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Circular Economy for Construction and Demolition Waste in the Santiago Metropolitan Region of Chile: A Delphi Analysis

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Abstract: This study investigates the design and implementation of circular economy (CE) strategies for managing construction and demolition waste (CDW) in the Santiago Metropolitan Region of Chile (SMRC). The research aimed to identify key factors influencing the current and future adoption of CE practices for CDW management related to socio-environmental, technical, financial, and strategic-regulatory aspects, employing the Delphi method to gather expert insights. Findings reveal that the lack of knowledge about sustainable practices and the absence of regulatory frameworks for CDW disposal are the most critical barriers to effective CE implementation. The study recommends enhancing public awareness and environmental education through government and school programs, as well as enacting stricter legislation to combat illegal disposal and encourage sustainable practices and valorization of secondary raw materials within companies. Additionally, it emphasizes the importance of designing projects that prioritize waste avoidance and the development of infrastructure, technology, and processes for efficient material separation and recycling. The research also highlights potential challenges such as stagnation in the adoption of sustainable practices, skilled labor shortages, and limited research and innovation. It underscores the need for a comprehensive approach to CDW management that integrates socio-environmental, technical, financial, and regulatory dimensions to promote sustainability at both regional and global levels.

Keywords: circular economy (CE); construction demolition waste (CDW); Delphi methodology; Santiago Metropolitan Region of Chile (SMRC)

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Academic Editor: Paulo Santos

Received: 10 December 2024
Revised: 20 January 2025
Accepted: 24 January 2025
Published: 27 January 2025

Citation: Véliz, K.D.; Busco, C.; Walters, J.P.; Esparza, C. Circular Economy for Construction and Demolition Waste in the Santiago Metropolitan Region of Chile: A Delphi Analysis. *Sustainability* **2025**, *17*, 1057. https://doi.org/10.3390/su17031057

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1. Introduction

The concept of the circular economy (CE) links economic performance with environmental protection [1], presenting opportunities for waste management and innovation that enhance overall welfare [2]. CE is increasingly recognized worldwide [3], as evidenced by national policies within the European Union [4] and legislative efforts in countries like Germany, Japan, and China [5].

Globally, construction and demolition waste (CDW) accounts for approximately 30–40% of solid waste generation [6]. This sector significantly contributes to environmental challenges such as waste accumulation, greenhouse gas emissions, and excessive water consumption [7]. However, CE practices for CDW management can mitigate these impacts, aligning with sustainability principles across economic, social, and environmental dimensions [8–10]. For instance, the reduction of CDW minimizes environmental harm, conserves resources, and supports the circularity of the economy by lowering landfill use and carbon emissions. Meth-

ods for decreasing CDW include material reuse, recycling, design for deconstruction, and adopting sustainable construction practices and business.

In Chile, CDW management faces similar challenges. An estimated 7 million tons of CDW are generated annually, primarily from residential and commercial construction [11]. The Santiago Metropolitan Region of Chile (SMRC) alone produces 1,151,299 m^3 of CDW annually, representing 41% of the national total and leading to 931 unauthorized disposal sites [12]. This makes the SMRC the largest CDW generator in the country. Adopting CE principles in the SMRC's construction sector offers opportunities to improve productivity, reduce emissions, and enhance resource sustainability, as it is established in the Circular Santiago initiative, which seeks to involve organizations in the reconversion of their business models, incorporating circular criteria into the processes, goods and/or services they produce.

Despite the pressing need for better CDW management policies with the aim of reducing waste, further research is required to identify the factors influencing CE implementation in CDW (CE-CDW) management, both locally and globally, in the socio-environmental, technical, financial, and strategic-regulatory domains. Previous studies have used diverse methodologies, including systematic reviews, meta-analyses [13], surveys, and expert interviews [14]. Some studies have identified and ranked CE-CDW barriers using approaches like TOPSIS [15] or mixed-method analyses [16,17]. Others have focused on waste quantification methods [18] and sustainability assessments through multidisciplinary approaches [8]. However, there is limited understanding of expert perspectives on factors shaping CE-CDW implementation in dense urban areas [19], as it is the SMRC.

This study addresses this gap with a semi-quantitative analysis of key factors influencing CE-CDW implementation, using the SMRC as a case study. While some research has explored sustainable construction materials, such as recycled aggregate concrete [20] and recycled concrete [21], comprehensive studies on CE-CDW factors in the SMRC remain absent. Additionally, recent studies in the Aysén Region have investigated barriers to CE implementation in CDW using alternative methodologies, such as mixed-method approaches [16]. However, given that over 40% of Chile's population resides in the SMRC [22], understanding the factors' influence on CE-CDW implementation in this region is essential, as it is stated within the priority guidelines for the Santiago Circular Initiative.

The study aimed to answer the following research questions (RQs):

RQ1: What are the most relevant factors influencing the adoption of CE-CDW strategies in the SMRC?
RQ2: Which factors inhibit or enable CE-CDW adoption?
RQ3: How can identifying these factors inform current and future CE-CDW strategies?

To address these questions, a remote multi-round Delphi survey was conducted with local CDW experts. This study provides critical insights into the key factors influencing the adoption and sustainability of CE-CDW practices in the SMRC, offering a foundation for developing effective strategies that can address pressing urban waste management challenges in Chile and beyond.

2. Methods

The study employed the Delphi methodology, a systematic and controlled approach to asking opinions in order to achieve consensus among a panel of experts on complex issues through iterative rounds of anonymous questionnaires [23–26]. This method is particularly suitable for multi-dimensional problems, such as identifying and analyzing factors influencing the implementation and sustainability of CE-CDW practices in the SMRC, where empirical data are limited, expert consensus is required, and stakeholder perspectives play a crucial role in decision-making.

The adoption of CE-CDW in the SMRC involves various interrelated factors, including regulatory frameworks, economic incentives, technological constraints, and industry perceptions. Given the diversity of stakeholders—such as policymakers, industry professionals, and researchers—achieving consensus through structured rounds ensures a systematic refinement of expert judgments while minimizing biases from dominant opinions. The Delphi method's iterative and anonymous nature allows experts from different backgrounds to contribute insights without external influence, enhancing the reliability of the findings.

Consensus in Delphi studies is generally achieved by analyzing the variability in expert responses across rounds, using statistical measures such as absolute deviation [27] or interquartile range (IQR) [28]. For this study, three Delphi rounds were conducted, following recommendations by Keeney et al. (2001) [29] to limit rounds to avoid participant fatigue. Each round engaged experts in evaluating the importance and influence of 16 factors identified in the literature as impacting CE-CDW adoption. These factors, categorized into socio-environmental, technical, financial, and strategic-regulatory dimensions, were informed by Véliz et al. (2023) [16] and presented in Table 1.

Table 1. Factors considered by the Delphi panel of experts, categorized by dimension, and defined based on the literature.

Dimension	Factor	Definition
Socio-Environmental	Awareness, Knowledge, and Sustainable Actions	Level of awareness of CDW recycling and environmental protection [30,31].
	Short-Term Interest	Construction companies prioritize short-term monetary savings over environmental care, thus preferring the use of illegal landfills and unauthorized personnel to manage their CDW [32–34].
	Population Density and Urbanization	Population growth pressures companies to build, prioritizing rapid construction instead of sustainable CDW management [30,31,34–37].
	Risks and Natural Disasters	Lack of assignment of responsibility in the management of CDW in the face of natural disasters [36,38].
Technical	Infrastructure, Technology, and Processes	Lack of adequate infrastructure, technology, and processes that allow classification, transport, and recovery of CDW [32,33,39–41].
	Technological Knowledge	Stakeholders have inadequate technological knowledge and information along with a lack of experience in CE, which translates into traditional CDW management [30,35,36,40–44].
	Project Design and Execution	Presentation and implementation of initiatives, integrating sustainable CDW principles [45].
	Certification of Recycled Materials	Lack of technical certification of waste quality, leading to a low preference for recovered materials [15,42].
Financial	Capital Investment Budget	Difficulty and lack of budget for capital investment given its high value [30,32].
	Expected Return on Investment	Estimation of financial benefits [44].
	Willingness to Pay for Recycled Materials	Willingness to pay for recycled materials below their market price, leading to substitution of new materials [36,39,43].
	Cost of Production of Recycled Materials	The production cost of recovered materials is greater than the market price, discouraging new supply of these materials [36,42].
Strategic-Regulatory	Political–Strategic Vision	Political priorities and state agents are not focused on strategic CE objectives for CDW, which increases uncertainty and demotivation for sustainable waste management [30,35,46].
	Specific Legislation and Regulations	Specific laws and regulations established by the government that regulate and promote sustainable practices [30,34,36].
	Incentives for CE	Lack of incentives and supervision to recognize those who recirculate CDW and penalize those who manage CDW in non-authorized sites [32–34,40,41].
	Stakeholder Collaboration and Coordination	Collaboration that maximizes social benefit between interest groups is hindered by asymmetries and lack of coordination systems at central and local levels, due to lack of information [30,33,35,36,44].

2.1. Selection of Expert Participants

The study targeted a diverse range of professionals and experts in Chilean construction and demolition for the expert panel. Participants were selected based on their academic credentials related to the construction industry, affiliations with CDW-related organizations, and involvement in research or practice related to CE to represent the public and private sectors as well as civil society and academia. The search process included the following:

i. A systematic review of LinkedIn profiles using the keyword "circular economy".
ii. Outreach to experts featured on the "Economy Becomes Circular" podcast on Spotify.
iii. Recommendations from existing panel members.
iv. Identification of contributors to the CE-CDW report [11].

Diversity in expertise and background was prioritized, as heterogeneous panels tend to yield more reliable results in Delphi studies [47]. Table S1 summarizes the qualifications of experts who participated in at least one round, showing that 37% of them belong to the public sector, 26% to the private sector, 16% to civil society, 16% to academia, and 1% to NGOs. While there are no strict rules on the number of participants for a Delphi study [48], a larger initial panel was chosen to account for potential dropouts due to time constraints or other factors [27]. Participants were contacted equitably, without bias regarding demographic factors such as age or gender, to ensure impartiality.

After identifying potential participants, experts were invited via phone or email. Each invitation outlined the research topic, scope, and the requirement for anonymous and confidential participation. Experts who agreed to these terms were included in the Delphi panel. Initially, 39 experts accepted the invitation, demonstrating strong interest in the study. Of these, 19 participated in the first round, 13 in the second, and 7 in the third. Follow-up procedures conducted right after each round included up to three phone calls and emails for non-respondents. The incentives offered to respondents were mugs and pens printed with a logo for the development of circular construction in the country.

2.2. The Delphi Process

The three Delphi rounds were conducted using the online Qualtrics platform [49]. Participants were given two weeks to complete each round's questionnaire, distributed via email. The first round addressed the following:

i. Factor importance: Experts rated each factor's importance using Likert-scale questions [50] on a 5-point scale, where 1 indicated "*not important*", 2 "*somewhat important*", 3 "*moderately important*", 4 "*very important*", and 5 "*extremely important*", addressing RQ1.
ii. Factor influence: Experts identified each factor as "*enabling*", "*neutral*", or "*inhibiting*" CE-CDW adoption, addressing RQ2.
iii. Open-ended questions allowed participants to justify their ratings, suggest additional factors, and provide insights into the anticipated evolution of CE-CDW practices between 2025 and 2035.

In the second round, factors that lacked consensus in Round 1 were re-evaluated. Experts were shown their previous ratings, the group median and mode, and invited to adjust their responses. Consensus was determined using IQR and absolute deviation, with thresholds of ≤ 1 [26]. These statistical metrics were employed to not only evaluate consensus but, more broadly, the variability and uncertainty in responses, in order to draw conclusions about the relative importance of different factors. A comment field was provided for participants to explain their decision to maintain or revise their scores.

The third round focused on factors that still lacked consensus. Experts were asked to provide qualitative insights to better understand the divergence in opinions. This round aimed to capture a more nuanced understanding of factors that did not achieve consensus. Figure 1 provides an overview of the Delphi process across all three rounds.

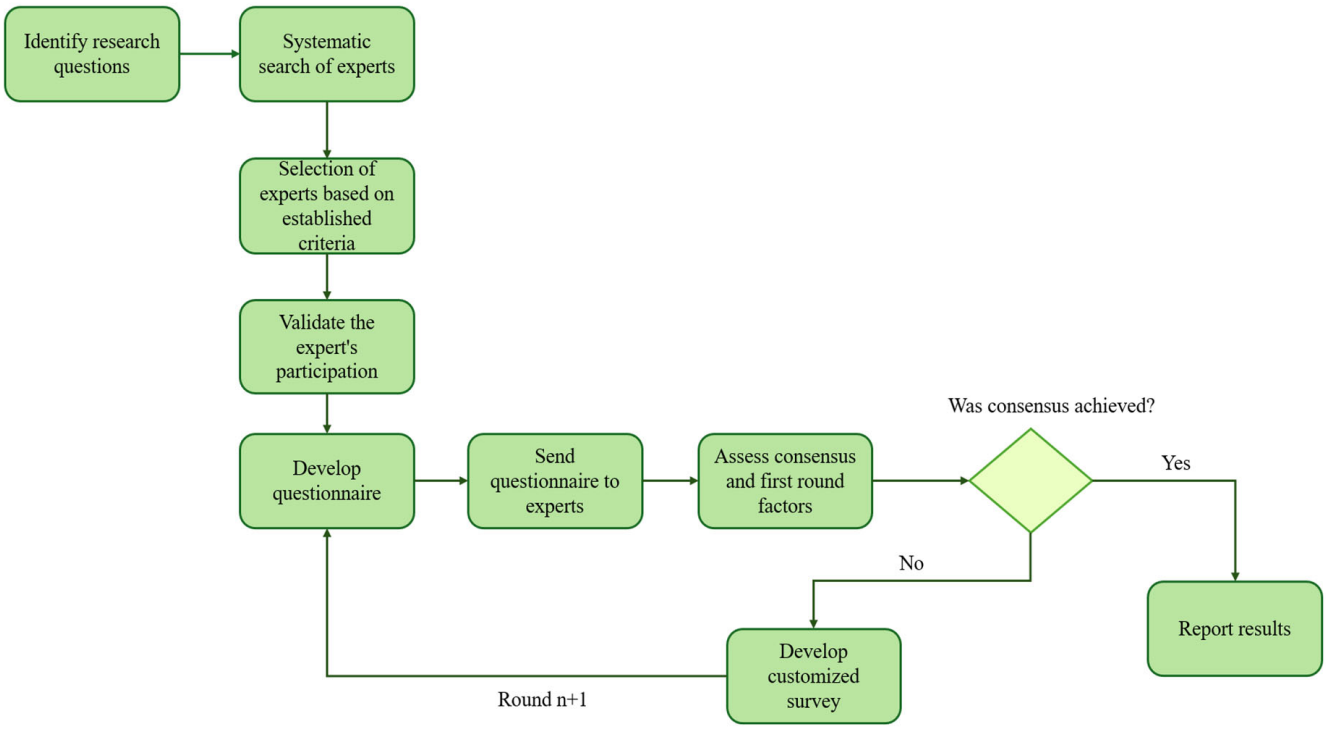


Figure 1. The Delphi process used in this study.

To evaluate the relative importance of factors (RQ1), a hierarchical ranking was performed using *average range*—a non-parametric statistical technique that accounts for repeated Likert scores [51–53]. This method was chosen for its suitability in capturing the aggregated opinions of multiple experts. Additionally, all qualitative information gathered during the three Delphi rounds was coded according to the identified factors and subsequently used to better explain the results, incorporating direct quotes from the participants.

3. Results

The Delphi process provided valuable insights into the factors influencing the adoption of CE-CDW practices in the SMRC. Across three iterative rounds, expert evaluations highlighted areas of consensus and disagreement, offering a nuanced understanding of the factors' importance and their roles as enablers or inhibitors. The results reveal key dimensions driving CE-CDW implementation and shed light on unresolved factors requiring further exploration. A summary of the findings is presented below, structured by each round of analysis.

In the first round, 16 factors were evaluated, revealing that nine factors achieved consensus on importance, while seven did not. Among the consensus factors, "Awareness, Knowledge, and Sustainable Actions" had the highest average range score, followed by "Specific Legislation and Regulations" and "Infrastructure, Technology, and Processes". Factors lacking consensus primarily fell within the socio-environmental and financial dimensions, whereas technical dimension factors exhibited strong agreement (see Table 2).

Table 2. Factor importance results for Round 1.

Dimension	Factor	Min	Max	Med	Average Range	Abs. Deviation	IQR	Consensus
Socio-Environmental	Awareness, Knowledge, and Sustainable Actions	2	5	5	5.87	0.84	0.0	Yes
	Short-Term Interest	1	5	4	3.34	1.10	1.0	No
	Population Density and Urbanization	1	5	3	2.89	1.31	1.0	No
	Risks and Natural Disasters	1	5	4	3.34	1.10	1.0	No
Technique	Infrastructure, Technology, and Processes	3	5	5	5.32	89	1.0	Yes
	Technological Knowledge	3	5	4	4.24	1.00	1.0	Yes
	Project Design and Execution	3	5	5	5.42	0.89	0.5	Yes
	Certification of Recycled Materials	3	5	5	4.84	0.94	1.0	Yes
Financial	Capital Investment Budget	1	5	5	4.39	1.42	1.5	No
	Expected Return on Investment	2	5	4	4.55	1.10	1.5	No
	Willingness to Pay for Recycled Materials	1	5	5	4.50	1.15	2.0	No
	Cost of Production of Recycled Materials	2	5	4	3.58	0.73	1.0	Yes
Strategic-Regulatory	Political–Strategic Vision	3	5	5	4.97	1.05	1.0	No
	Specific Legislation and Regulations	4	5	5	5.71	0.63	0.5	Yes
	Incentives for CE	4	5	5	4.82	0.89	1.0	Yes
	Stakeholder Collaboration and Coordination	3	5	5	5.21	0.89	1.0	Yes

For influence type, 10 factors reached consensus, of which nine were considered enabling. The sole consensus factor identified as inhibiting CE-CDW adoption was "Production Costs". Factors that did not achieve consensus on importance or influence type were reevaluated in subsequent rounds (see Table 3).

Table 3. Factor influence results for Round 1, presented as percentages (%) of experts indicating each of the influence types.

Dimension	Factor	[1: Enables+]	[2: Does Not Contribute]	[3: Inhibits−]
Socio-Environmental	Awareness, Knowledge, and Sustainable Actions	68	16	16
	Short-Term Interest	37	11	52
	Population Density and Urbanization	26	26	48
	Risks and Natural Disasters	57	11	32
Technique	Infrastructure, Technology, and Processes	79	0	21
	Technological Knowledge	78	11	11
	Project Design and Execution	84	5	11
	Certification of Recycled Materials	79	5	16
Financial	Capital Investment Budget	58	11	31
	Expected Return on Investment	32	16	52
	Willingness to Pay for Recycled Materials	37	16	47
	Cost of Production of Recycled Materials	21	26	53
Strategic-Regulatory	Political–Strategic Vision	74	21	5
	Specific Legislation and Regulations	63	16	21
	Incentives for CE	90	5	5
	Stakeholder Collaboration and Coordination	79	5	16

In the second round, seven non-consensus factors for importance (Table 4) and six for influence (Table 5) type were analyzed. Key factors included "Short-Term Interest", "Population Density and Urbanization", "Risks and Natural Disasters", "Capital Investment Budget", "Expected Return on Investment", and "Willingness to Pay for Recycled Materials".

By the end of Round 2, five factors achieved consensus on importance, with "Political–Strategic Vision" ranked as the most important. However, "Population Density and Urbanization" and "Willingness to Pay for Recycled Materials" remained non-consensus factors. For influence type, only "Population Density" achieved consensus, leaving five factors unresolved.

Table 4. Factor importance results for Round 2.

Dimension	Factor	Min.	Max	Med	Average Range	Abs. Deviation	IQR	Consensus
Socio-Environmental	Short-Term Interest	3	5	4	2.27	0.38	0.0	Yes
	Population Density and Urbanization	2	5	4	1.31	1.07	2.0	No
	Risks and Natural Disasters	1	5	4	2.19	0.76	1.0	Yes
Financial	Capital Investment Budget	2	5	5	3.27	0.61	1.0	Yes
	Expected Return on Investment	4	5	5	3,58	0.30	1.0	Yes
	Willingness to Pay for Recycled Materials	3	5	5	1.69	0.76	2.0	No
	Political–Strategic Vision	4	5	5	3.69	0.23	0.0	Yes

Table 5. Factor influence results for Round 2, presented as percentages (%) of experts indicating each of the influence types.

Dimension	Factor	[1: Enables +]	[2: Does Not Contribute]	[3: Inhibits −]
Socio-Environmental	Short-Term Interest	46	0	54
	Population Density and Urbanization	62	15	23
	Risks and Natural Disasters	46	15	38
Financial	Capital Investment Budget	54	0	46
	Expected Return on Investment	46	0	54
	Willingness to Pay for Recycled Materials	46	23	31

Table 6 summarizes the rankings of consensus factors by average range scores and their influence type. Notably, factors ranked higher in Round 1 retained their position over those achieving consensus in Round 2, even if their scores were slightly lower (e.g., "Cost of Production of Recycled Materials" outranks "Political–Strategic Vision" due to earlier consensus).

Table 6. Ranking of consensus factors for Round 1 and Round 2. Each factor in this table reached consensus for influence type (enables, no influence, or inhibits). The mode for influence type for each consensus factor is also provided.

Factors	Ranking (R)	Average Range	Influence Type	Consensus Round
Awareness, Knowledge, and Sustainable Actions	R1	5.87	Enables	1
Specific Legislation and Regulations	R2	5.71	Enables	1
Project Design and Execution	R3	5.42	Enables	1
Infrastructure, Technology, and Processes	R4	5.32	Enables	1
Stakeholder Collaboration and Coordination	R5	5.21	Enables	1
Certification of Recycled Materials	R6	4.84	Enables	1
Incentives for CE	R7	4.82	Enables	1
Technological Knowledge	R8	4.24	Enables	1
Cost of Production of Recycled Materials	R9	3.58	Inhibits	1
Political–Strategic Vision	R10	3.69	Enables	2
Expected Return on Investment	R11	3.58	Non-consensus	2
Capital Investment Budget	R12	3.27	Non-consensus	2
Short-Term Interest	R13	2.27	Non-consensus	2
Risks and Natural Disasters	R14	2.19	Non-consensus	2

The third round focused on gathering qualitative insights into the two non-consensus factors for importance and five for influence type. Expert responses highlighted underlying disagreements, particularly within the socio-environmental and financial dimensions, which informed the discussion on policy implications and recommendations (addressing RQ3).

The socio-environmental dimension displayed the widest variability in importance rankings, with "Awareness, Knowledge, and Sustainable Actions" ranked highest and "Short-Term Interest" and "Risks and Natural Disasters" ranked lowest. In contrast, the strategic-regulatory dimension demonstrated greater agreement, led by "Specific Legislation and Regulations".

For influence type, "Cost of Production of Recycled Materials" was the only factor identified as inhibiting CE-CDW adoption. Factors such as "Willingness to Pay for Recy-

cled Products", "Expected Return on Investment", and "Short-Term Interest" remained unresolved, with "Willingness to Pay for Recycled Products" failing to achieve consensus on any evaluated aspect.

4. Discussion

This study examines the complex interplay of socio-environmental, technical, financial, and strategic-regulatory dimensions in advancing CE practices for CDW management. The findings, based on a Delphi panel of experts, emphasize the critical factors influencing sustainable outcomes in this domain.

4.1. Socio-Environmental Dimension

The socio-environmental dimension is vital for circular construction and has a high potential for workability as it fosters awareness and knowledge, enabling stakeholders to understand the benefits of resource efficiency and waste minimization. By promoting sustainable actions and engaging communities, it builds a culture of shared responsibility, encouraging practical implementation. This collective approach ensures long-term workability and progress toward circularity in the construction sector. The findings highlight this dimension as the most outstanding given that "Awareness, Knowledge, and Sustainable Actions" is the most significant factor among all dimensions, achieving consensus among experts. This factor's prominence reflects its centrality in strategic decision-making processes for advancing CE practices globally [54]. Diverse strategies aimed at conserving material and waste value chains often emerge from shared cultural and legal contexts, offering valuable insights for shaping guidelines in other regions. As one expert observed, "*Knowledge of sustainable actions allows for proper planning in a circular economy strategy*". Education forms the foundation for this awareness, serving as both an informational and motivational tool [55]. This dual role bridges the gap between theoretical knowledge and pro-ecological behavior, fostering attitudes conducive to sustainable development. To address this, government awareness campaigns and environmental education from early childhood are recommended to instill sustainable practices.

Panelists consistently emphasized education's transformative potential, aligning with Sukiennik et al.'s (2021) [55] argument that cultivating pro-ecological attitudes requires long-term, systemic efforts. One expert reinforced this, stating, "*One must be educated to be aware of the decisions that are made*". Early childhood education on CE benefits, such as how sustainable practices strengthen communities, was highlighted as pivotal for driving cultural change [56]. Such education promotes ethical reflection and conscientious decision-making across individual, organizational, and policy levels. In addition, the identification of areas in which training is needed to prepare the future workforce for the challenges of circular construction, by establishing the necessary theoretical, practical, regulatory, and technological guidelines for professionals and technicians, as well as the respective training offerings in university and technical education institutions, would be a starting practical measure at the policy level. In contrast, "Short-Term Interests" emerged as a barrier to progress, ranking lower within the socio-environmental dimension. Experts noted that reliance on short-term perspectives hampers the implementation of infrastructure and processes critical for CE-CDW. As one panelist remarked, "*A medium- and long-term vision is required*". Short-term approaches like green roofs and CDW recycling plants offer viable, low-risk investments with relatively rapid payback periods [57,58]. However, the broader transition to circularity requires aligning immediate benefits with long-term sustainability goals.

The factor "Risks and Natural Disasters", which also reached consensus, underscores the vulnerability of CE-CDW initiatives to external shocks such as earthquakes, floods,

and fires. These events not only generate substantial amounts of CDW but also amplify the need for proper disposal systems and regulatory frameworks. One expert highlighted that these elements "*pose a risk to the population; therefore, when events occur, the importance of proper disposal is highlighted, and with it, a responsibility is given to whoever generates the waste*". This dual focus on immediate response and long-term planning highlights the intricate relationship between disaster resilience and sustainable waste management [59,60].

4.2. Technical Dimension

The technical dimension demonstrates broad consensus across factors, with "Project Design and Execution" leading the ranking. Experts emphasized that incorporating circularity principles from the design phase minimizes waste and optimizes resource use. Effective project execution not only ensures compliance with environmental regulations but also aligns with international sustainable development objectives [4,61,62]. By prioritizing designs that minimize waste generation and incorporate CE principles, the sector can enhance its contribution to sustainability.

Infrastructure, technology, and processes are equally crucial. Adequate facilities and advanced technologies enable proper CDW management and maximize resource utilization [63]. However, the lack of enabling infrastructure in regions like Chile poses significant challenges. Certification of recycled materials also emerged as a critical yet underdeveloped area, with stakeholders expressing concerns about the absence of certifying entities to ensure quality standards [64]. Addressing these gaps, alongside incentivizing CE practices, is essential for fostering market confidence and broader adoption.

Technological knowledge remains a limiting factor, as highlighted by one expert: "*Few actors in the industry really know about life cycle or circularity*". Innovations such as building information modeling (BIM) offer promising solutions, reducing costs, time, and waste while driving industry transformation [65]. Continued investment in technological literacy will be pivotal for achieving CE-CDW goals.

4.3. Financial Dimension

The financial dimension reflects a nuanced dynamic, with "Cost of Production of Recycled Materials" being the only factor to achieve consensus in Round 1. High production costs often hinder the adoption of recycled materials, underscoring the necessity for policies that reduce costs while promoting the valorization of CDW [66]. Nonetheless, experts noted the potential for significant economic returns when strategies align with environmental and regional characteristics [63]. As one panelist noted, "*Despite the higher cost of producing a product with recycled material, we achieve a higher value of the product itself*". Effective cost management and tailored strategies can help mitigate financial barriers and enhance economic returns [63].

Interestingly, while financial factors are often seen as central to CE-CDW success [67–69], the experts placed greater importance on socio-technical, socio-environmental, and socio-political dimensions. This prioritization reflects the multifaceted nature of CE adoption, where financial considerations, though significant, must integrate with broader systemic factors.

Round 2 further emphasized the importance of "Expected Return on Investment" and "Capital Investment Budget". Although returns often require longer time horizons, they are integral to organizational growth and financial planning. For example, research from Thailand indicated that recycling programs might require up to 17 years to become financially feasible [70]. This extended payback period [43] reflects the broader challenge of aligning long-term sustainability goals with the short-term priorities of investors and businesses. However, the high initial costs and delayed returns make CE-CDW investments less attractive in developing contexts, where municipal solid waste management already strains budgets [71]. Address-

ing these financial constraints through targeted policies and incentives will be essential for fostering investor confidence and supporting sustainable initiatives.

4.4. Strategic-Regulatory Dimension

The "Specific Legislation and Regulations" factor ranked second in importance within this dimension, highlighting the critical role of clear and enforceable rules in advancing CE-CDW practices. Geels (2019) [72] notes that legislation alone is insufficient without pragmatic guidelines and awareness among stakeholders. For instance, in Chile, 60% of construction professionals are unaware of CDW-related laws, contributing to widespread illegal disposal and associated environmental impacts [11,12,73]. Similar challenges are seen globally, as in China, where CDW-specific legislation failed to achieve its goals due to unclear regulations and a lack of economic incentives [74,75]. Without strong regulations, companies are not compelled to implement sustainable practices, leading to improper waste disposal, such as the prevalence of illegal sites in Chile. Thoughtful and enforceable regulatory frameworks are critical to overcoming this challenge, especially for the valorization of secondary raw materials within companies. These policies have the potential to create markets with economic incentives that provide certainty for the infrastructure investments needed and speed up permit processing. Also, a regulatory framework focused on increasing recovery rates is relevant for significant progress in the proper management of CDW. Furthermore, a regulatory development focused on industrial symbiosis would allow the creation of new business models of design, use, and circular reuse through digital platforms where there are georeferenced records of demand and supply centers of CDW with their respective recovery, along with information on transporters, waste managers, and final disposal centers.

"Stakeholder Collaboration and Coordination", ranked fifth, emphasizes the need for synergy among key actors, including governments, recyclers, and builders [76]. Effective collaboration fosters local initiatives and a circular construction paradigm, as one expert noted, "*local initiatives are being generated thanks to the different stakeholders*".

The Incentives for CE factor, ranked seventh, underscores the importance of financial mechanisms to encourage sustainable practices. Experts stressed the need for incentives to drive investment in recycled materials, enhance compliance, and reduce illegal landfill practices [77,78]. As one panelist observed, "*Everyone should have an incentive to invest in recycled materials and, in turn, have certainty and a standard of differentiation*".

Consensus in Round 2 reflects its importance in integrating technical innovation, customer engagement, and regulatory frameworks. International examples such as the EU's Waste Framework Directive and Vietnam's Circular 08 demonstrate how political commitment can drive CE-CDW success [43,79]. However, contrasting cases like France reveal that technical progress alone is insufficient without political support and logistical coordination, emphasizing the role of public policies in transforming CDW management practices [80].

Effective CDW management requires comprehensive policies spanning design, reuse, and recycling, as one expert remarked, "*Transformation doesn't happen naturally; it requires public policies*". Addressing these strategic-regulatory dimensions can ensure sustainable practices and drive meaningful change in CE-CDW systems.

4.5. Study Limitations

The study findings were influenced by three key constraints, potentially impacting their accuracy and generalizability. Firstly, the geographic focus on the SMRC and the limited availability of experts in CE or CDW restricted the participant pool. Since the research relied on sector experts' perceptions, maintaining enough panelists across the

three rounds of Delphi surveys was challenging. This limitation in participant numbers may affect the robustness of the study.

Secondly, the dynamic nature of factors influencing CE and CDW, combined with the static nature of the factors discussed during the brief expert engagement period, limits the study's capacity to derive high-level findings. Extending the timeframe of future research and broadening its geographic scope to include additional regions nationally or globally could provide a more comprehensive understanding of the factors affecting CE implementation. Such an expanded approach could better inform future scenarios for CE-CDW adoption.

Thirdly, participant attrition across the three Delphi rounds posed a challenge to the study. As experts withdrew, the diversity of perspectives may have been reduced, potentially biasing the final consensus. This drop-off could also shift group dynamics, leading to less engagement or a homogenized set of responses, diminishing the richness of the findings. While participant loss is a common issue in Delphi studies, the author Landeta (1999) [81] recommends a panel size of 7 to 30 experts for meaningful results. To mitigate this challenge, we implemented several strategies to encourage sustained participation. We followed up with participants via email (three times within a 10-day period) and phone calls (twice within a 5-day period when the previous method was not effective), offering both in-person visits to their workplace and online meetings to guide them through the questionnaire. Additionally, we provided direct assistance using a tablet to facilitate responses and reduce respondent burden. As an incentive, we offered the respondents mugs and pens printed with a logo for the development of circular construction in the country, and also the commitment to sharing the study's findings with participants once the paper is published. Despite these efforts, we acknowledge that the length of the instrument, designed to comprehensively assess both importance and influence, may have contributed to participant fatigue and reduced engagement in later rounds. Regardless of these limitations, the study provides a comprehensive discussion of factor importance (RQ1), influence types (RQ2), and actionable recommendations for CE-CDW policy and practice in Chile (RQ3). These insights contribute to future research on applying CE principles in the construction sector.

5. Conclusions

This study employed a multi-round Delphi survey with a diverse panel of experts to identify and characterize key factors influencing the adoption of circular economy (CE) practices in construction and demolition waste (CDW) management within the SMRC. Factors were evaluated across socio-environmental, technical, financial, and strategic-regulatory dimensions. The findings highlight the lack of knowledge about sustainable actions promoting CE in CDW as the most significant barrier to circularity. Additionally, the absence of enforceable laws and regulations governing CDW disposal and the need for comprehensive awareness initiatives emerged as critical challenges.

To advance CE-CDW adoption in the SMRC, public awareness campaigns and environmental education programs, particularly in schools, are strongly recommended. These initiatives can foster a culture of waste reduction and recycling. Equally important is the establishment of robust and enforceable legislation to compel companies to adopt sustainable practices and address issues such as illegal disposal sites.

Effective project design and execution must prioritize waste prevention and adherence to CE principles, while the development of infrastructure, technology, and processes is critical for enabling efficient separation, processing, and reuse of materials. However, challenges such as stagnation in the implementation of sustainable measures, a shortage of

skilled labor, and insufficient research and development continue to hinder the adoption of innovative technologies necessary for comprehensive life-cycle management.

In conclusion, this study provides a comprehensive evaluation of socio-environmental, technical, financial, and regulatory factors affecting CE implementation for CDW management. It underscores the need for a balanced approach across these dimensions to achieve reliable and sustainable outcomes. Beyond addressing regional challenges, the findings have broader implications, emphasizing the importance of strategic political commitment to sustainability in CDW management. This commitment is essential for embedding CE principles in metropolitan areas across Chile and beyond, contributing to a more sustainable global framework for CDW management.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/su17031057/s1; Table S1: Profile of Delphi panel experts selected; Table S2: Factor influence results for Round 1; Table S3: Factor importance results from Round 2; Table S4: Factor influence results for Round 2.

Author Contributions: Conceptualization, K.D.V., J.P.W. and C.B.; methodology, J.P.W. and C.B.; software, C.E.; validation, K.D.V., C.E. and J.P.W.; formal analysis, K.D.V., C.E. and C.B.; investigation, K.D.V., C.B. and C.E.; resources, K.D.V.; data curation, C.E.; writing—original draft preparation, K.D.V. and C.E.; writing—review and editing, K.D.V., C.E., C.B. and J.W; visualization, C.E., C.B. and J.P.W.; supervision, K.D.V., C.B. and J.P.W.; project administration, K.D.V.; funding acquisition, K.D.V. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by FONDECYT INICIACION (Grant No. 11230895).

Institutional Review Board Statement: This research was approved by the ethics committee at Universidad Diego Portales, approval number 018-2023, obtained on 29 May 2023.

Informed Consent Statement: Informed consent was obtained from all participants involved in the study.

Data Availability Statement: Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

Acknowledgments: We sincerely thank the stakeholders surveyed for their valuable time. This study would not have been possible without their knowledgeable input.

Conflicts of Interest: The authors declare no conflicts of interest.

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