Barriers to implementing circular economy principles and practice: Lack of knowledge, voluntary nature of participation, and lack of monitoring

This section first acknowledges the barriers to implementing circular economy principles, and then it uses the data gathered from the interviews focusing on the participant's experience in the industry. The objective is to contribute to the social and cultural space in the construction waste management industry using the data gathered during the interviews.

The lack of knowledge of the meaning and ways to implement circular economy principles in construction waste management is evident among all participants. Only two out of the six interviewees were aware of circular economy and sustainable definitions and practices, which reflects the lack of responsibility from the industry overall to educate professionals in these subjects. The amount of awareness of sustainable practices and circular economy is directly related to the seniority of the people in the industry. The participants who knew were in senior positions with more than ten years of experience, which means that the knowledge has been gathered through professional experience, not because it is part of the discipline-required knowledge. Out of the six interviewees, two had less than ten years of experience, and neither of them where familiar with the circular economy principles.

Moreover, when asked about the circular economy, all the interviewees transition the conversation to sustainability and sustainable practices, suggesting that sustainability is more embedded in the construction waste management industry. This creates a challenge in implementing circularity, as there are no evident distinctions between the two. However, as outlined in Chapter 2, the definitions vary, but this is not perceived during the interviews; the two are interchangeable when discussing circular economy practices.

Circular economy aims not only to reduce the number of required resources building an economy around the processes focusing on the financial benefit. All participants, including the ones that did not know what circular economy is, provided a list of practices that they referred to as sustainable. However, being sustainable does not mean that it implements the circular economy principles and circularity does not mean sustainability (Geissdoerfer, et al., 2017. All circular economy practices are sustainable, but not all sustainable practices embed circular economy principles.

Interviewees mentioned the lack of regulation for construction waste management (CN, 2022; FT, 2022; EP, 2022), which directly impacts the levels of responsibility the actors are willing to carry. For example, one respondent noted:

> … well we have a number of projects where for example you know you NSW or other places where we have to have a certain amount of reduction in materials that go to landfill when we demolish or avoiding construction waste but um I don't think they are really regulations in terms of waste reduction much at the moment across Australia (MI, 2022).

This means that any circular economy practice is voluntary as there is no government incentive to make a transition or bridge the gap between circular economy practices in

the construction waste management industry, which is reflected in the lack of knowledge of the circular economy and sustainability concepts and regulations around the subject boycotting any circular economy practice in the day-to-day practices.

Five of the six interviewees shared their knowledge of which materials were part of a circular economy model. The most commonly mentioned materials that could be recycled or reused were bricks, timber, and concrete. Steel is part of the focus of the interview. However, participants did not have any information or previous experience with the waste management of steel. ND mentioned the ability to “order the right amount of reo” (ND, 2022), which means that the residual steel on-site is minimized. Bricks were mentioned by five participants noting that they are used in localized areas of a project as “recycled brick is more expensive” (MI, 2022). In some cases, it is cleaned on-site; however, other logistics must be considered, such as transportation and storage. Another material mentioned is the required formwork. “Formwork … got their own circular economy going … they reuse every bit of form” (ND, 2022); the amount of material disposed on site is minimal compared to the amount used. For example, one respondent noted:

> … there's formwork and the guys are happy to they they've got their own circular economy going 100% they reuse every bit of form very little form leave site in a bin. There is steel the guys are actually pretty good at just ordering the right amount of reinforcement and bar and mesh and PT. Concrete wise they're actually pretty good concrete wise as well so it's really unfortunate that in high rise the area which is the most easy to govern is actually got its own circular economy going on anyway so you know steel pretty much all of it finds its way into the actual decks around to the columns or into the walls formwork again it pretty good they even the little off cuts and whatnot that they saw off they will use for chalking up something over here or maybe a bit of packing over there very little waste leave site they reuse all the formwork from level to level (ND, 2022).

The current voluntary nature of incorporating circular economy principles into practice is a concern, as noted in the policy review findings. The design proposals are put forward per the design brief provided by the client. All interviewees mentioned that the desire for circular economy practices “rarely comes from the client” (MI, 2022), meaning that architects and consultants must engage with the client to bring them on board with any new practices, taking into consideration the risks created by the lack of information about construction waste management and circular economy practices. For example, one respondent noted:

> I would say it's the architect and the architect is then convincing the client and when the builders engaged then you basically give them the brief look in this building we're going to only we you know use we use timber beams

> so we need to source them and then the builder would go and try to source them and then hopefully report back I found some and then where it's not where it wasn't possible then we would have to use new materials there but the initial kind of starting point is from the architect. Sometimes on the client so it's very rarely (MI, 2022).

Out of the six interviews, only three express a clear drive to implement circular economy practices applicable to the current construction industry dynamics. It is evident that the drive and motivation are through the organizations' design principles and criteria. Even though they all showed interest in implementing circular economy practices, the complexity of the construction environment on-site creates a challenge that still requires further research. For example, SH noted “the potential to sort out materials during construction ... on-site from the start …, but in most cases, that never happens, so things just get disposed of wherever” (SH, 2022). ND had a similar experience on-site, where site staff disposed of waste “on the closet bin” (ND, 2022), disregarding protocols and procedures. At the same time, ND, SH, and MI identified in their experience the lack of monitoring structures where waste is accounted for and classified according to the way it got sorted.

A fundamental limitation of current waste management practices is a lack of monitoring and requirement for actors to ensure waste is recycled or reused. None of the participants interviewed were involved in monitoring construction waste management. They all emphasized that the building contractor must provide a report with a breakdown of the recycled, burned, or disposed of waste. However, “No one monitors if that is true” (MI, 2022). The lack of monitoring of the construction waste is identified as a transferred responsibility from the builder to the waste contractor (EP, 2022; ND, 2022; FT, 2022), as there is no obligation for any of the other identified actors to monitor beyond the boundary of the project. For example, one respondent noted:

> So, we don't really monitor or like oh that building being efficient like how much power does the building consume in a month like we don't get to see those details because unless from my perspective once you've finished a project you are already thinking of the next one and there is no one unless it is the project manager or the client coming to you with those numbers or like with that data you wouldn’t really know if the product that you had in mind is what you've been executed (EP, 2022).

Moreover, all the participants commented on the lack of monitoring from the actors involved regarding the waste, as long as the report “says we have avoided the landfill … they do not care if the waste has found its way back into a circular economy” (ND, 2022).

The key identified barriers are the lack of knowledge of the actors regarding circular economy practices, which challenges the implementation of any new practice, including sorting the materials. Lack of regulatory incentives and directions turns the transition into a voluntary process, and the inability to monitor that the current practices are achieving the circular economy expectations.

5.4 Barriers to implementing circular economy principles and practice: Industry reflection

Industry incorporation of sustainability principles is a key theme discussed by interview respondents. Current practices show industry is motivated to incorporate circular economy principles for specific projects that intend to reach an environmentally concerned market. Interview participants reflected on specific examples while noting the critical driver of practice throughout all the interviews. Two common motivators arose from each conversation, costs, and organizational drive. One participant noted that, well, it is property development, and it is never driven by carbon unless it is a boutique niche sustainability-driven development (CN, 2022). The industry's appetite for incorporating such principles depends on the type of project, budget, and design criteria the client has in mind (FT, 2022; CN, 2022; MI, 2022; ND, 2022). For example, in CN's experience, developing a unique project in Sydney’s CBD included circular economy practices that minimized construction waste. The project retained approximately 68% of the existing core and built a structure that is joint with the existing core. The circular economy practice and the reduction of construction waste is an “added bonus,” but the project costs and intentions of the program were key factors.

The construction industry has moved towards sustainable practices through a growing incorporation of accounting for embodied carbon. “Embodied carbon emissions is the carbon dioxide produced in the making of a building upfront “ (Attia, 2018), meaning that it is possible to consider the environmental impact during a project's design and planning stage. FT, an interview participant, shared a tool that is being developed by his architectural firm to provide responsible and sustainable designs. The software allows analyzing the impact of the material selection. For example, it determines the embodied carbon of the building with a timber or concrete structure. Comparing the different buildability approaches allows a study of the design proposals' costs, benefits, and

impacts. This is key for competitions where sustainability is a decision criterion for the winner.

Three interviewees identified digital technologies as part of the current practices, none of which are directly related to construction waste management. EP mentioned Revit and Archicad, which are design software that aid the design and construction process. The BIM platform allows all the actors involved to have a fully modeled 3D version of the project at any moment allowing the integration of multiple designs and coordinating the resources required for a project. However, in practice, what happens is different, “not all consultants have the 3D model” (EP, 2022), or in some cases, not all of them. These digital technologies have the potential to aid the transition towards circular practices, as noted by one interviewee whose organization is developing a software to determine the embodied carbon of a project. Even though this relates directly to sustainable practices, the potential of digital technologies is subject to future research.

5.5 Summary

Overall, the interviews provided key insights into the current practice of construction waste management in the industry and how they do or not incorporate circular economy principles. The lack of knowledge of the circular economy theory and the misunderstanding and misuse of the concept in the construction industry creates a challenge to its applicability. Moreover, the lack of clear differentiation between sustainability and circular economy practices significantly impacts the industry practices as it confuses actors and stakeholders involved, altering the desired results.

Existing practices are determined by key actors with the power and authority to implement circular practices. However, these decisions are made taking into consideration mainly the financial viability and feasibility of the practices, putting the consultants in a position where they are the ones that need to propose an argument that the circular economy practices are the best option and will provide the best outcomes for the project.

The construction industry already incorporates certain waste management practices for specific materials, such as bricks and timber, that reflect circular economy principles to some extent. However, participants discuss such practices and understand such practices as sustainable practices rather than as part of a circular economy approach.

For example, recycled brick is recycled, but it is not used in the same project in most cases.

Finally, the industry desires to implement circular economy principles. However, a key barrier to such implementation is a lack of accountability and responsibility to the involved actors. This allows waste management practices to be within the compliant framework and only meet minimum requirements in contrast to fully integrating, implementing, and transitioning towards circular economy principles.

6. Discussion

The findings demonstrate that the construction industry has practices that address waste management but that the industry's perception is of sustainable practices rather than circular economy practices. This chapter addresses research question 3 and reflects on the challenges and opportunities of integrating the circular economy into construction waste management, considering the multiplicity of actors and responsibilities, policies, and current practices of construction waste management, situating the thesis findings within the academic literature. First, the chapter discusses the challenges for the transition from an epistemological perspective understanding the various definitions of circular economy. Second, understanding the level of influence of the policies in the industry and actors' practices considering the construction industry positionality regarding construction waste management. Finally, the chapter discusses the overall challenges and opportunities around current practices in the transition towards circular economy practices in construction waste management in the construction industry.

6.1 Circular economy or sustainable practices: Definitions and industry interpretations

There is an opportunity in the construction industry to enhance the collective understanding of the meaning and application of circular economy principles and practices. This section provides insights into key domains of intervention: the consistent incorporation of circular economy definitions in regulation and the need for more explicit industry understandings of circular economy to differentiate these from the concept of sustainability.

One key challenge is the inclusion of the concepts and definitions in the current practices, including policies that currently include discrepancies between definitions. This has created ambiguity in the industry as the definition is not even clear from a theoretical perspective. Kirchherr analyses 114 definitions and proposes an additional one; meanwhile, the construction industry struggles with an applicable definition to discuss current practices (Kirchherr, et al., 2017). The current policy review showed the incongruence amongst definitions; therefore, conceptual and practical understandings of the Circular Economy are not clearly outlined in the regulatory policies. Notwithstanding,

guidelines or statements such as the NSW Circular Economy Policy Statement – Too good to waste (EPA, 2019) provide a clear definition, strategies hierarchies, and objectives. Nevertheless, they lack regulatory power, as they are not mandatory for the industry.

A clear example is the definition of the environment across two relevant policies evidencing the difference between the Environmental Planning and Assessment Act No 203 (Government, 2022) from the Protection of the Environment Administration Act, as shown in Table 8. The discrepancy of definitions shown below presents a challenge for the policy implementation, impacting the scope of acquired responsibility by the actors as engagement with the environment in the construction practices. The lack of consensus or bridging between definitions allows actors to implement basic minimum requirements that comply with a less comprehensive understanding of their responsibility.

Policy	Environment: Definition
Environmental Planning and Assessment Act No 203	"includes *all aspects of the surroundings of humans*, whether affecting any human as an individual or in his or her social groupings."
Protection of the Environment Administration Act	"*means components of the earth*, including— (a) land, air and water, and (b) any layer of the atmosphere, and (c) any organic or inorganic matter and any living organism, and (d) human-made or modified structures and areas, and includes interacting natural ecosystems that include components referred to in paragraphs (a)–(c)".

Table 8 - Definition discrepancy of Environment in the policies with regulatory power

The research showed the need for a consistent definition and framework of circular economy principles and practices to be incorporated into construction waste management. The interviews demonstrated that multiple definitions and understanding of the circular economy practices impose a challenge to consistently implementing guidelines and policies. ND explained, "I think maybe part of the problem is the way we have complicated the word circular economy…" (ND, 2022). The challenge arises not only from the multiplicity of definitions but also from the level of knowledge involved in the various actors involved in a project. People working in the construction industry have various levels of education such as those who did not finish high school working on the same project as those with degree qualifications. There is an evident need to simplify the

definitions of circular economy for it to be applied throughout the construction industry and communicated across projects.

Another identified challenge is the participants' interchangeable use of sustainability and circular economy. Providing a clear industry understanding of the differences between circular economy and sustainability would assist the incorporation of circular economy ideals in construction waste management processes. Industry actors have different experiences and diverse understandings of circular economy principles depending on their positionalities. For example, three out of the seven interviewees were unaware of what the concept meant, demonstrating a knowledge gap within the construction waste management field as circular economy principles are not applied throughout a project's entire construction, let alone through waste management processes. Nonetheless, the interviewees who were aware of the circular economy practices tended to shift to wording the practices as sustainable practices. The understanding of how the model works is there; however, the industry has approached it as sustainable practices that happen to include circular economy principles, as demonstrated in the response by ND:

> Firstly, I don't think many people know what circular economy are, only those that either attend the seminars and … listen to things or those who actually work in sustainable circles, and the unfortunate thing is they are a small part of the industry. The bulk of the industry got a little bit of an understanding around what sustainability is, but only where it comes into their data… (ND, 2022).

This means that the interpretation of the existing concepts of the industry fails to serve the existing practices. This aligns with Kirchherr says that

> a concept which fails to cohere may collapse or remain in a deadlock due to permanent conceptual contention, not only in research, but also in practice, since cumulative knowledge development on it is impeded (Kirchherr, et al., 2017).

Financial viability is a key consideration for scholars working in the circular economy field, which differs slightly from the equal weighting placed upon social, economic, and environmental benefits evident in triple-bottom-line sustainability approaches. For example, Kirchherr & Van Santen considered that "the main aim of the circular economy is considered to be economic prosperity, followed by environmental quality; its impact on social equity and future generations is barely mentioned." (Kirchherr & Van Santen, 2019, p. 2) The interviewees corroborate such emphasis on economic viability as one of the main criteria for incorporating circular economy principles putting into evidence that for a total embracement of circular economy practices, the consideration of economic prosperity is vital, as it determines the sustainability of the circular model in the

construction waste management reducing the financial stress on the industry. All interviewees agree that a market of recycled materials where supply can keep up with demand is key, as it is a preferred practice to use recycled materials that can be guaranteed.

Opening the opportunity to demonstrate that a circular economy can be attained through sustainable practices. In summary, the main challenges stem from the lack of consensus in the definition of the circular economy concept and strategies in the policies relevant to construction waste management impedes the transition using current policies as it allows for a free interpretation and implementation throughout the industry. Moreover, unawareness of the differences between sustainability and circular economy practices creates confusion in implementing the concept during construction. Furthermore, the education of involved actors in the construction industry creates an excellent opportunity to transition towards circular economy practices. However, the process cannot be made disregarding the existing practices, and the definitions must be congruent across the construction industry, construction waste industry, and policies to achieve an effective transition.

6.2. Policies Influence and Actors' Responsibility in practice

Discussions throughout chapters 4 and 5 points to the need for additional waste management regulation for circular economy principles to be implemented. As previously mentioned, actors are acting on the minimum legal requirements because the current regulations do not specifically target construction waste, and the responsibility of managing waste is transferred to the waste consultant alone. Interviews reiterated the need for further actors in the construction to take responsibility. Despite interviews involving a design architect, project manager, director project manager, property developer, and an architecture sustainability manager, the only interviewee indicating a desire to integrate circular economy principles into construction waste is the architecture sustainability manager.

The insights about the need for further regulation and specific policies to integrate circular economy principles confirm Kirchherr's (2017: p3) point that "neither business models nor consumers are frequently outlined as enablers of the circular economy" they are all looked at as part of an existing structure that considers them as a component rather than enablers. At the same time, the existing roles in construction waste management practices need to further understand the factors that enable the transition towards circular

economy principles being integrated into practice. However, after analyzing the data, one can identify that three main variables must be considered when integrating circular economy practices in the construction waste industry: financial viability, the complexity of actor responsibility, and supply and demand.

Firstly, financial viability is a crucial topic discussed with the interviewees as influencing the three stages of construction projects. Actors are indisputably interested in including circular economy principles in construction waste practices. Each interviewee shows significant interest in including such practices to promote sustainable approaches to construction waste management. However, the lack of information available to actors within the industry is challenging, creating a gap between the people who can transform the industry and those with the relevant information and understanding that facilitates such transformation. This gap results in the perpetuation of a perception that implementing circular economy principles will be expensive and complicated, resulting in enthusiasts being discouraged from implementing it.

Secondly, one participant explains, “everyone knows the right thing to do, people have different authority levels to make things happen, but they will not know what to do” (ND, 2022). Actually, “doing the right thing” by following circular economy principles requires actors to ensure proper demolition processes are being followed for the industry to recover the materials, transport them, store them, and facilitate their redistribution. Such a complex process may not be enticing enough to attempt such a task. As (Kirchherr, et al., 2017) explain, companies

> “…may take the path of least resistance to adopt CE if waste hierarchies are not explicated, e. g. only improving their recycling and thus only a small part of their operation, without the needed overhaul of the entire supply chain, mode of operation and the radical change in product materials. Particularly CE implementation based on definitions that do not outline ‘Reduce’ as CE’s priority can result in CE subverted to the cause of continuing an unsustainable business-as-usual model”.

When the preference for the least resistance path is combined with lax policies, expectations for any improvement in the construction industry go out the window. The construction waste management industry requires specific policies and appointed responsibilities to be able to achieve the goals that the government set. This is not only to make sure that the industry is improving its practices but also to ensure they are committing to such policies long-term, as several companies in studies by (Kirchherr, et al., 2017) quickly lost interest in incorporating circular economies as it was not promoted as a long-term undertaking for future generations. Moreover, understanding the

embodied carbon of recycled materials versus new materials is a critical component of any case for circular economy principles to be incorporated, as the recycling and reusing of the materials must produce a minor impact than manufacturing new materials for this to be considered. This added complexity of embodied carbon and its implications for a broader understanding of the need to incorporate circular economy principles requires further analysis and research.

Thirdly, supply and demand are other factors required to aid the transition to a more circular economy model. Supply and demand are closely connected to the financial viability of circular economy practices, as the construction industry's supply of materials must endure the constant demand for construction. Rose & Stegemann (2018) identified the supply of recycled material, as she mentioned the lack of information about the materials and the potential for interrupted supply chains. Interviewees echoed such sentiments, indicating that despite the desire to include recycled materials in construction, they were concerned that there is not enough in the market to be used across multiple construction projects (Rose & Stegemann, 2018). Some materials that are identified as easy to recycle and reuse come with significant challenges must be analyzed through a multilayered lens. For example, plasterboard can be reutilized, as it can be easily patched and repainted. However, the recovery process, recertification, and transportation make such reuse challenging. Additionally, the constructability requirements of walls that use plasterboard need to be considered, as there is an expectation that such walls are rigid and sturdy, adding on a construction requirement that the plasterboard is also de-constructible, which in practice would be challenging.

Finally, there is a need for clear guidelines with regulations that specifically incorporate circular economy principles. The construction industry is heavily regulated and has many different codes, laws, and standards that need to be considered at the moment of execution of a construction project (Standards, 2022; Australian Building Codes Board, 2022). Australia’s efforts to promote sustainable practices, standards, and codes have included considerations that allow the usage of recycled and reclaimed materials that comply with a project's technical and mechanical requirements. The application and practices of sustainable approaches to construction reflect construction waste management throughout the whole life cycle of a project and its requirement of explicit legislation specifically addressing construction waste (Shooshtarian, et al., 2022).

In summary, the positionality of the participants from the specificity of their roles provides an integration of existing relations between participants in construction waste

management and existing policies. It shows how the policies are involved in the current practices and how it allocates responsibilities in the industry. The current challenge is the lack of regulations targeted toward the industry practices, allowing the vague implementation and dismissal of any best practice of circular economy. The opportunity here lies in the future development of policies that consider the circular economy in the policies with legislative power, including the allocation of responsibilities for the different actors in consideration of the current relation between actors and policies found in this thesis.

6.3 Construction Waste Management Practices: Challenges and Opportunities

An overview of six key opportunities and challenges was identified across the data gathering and discussing chapters for incorporating circular economy principles into construction waste management our outline throughout this section. First, including resource recovery in the construction industry ecosystem promotes and creates a construction waste management industry. Second, the opportunity to understand the financial feasibility of circular economy practices will potentially increase the circular economy implementation. Third, the opportunity to use new technology that supports circular economy practices, making materials' information readily available for actors to use. Fourth, the key challenge of identifying the potential impacts and risks in the construction process circular economy practices could have, including material quality and delays in the construction program. Fifth, the opportunity to update regulations considering the recommendations made by the relevant actors, and the current inefficiencies, such as ambiguity in the policies. Sixth, information is a key component in the transition as it provides the tools and key strategies in the construction waste management practices promoting circular economy.

First, as shown in Figure 6 the industry has the potential to include a resource recovery actor, which can be made by an individual actor or be adopted by the existing ones. This means that every actor could feed the supply chain with recycled materials and offset the waste that ends in landfill. The need for new materials would be reduced, and each actor's accountability level would increase by taking such a step. Recognition of all actors as enablers of circular economy principles in the multiple cycles of supply and different relationships between actors is the key component to fast-track the transition. The

transition towards circular practices cannot be made in isolation. It requires all actors within the construction industry to make sure that the materials are in constant movement, reducing the costs and impacts on the environment. This will promote the development of a new industry that promotes and distributes recyclable and reusable materials that can be quickly re-introduced in the supply chain to construct new projects.

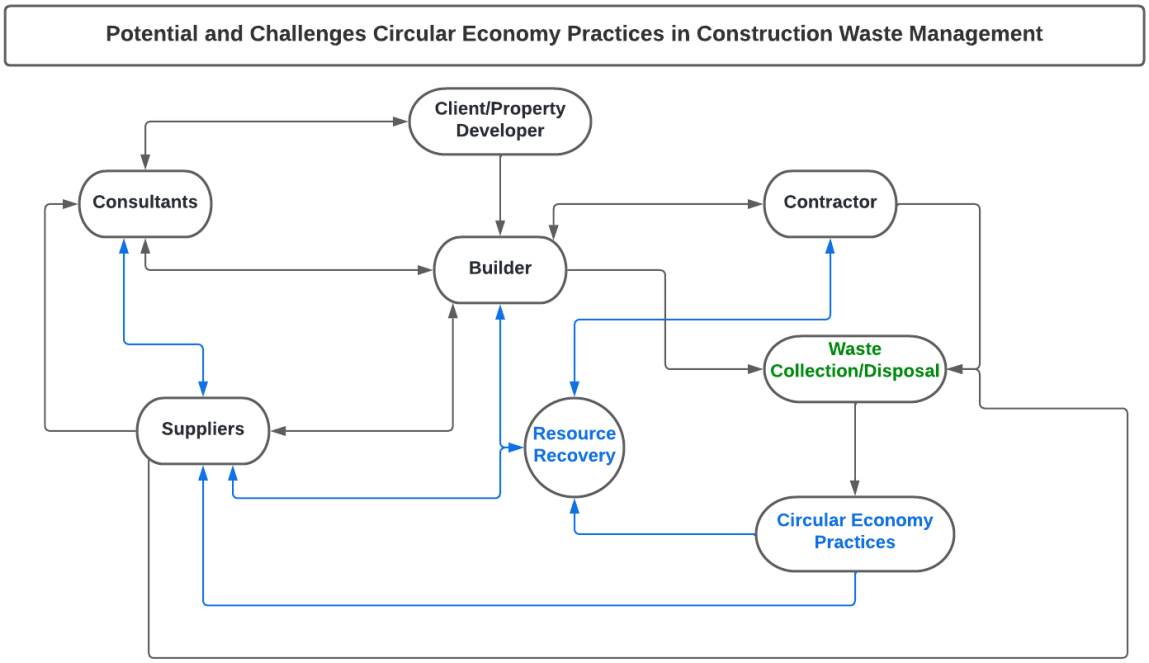

Figure 6 – Integration of Resource Recovery

Second, any incorporation of circular economy principles must address the waste management processes' financial viability to justify any change. When construction materials are cost-effective and justify the costs of implementing new practices, the industry will consider and prefer them to existing practices (CN, 2022; EP, 2022; ND, 2022; FT, 2022; MI, 2022). For example, one respondent noted that

> ... in order to implement all of these things you need to supplement the economy somehow needs to pay for itself but there also needs to be the right resources around the place so you're not overstretching the builder in the middle that's the difficult bit if you've got a senior project engineer on a big tower there's already working 12 hour days for two or three years on a project you're not going to have a lot of luck going to them and saying I want you to walk the job all day every day and administer people or I want you to allocate one of your engineers who's already stretched comes in six days a week (ND, 2022).

The construction waste management industry is full of opportunities as its development has been staggered and slowed by depending on private funding as government funding was not a common practice in the past. Nowadays, there a several business grants that waste companies can access to innovate and explore new practices throughout the industry. The potential to develop technologies that control and reduce construction waste management is evident.

Third, introducing new digital technologies is a key opportunity for assisting in selecting materials and measuring environmental impact through embodied carbon analysis. Such opportunities were mentioned by two of the participants. Integrating embodied carbon into software shows the industry's desire to introduce new practices into the construction industry. Current practices are starting to introduce digital technologies that allow the measurement of embodied carbon which uses the life cycle assessment (LCA) methodology aiming to quantify the environmental impacts of products and processes throughout their entire life cycle, i.e., from 'cradle-to-grave.' As Rock, et al., 2020 note, "this approach provides a sound methodological basis for calculating energy consumption and assessing resource depletion, GHG emissions and other environmental indicators over the full life cycle of buildings" (Rock, et al., 2020, p. 2). New technology is currently being developed to assist such measurement, as there is no actual data about the effectiveness or impact of new technology in construction waste management. However, as mentioned by some interviewees, the challenges continue, as it is not a common practice for life cycle assessments to be applied to every project. The opportunity to improve construction waste management practices and make informed decisions that consider the life cycle of materials and understand the percentage that can circle back into the supply chain is critical to promote the transition towards circular economy practices.

An additional opportunity identified is the use of the embodied carbon app, as it will aid in consideration of material selection, including transportation, the amount of raw material, and recycled material needed. In addition, such an app will provide architects with multiple options for building design. However, that still leaves the challenge of the supply of recycled materials. Digital technologies have the potential to facilitate information and integrate data from suppliers analyzing the carbon footprint, financial impact, and material availability. Although the software is still in the early stages, the potential for a ripple effect in the industry is there.

Fourth, the circular economy strategies must address material quality and impacts on the project's budget. This is a critical challenge in the transition to circular economy practice as those practices are typically perceived as more expensive. For example, when a brick building is demolished but the new construction does not include brick, it is most likely that the project team disposes of the bricks as they would not use bricks in the same project. Therefore, in this instance, the waste contractor could apply the circular economy, not the builder. In contrast, when a new project includes brick, the costs increase as recycled brick is more expensive than new brick. Rose and Stegemann (2018: p. 15) note that "the potential of reuse to reduce disposal costs for waste generators and reduce material costs for new construction has not been adequately demonstrated," and therefore, the resistance to transitioning construction towards a circular economy approach persists.

Fifth, there is a need and opportunity for regulation to play a key role in facilitating the implementation of clear, comprehensive, and appropriate circular economy processes in the construction industry. When we look at the history of the most significant changes in the construction industry, Work Health and Safety provides a great example of how the industry had to adapt to improve the existing practices and the critical role regulation played. Initially, Work Health and Safety processes were guided by national standards and codes of practices that were not mandatory:

> The National Standards did not have legal status and were not enforceable unless a jurisdiction adopted them into their OHS regulations. This led to significant differences nationwide regarding which protocols were adopted, how jurisdictions drafted and applied them, and whether they were adopted as a code of practice or regulation (Australia, 2022).

Despite all efforts, change in practice did not occur until the government developed work health and safety regulation that made healthy and safe practices mandatory. Similarly, there is a sincere desire to do things right, and some actors are taking responsibility for the environment and being accountable in their practices. However, the complexity of the construction waste management industry requires all actors to be involved and accountable and transparent regulations that make such practices mandatory rather than voluntary to be successful.

Sixth, Rose, and Stagemann (2018) identified the lack of available information about the recycled materials that can be used in new construction as a challenge for incorporating circular economy practices in construction processes. This challenge is corroborated by the interviewees, who expressed a desire to implement circular economy practices but did not understand where to find information. Such a challenge presents an opportunity

for developing new practices that allow the integration of circular economy principles in a way that provides a bridge between theory and practice. Distributing targeted information on how to incorporate circular economy principles throughout the construction waste industry could significantly fast-track the transition toward circular economy practices. Moreover, the challenge extends into the lack of information about the circular economy in the construction industry, which is sustained by the literature and the interviewees' responses, which constantly diverted to sustainable practices.

6.4 Summary

Overall, this discussion has addressed the challenges and opportunities existing in the construction waste management industry for incorporating circular economy principles. Participants clearly articulated a desire to implement circular economy practices that allow the reduction of the impact of the activities on the environment. However, the knowledge gap in implementing circular economy practices is considerable. It is exacerbated by the lack of regulations and policies around construction waste, leaving any change or transition at the discretion of an industry with a small profit margin and constantly overstretched. That is why it is so important to minimize the impact that the transition has on current practices. Actors provided insight into the different relationships, engagement, and responsibilities between the relevant stakeholders and the existing policies enabling and restricting the incorporation of circular economy principles.

Some critical challenges identified by actors, and reinforced by the literature, are the multiplicity of definitions of circular economy which impedes the integration of the principles into the current practices of the construction industry due to the conceptual slippage between the concepts of sustainability and circular economy. The free interpretation of the concepts allows actors to interact with the principles and definitions as they wish, creating an environment of convenience and a lack of accountability. This flexibility extends to the existing policies as they do not provide a clear definition that can be consistently applied to the circular economy practices in the construction waste management industry.

Another challenge for the policies is implementing regulations that directly target the construction waste stream and the general definition of the various waste streams. The lack of specificity provides an easy way away from circular economy practices, as no

specific strategies apply to construction waste management. Moreover, the lack of integration of practical information into the policies challenges any transition as it will result in the expression of the market's desire to develop new practices.

Information and availability around the quality and availability of materials that support circular practices impose one of the biggest challenges as the high demand for products in the construction industry. National quality standards and quality expectations must be met regardless of the origin of the materials causing, demanding the material that is recuperated must ensure the required specifications as if they were new. Consumers who use circular materials must have confidence in the quality of the process. The challenge is the supply and quality of information around the available materials. At the same time, this provides a challenge for operational processes which are required to transition towards circular economy practices in the construction industry. The lack of empirical research and information available that demonstrates how to implement circular economy practices on-site creates frustration for potential advocates and reinforces the lack of interest, as the complexity of the task requires a considerable amount of initial funding and resources that no one is willing to pay for at present.

As construction waste management is still developing, the opportunity to integrate multiple products and manufacturing industries through circular economy practices can support data collection and promote circular economy practices in the construction industry. Moreover, the opportunity to integrate circular economy principles throughout the whole process of project construction creates an ecosystem that shares the responsibility and is accountable for their involvement as materials could potentially travel across multiple processes extending the life cycle indefinitely. This means that expanding the knowledge from the multidisciplinary perspective of the various consultants could create new knowledge in various areas of the construction industry, not only construction waste management.

7. Conclusion

This thesis aims to investigate the current practices of the construction waste industry through the circular economy lens to determine, if so, how the current practices in the industry implement the circular economy principles. This chapter summarizes the essential findings and the study limitations and opportunities for future related research.

7.1 Summary of findings

This section summarises the findings by addressing the research questions in turn.

RQ1 How are principles of the circular economy considered within policies relevant to construction waste management?

The research found that the policies with regulatory power do not have embedded circular economy principles despite mentioning recycling and reuse as strategies in construction waste management.

Policies do not consider the construction waste stream as an independent material source. They treat construction waste as a homogenous mix of resources enabling the mixing of materials and discarding the possibility of sorting practices on site which allows transportation as a resource rather than waste. Even though it belongs to one of the primary industries in NSW, Australia, it does not have special consideration for construction waste management.

Lastly, policies do not consider the multiple actors as enablers of circular economy practices nor as responsible agents. This perpetuates the lack of accountability across the industry actors, as the responsibility of construction waste management rests on a consultant at the project's construction stage.

RQ2 How does the construction industry put the circular economy into practice in construction waste management?

The responsibility of construction waste management is centralized on the builder; this promotes a diminished sense of accountability, taking the responsibility away from consultants in their practices. Even though it is a considerable challenge, it presents an equally great opportunity. The ability to expand the multiple disciplines' knowledge with new practices that consider the interconnectivity of the construction ecosystem and promotes circular economy practices, such as using up-cycled material from other projects.

Relating to the supply and demand of materials, the challenge lies in the industry's ability to maintain balanced supply and demand levels. One of the challenges and concerns of builders is the procurement process, where they must maintain the construction program keeping the project execution on track and within budget.

Budget-friendly practices are a key finding from the interviews as current actors and stakeholders have the challenge of balancing the quality of the materials and the environmental cost providing an argument for the value of the project. Architects, for example, have the challenge of starting the conversation of the circular economy practices when the design is being developed, allowing the builder to have the consideration when planning the execution of the project. Not all the existing practices in the construction industry that have been discussed despite being sustainable include the circular economy principles.

The continuous implementation of circular economy practices in construction waste management has the potential to change the responsibilities of the actors, as they would be distributed in consideration of the stage of the project. This means that the construction practices will be proactive towards construction waste as it will be addressed from the early stages rather than when it is generated.

RQ3 What are the challenges and opportunities of incorporating circular economy principles into construction waste management?

Most of the challenges in the construction waste management impose an excellent opportunity to develop a circular economy around materials that are easy to sort and process, being able to introduce practices that can promote the development of the construction waste industry, transforming the waste stream into resources not only for the construction industry but for others.

Three identified challenges are the lack of information on empirical research of circular economy practices in the construction waste industry. Despite the actors' desire, the lack of incentives results in the implementation of the practices by the more prominent players such as Mirvac, Built, and other big companies leaving the more minor actors bound to the traditional practices due to a lack of financial availability to develop new practices.

One of the main opportunities is the integration of circularity in the construction industry throughout all project stages, promoting the circular economy principles across multiple consultants. However, the main challenge is the lack of evidence of the financial feasibility of the practices.

The financial viability and the costs of the circular economy practices are a big challenge, as the construction industry is under significant financial pressure, resulting in a lack of additional budget for practices that are not required. The desire to implement the new practices goes until the budget is impacted.

7.2 Limitations and future research

The research did not focus on the structural composition of the policies across Australia; the geographical positionality limited the understanding of the complete legislative structure around construction waste management, and the findings of lack of policies apply solely to New South Wales, Australia. Further research must be conducted to analyze the extent of the legislations across the federal, state, and local levels of the scope of the acts.

One of the main limitations of the research is the analysis of the current practices from the circular economy standpoint identifying the financial viability of the practices integrating the theoretical with empirical analysis of the existing practices. At the same time, due to the limited amount of time, the research could not produce statistical or numerical information that supports that the current practices are meeting the objectives of the circular economy by reducing the amount of required virgin material. Further research where the practices are analyzed in the complete context of the construction industry using materials rather than projects as case studies, where the life cycle is understood and followed through, focusing on the financial sustainability of the process, can determine the effectiveness of current practices while utilizing circular economy principles.

Moreover, the research did not include the code of conduct and responsibilities of the multiple disciplines involved in the construction industry to understand the extent of responsibility and knowledge around circular economy practices. Further research can be developed around the situationality and the implementation of circular economy in the construction industry using the individual actors involved in construction waste management to understand the social and cultural impact of the practices.

The participant pool is small (seven participants) and does not include waste contractors or demolition companies. This is subject to future research considering the financial feasibility of the empirical implementation of circular economy practices.

The integration of circular economy in the construction waste management industry has been slowly engaged by actors who desire to improve construction practices and facilitate further the transition towards circular economy practices. Actors must be the enablers of the voluntary transition. Education and responsibility understanding is required across the whole construction industry as the multiplicity of definitions of circular economy acts as a barrier that permits the bare minimum in circular practices. Moreover, actors must be empowered through their disciplines to understand their influence in the construction waste management industry regardless of the project's stage. Finally, the integration must include the intervention of policies that promote and incentivize the circular economy principles embedded in the regulations. The clarity of the definitions of concepts and goals is imperative to guarantee congruency across the construction waste management industry.

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APPENDICES

Appendix A – Interview Questions

1. **Background**
    - Sustainability or circular economy?
    - Construction waste management practices?
2. **Circular economy**
    - What do you understand by circular economy or circularity?
    - Do the current practices adopt any circular principles?
    - What are the impacts of the practices?
    - How does the circularity permeate or influence the construction waste management practices?
3. **Construction Waste management**
    - Is waste management a key consideration in the development of the project?
    - What are the current practices for the CWM?
    - Are the practices embedded in the organisations culture?
        - Project specific?
        - Location specific?
        - Policy specific?
    - How is the waste monitored in the stage of the project?
        - Design and planning / Procurement / Construction
    - Is there a specific process for steel in the construction waste management?
    - Who are the actors involved in the construction waste management?
        - Individual responsibilities? I.e. Monitoring, reporting quantities.
        - Communications
        - Interactions
4. **Digital technologies**
    - What do you understand by digital technologies?
    - Are digital technologies part of the culture and practices of the organisation?
    - Which digital technologies are being used in the stage of the project from the construction waste management?
        - Design and planning / Procurement / Construction

- Is there a specific tool to monitor the waste amounts disposed? How is steel being monitored?
- Is the digital technology available easy to use and user friendly? Valuable to the project's requirements?

5. **Steel**
    - How is the circularity put into practice in the Construction waste management?
        - General / Steel
    - Does steel have a different process?
        - Reused
        - Sold
        - Recycled
    - What are the actors involved in the process?
    - Is there a gap between the practices and the organisations/policy requirements and procedure?

Appendix B – Participant Information and Consent Form

Discipline of Geography and Planning
Macquarie School of Social Sciences
Faculty of Arts
MACQUARIE UNIVERSITY NSW 2109

Phone:
Email: lizethvanessa.arangocardozo@students.mq.edu.au
Supervisors: A/Prof Sara Fuller and Dr Miriam Williams

Participant Information and Consent Form:
Construction waste, digital platforms and the circular economy

You are invited to participate in a study exploring the use of digital platforms in construction waste management in New South Wales. The purpose of the study is to determine how the construction industry has implemented digital technologies to facilitate a transition to a circular economy, specifically in relation to steel. This study involves speaking to representatives from organisations across the construction industry. In this capacity, your experiences are important and will be crucial for the study.

The study is being conducted by Lizeth Vanessa Arango Cardozo to meet the requirements of the Master of Research degree under the supervision of Associate Professor Sara Fuller, (02 9850 8385, sara.fuller@mq.edu.au) and Dr Miriam Williams (02 9850 2153, miriam.williams@mq.edu.au) from the Discipline of Geography and Planning, Macquarie School of Social Sciences.

Participation in the study will involve taking part in an interview, either face-to-face or on Zoom, exploring current practices regarding the use, treatment and disposal of steel in the construction process. The interview will last 30-45 minutes and will consider the adoption of circular economy principles, organisation's practices, and considerations around waste in the construction industry, and the digital tools used in the process, including the challenges and potentials.

Participation in this study is completely voluntary and you are free to withdraw at any time without having to give a reason and without consequence.

If you agree, interviews will be recorded to assist in the analysis of the information and subsequently be transcribed. Only the research team will have access to the original data generated through this research and individuals or organisations will not be named in any publication of the results. A summary of the findings and any subsequent publications will be provided if requested. Transcripts from the interviews will be provided for review and redaction after each interview.

You will be asked a series of questions to confirm your consent to participate prior to the commencement of the interview.

Thank you for considering participating in this research project. If you have any questions about this project, please feel free to contact us.

Version 2 26/07/2022

Appendix C – Verbal Consent Script Form

Verbal Consent Script:
Construction waste, digital platforms and the circular economy

Interview no:
Date:
Time:
Interviewer:

Thank you for agreeing to speak with me today about construction waste, digital platforms and the circular economy. We can stop the interview at any time if you need to take a break. The interview will take approximately 45 minutes. If you feel that you would rather not go on with the interview that is fine too.

[Wait for participant to confirm they are happy to continue, otherwise thank them for their time.]

Thank you. Now I just need to confirm some information about you, and I'm going to start audio recording. This will help us to accurately record your responses, but all this information will remain completely confidential. Is that OK?

First, I need to ask you some questions to confirm that you consent to participating. Remember, even after you've answered these questions, you can withdraw your consent at any time during the interview. Do you have any questions so far?

The consent questions are:

Question	Yes	No
Have you read the information contained in the participant information sheet?		

Have you had an opportunity to ask questions and are you satisfied with the answers you have received?		
Do you understand that the research will produce academic publications?		
Do you freely agree to participate in this activity, with the understanding that you may withdraw at any time?		
Do you agree to having this interview audio recorded and transcribed?		

(If answered NO to any of these – clarify and/or discontinue interview)

If you have any concerns about the research you can contact Lizeth Arango, whose contact details are on the information sheet I gave you.

If you would like to talk to someone who is not connected with the research, you may contact the Director of Research Ethics (telephone 9850 7854; email ethics@mq.edu.au)

Verbal Consent Script

Version 1 04/07/2022

Appendix D – Ethics Approval Consent Letter

Arts Subcommittee

Macquarie University, North Ryde

NSW 2109, Australia

02/08/2022

Dear Dr Fuller,

Reference No: 520221180240122

Project ID: 11802

Title: Construction waste, digital platforms and the circular economy

Thank you for submitting the above application for ethical review. The Arts Subcommittee has considered your application.

I am pleased to advise that ethical approval has been granted for this project to be conducted by Dr Sara Fuller, and other personnel: Miss Lizeth Vanessa Arango Cardozo, Dr Miriam Williams .

This research meets the requirements set out in the National Statement on Ethical Conduct in Human Research 2007, (updated July 2018).

Standard Conditions of Approval:

1. Continuing compliance with the requirements of the National Statement, available from the following website: https://nhmrc.gov.au/about-us/publications/national-statement-ethical-conduct-human-research-2007-updated-2018.
2. This approval is valid for five (5) years, subject to the submission of annual reports. Please submit your reports on the anniversary of the approval for this protocol. You will be sent an automatic reminder email one week from the due date to remind you of your reporting responsibilities.
3. All adverse events, including unforeseen events, which might affect the continued ethical acceptability of the project, must be reported to the subcommittee within 72 hours.
4. All proposed changes to the project and associated documents must be submitted to the subcommittee for review and approval before implementation. Changes can be made via the Human Research Ethics Management System.

The HREC Terms of Reference and Standard Operating Procedures are available from the Research Services website: https://www.mq.edu.au/research/ethics-integrity-and-policies/ethics/human-ethics.

It is the responsibility of the Chief Investigator to retain a copy of all documentation related to this project and to forward a copy of this approval letter to all personnel listed on the project.

Should you have any queries regarding your project, please contact the Faculty Ethics Officer.

The Arts Subcommittee wishes you every success in your research.

Yours sincerely,

Dr Mianna Lotz

Chair, Arts Subcommittee

The Faculty Ethics Subcommittees at Macquarie University operate in accordance with the National Statement on Ethical Conduct in Human Research 2007, (updated July 2018), [Section 5.2.22].