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Analysis of preparedness for climate change in construction projects from the perspective of multiple stakeholders in Chile

Análisis de la preparación para el cambio climático en proyectos de construcción desde la perspectiva de múltiples partes interesadas en Chile

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Abstract

Climate change and its effects are becoming more latent every day, and the construction industry plays a significant role in this context. Therefore, this study aims to analyze the level of development of construction projects in climate change preparedness according to the various stakeholders of the industry in Chile through semi-structured interviews with construction and environmental professionals. The findings show that Chile is at an early stage in preparing for climate change both in the development of regulations and in the proper management of waste generated during construction projects. It highlights the crucial role of the government in implementing legislation and incentivizing more sustainable practices in the construction sector. Additionally, we found the importance of making changes from the design stage of projects to improve climate change preparedness in construction projects. This work contributes to filling the knowledge gap on the current approach of the construction sector to climate change in Chile and to a deeper understanding of the context of the climate crisis in a developing country. It also provides valuable background for the development of future environmental policies in the sector.

Keywords: Climate change; construction; stakeholders.

Resumen

El cambio climático y sus efectos se está convirtiendo cada día más latentes en nuestra sociedad; en este contexto, la industria de la construcción juega un rol significativo en la preparación frente al cambio climático. Entonces, comprender el nivel de preparación de esta industria puede entregarnos hallazgos clave para políticas públicas y tomadores de decisiones en la batalla en contra del cambio climático. En este contexto, este estudio busca analizar qué tan preparados están los proyectos de construcción en Chile para lidiar con el cambio climático desde la perspectiva de diversas partes interesadas. Esto se realiza al analizar cualitativamente entrevistas semi-estructuradas con partes interesadas del sector de la construcción chilena. Nuestros resultados sugieren que el realizar cambios desde la etapa de diseño de los proyectos podría mejorar la preparación para el cambio climático en proyectos de construcción. además, encontramos que los proyectos de construcción en Chile se encuentran en una etapa temprana en su preparación frente al cambio climático, por ejemplo, en el desarrollo de regulaciones y la apropiada gestión de los residuos generados durante la construcción de proyectos. Como tal, el estado juega un rol clave en desarrollar y actualizar legislación existente así como también el incentivar practicas sostenibles para que sean implementadas en proyectos de construcción. Esta investigación contribuye al proveer una conceptualización y un mejor entendimiento sobre qué tan preparado los proyectos de construcción en Chile se encuentran para lidiar con el cambio climático. Por último, nuestros resultados proveen una mejor comprensión sobre la construcción y partes interesadas para diseñar y desarrollar planes y políticas para enfrentar el cambio climático.

Keywords: Cambio climático; construcción; partes interesadas.

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1. Introduction

Climate change encompasses transformations in climate conditions that occur over an extended period of time, whether due to natural or human-made changes. These changes generate variations in the planet's climate, causing extreme weather events to become more frequent and intense, such as droughts, floods, rising temperatures, and sea levels (MMA, 2022). To address this issue, the United Nations Framework Convention on Climate Change (UNFCCC) was founded in 1992, creating commitments such as the Paris Agreement of 2015. This agreement seeks to limit the increase in global temperature to less than +2ºC, and preferably to +1.5ºC by the end of the century, by reducing greenhouse gas emissions (UN, 2015).

The construction sector, central to the global economy, is also a major contributor to greenhouse gas emissions globally. By 2021, approximately 37% of energy-and process-related CO2 emissions came from this sector (IEA, 2022; Global ABC, 2022). CO2 emissions from the operation of buildings reached record levels, and the manufacture of materials such as concrete, steel, aluminum, and glass has also contributed approximately 6 to 9% of global energy emissions (IEA, 2022; Global ABC, 2022). In addition to its impact on emissions, the construction industry is the largest consumer of resources and generator of a substantial amount of waste (Ellen MacArthur Foundation, 2020), using approximately 40% of total raw materials and generating around 40% of solid waste in countries such as the United States (WEF, 2016). Research has been conducted around the globe to understand existing barriers and challenges faced by the construction industry in the fight against climate change, highlighting concerns such as high costs (Zhang et al., 2011), lack of market demand (Ohene et al., 2022), low awareness of the benefits of sustainable buildings (Balasubramanian, 2012; Djokoto et al., 2014), and financial constraints to implement green technologies (Chan et al., 2018).

In Chile, the construction sector plays a key role in gas emissions and waste generation. Although official data on Greenhouse Gas (GHG) emissions from the construction sector are not available, estimates indicate that this sector could contribute up to 22.8% of total GHG emissions in Chile (Acuña et al., 2019). Furthermore, it was estimated that between 26% and 34% of the waste generated in the country came from construction and demolition waste (CDW), surpassing even municipal waste (CONAMA, 2010; Minvu, 2019). Given this context, the construction industry faces multiple challenges in dealing with climate change, spanning from the need to reduce emissions to a more efficient use of resources and the reduction of the generated waste. In this context, the objective of this study is to analyze the level of preparedness of construction projects in Chile in dealing with climate change.

2. Literature review

2.1 Construction and climate change

The construction industry plays a significant role in the context of climate change. While its socio-economic relevance is undeniable, this sector faces major environmental challenges, characterized by its contribution to CO2 emissions, energy use, high resource consumption, and waste generation (Acuña et al., 2019; Hurlimann et al., 2019; UN, 2015; Rodriguez and Fernandez, 2010). In this literature review, given the extensive body of knowledge about climate change, we focus on publications since 2010 to encompass roughly the last 15 years of research on the topic; nonetheless, studies published before that date were also considered to be included in exceptional cases. Regarding the topics explored, we mostly focus on gas emissions and waste generation as the main aspects that the construction sector contributes to climate change. Important to note, this was not a systematic literature review.

This review focuses on the state of the construction industry's preparation for climate change in various countries around the globe. A relevant study in this context is the one conducted by Hurlimann et al. (2019) in Australia, where it indicates that extreme weather is recognized as the main risk due to climate change and that most actions to deal with climate change focus on mitigation instead of adaptation. Similarly, studies by Gunawansa and Kua (2014) and Morton et al. (2011) emphasize that mitigation strategies dominate over adaptive ones. In fact, Kristl et al. (2020) pointed out that the capacity of the construction industry to adapt to climate change is often affected by ambiguous or inaccurate projections and lack of information on the consequences of climate change, which also affects economic consequences of climate change, and thus, leading to the conclusion that immediate or short-term strategies are too costly to be implemented. Similarly, the perceived unaffordability of climate change initiatives emerges as one of the main barriers, as well as inconsistent and unclear language, lack of awareness of climate change, perceived unfeasible initiatives, limited regulation, and lack of demand from clients to implement initiatives (Hurlimann et al., 2018). For instance, additional barriers and constraints were identified in the studies by Zhang et al. (2011) and Ying Liu et al. (2012), where they agree that lack of experience and awareness is a significant barrier, highlighting the high costs associated with green appliance design and those related to design

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and cost control in construction. They stress the importance of raising awareness among citizens to understand the advantages of green buildings (Wu et al., 2019; Abidin, 2010; Zhang et al., 2011; Ying Liu et al., 2012).

The development of sustainable buildings faces significant economic challenges, according to various studies. Durdyev et al. (2018) confirm that high costs of such buildings are a major barrier. Similarly, Weerasinghe et al. (2017) estimate that green buildings are 28% more expensive to construct but have operating and maintenance costs up to 28% lower than conventional ones. In different places, such as Ghana and the United Arab Emirates, studies such as Djokoto et al. (2014) and Balasubramanian (2012), respectively, agree that high upfront cost, low demand, lack of awareness, and government support are persistent barriers.

Important to note that multiple studies have found that the lack of knowledge is an underestimated but common barrier for dealing with climate change in construction (AlSanad, 2015; Durdyev et al., 2018; Fitriani and Ajayi, 2023). This may relate to limiting the understanding of the benefits of sustainable practices and their role in climate change (Francart et al., 2019). For example, Wilson and Rezgui (2013) emphasize the fragmented knowledge in the UK and Wales, while in Chile, 60% of construction professionals are unaware of waste management regulations (Construye 2025, n.d.). An explanation for the limited knowledge and awareness among construction sectors around the globe might be related to the lack of support and lack of government incentives to do so (Durdyev et al., 2018; Chan et al., 2018; Serpell et al., 2013; Djokoto et al., 2014; Bilal et al., 2020; Balasubramanian, 2012). Moreover, insufficient regulations, standards, and adequate policies hinder the widespread adoption of sustainable practices (Bilal et al., 2020; Fitriani and Ajayi, 2023; Wu et al., 2019; Darko and Chan, 2017; Serpell et al., 2013).

When it comes to the issue of waste generation, the construction sector is considered one of the sectors that generates the largest amount of waste globally (Esa et al., 2017; Alsheyab, 2022). The accelerated growth of construction in recent years has directly influenced the increase in waste generation (Bakshan et al., 2015). The large volume of waste is related to the linear economy typically used by the construction industry (Esa et al., 2017). For this reason, experts suggest the need to apply new ways, such as the circular economy (Merli et al., 2018), which seeks to minimize waste generation by keeping resources and materials in a closed loop (Ogunmakinde et al., 2022), contributing significantly to reducing the environmental impact of the industry (Núñez-Cacho et al., 2018). However, the circular economy faces several barriers in its implementation as well, such as a lack of awareness, upfront costs, current business models, lack of regulation (Guerra and Leite, 2021), and negative perception of recycled materials (Kim, 2021).

Ultimately, the importance of adopting sustainable design and construction practices to deal with climate change in construction requires collaboration from all stakeholders, from government to contractors and designers throughout the entire project life cycle (Sim and Putuhena, 2015). Therefore, there is an opportunity to explore how the construction sector is prepared to deal with climate change from the perspective of multiple stakeholders, in the context of a developing nation, such as Chile, where limited studies exist on this topic.

2.2 Construction stakeholders

Stakeholders, according to Molwus (2014), are individuals or groups with rights over the project, with the ability to perceive benefits or losses during or at the end of the project. Stakeholders can be divided into internal stakeholders and external stakeholders. Internal stakeholders can be defined as those who are formally connected to the project (Gibson, 2000), who actively participate in its implementation (Olander, 2006), are part of its organization, or who finance it (Calvert, 1995). External stakeholders do not participate in the implementation or form part of the project organization (Gibson, 2000). Although they do not have direct contractual links with the owner, they have interests and rights that can have a significant impact on the project (Calvert, 1995). However, it is recognized that stakeholders in the construction industry are more complex than in other sectors, due to the difficulty of construction processes (Yang, 2009), coupled with the long life of buildings and their environmental impact, a large number of stakeholders are involved throughout their life cycle.

Leung and Olomolaiye (2010) classified stakeholders into five main groups: clients, consultants, contractors, external public parties, and external private parties. While Molwus (2014) classifies the five groups into internal and external stakeholders. The former includes clients, professionals, and contractors, while public and private parties are external. He highlights that government authority can be internal or external depending on its role (Molwus, 2014; Wallbaum et al., 2010; Freeman, 1984).

In the context of sustainable construction, it is important to consider external stakeholders as it broadens concerns beyond organizations and business (Friedman and Miles, 2006). Focusing only on internal stakeholders can be problematic, as companies often prioritize economic benefits

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over sustainability (Li Ang and Wilkinson, 2008). It is essential to understand the interests and actions of external stakeholders (Aaltonen and Kujala, 2010), as their attitude can impact the project (De Schepper et al., 2014). A negative stakeholder attitude can cause conflicts and delays in implementation (Olander and Ladin, 2005). The Hallandsås tunnel in Sweden is an example of how inadequate external stakeholder analysis delayed the completion of the project for almost 20 years (Olarder, 2006). Existing studies have focused on either a wide range of stakeholders (Ying Liu et al., 2012) or specific stakeholder groups from the construction industry (e.g., Hurlimann et al., 2018; Serpell et al., 2013). Ultimately, this study focuses on covering a diversity of construction stakeholders to uagrnderstand the different perspectives of professionals working directly in the execution of a project, as well as advisors, consultants, and government agents.

2.3 Chile in the Latin American context

In Latin America, there is limited literature addressing the interaction between the construction sector and climate change. In recent years, researchers have started to explore this topic; for instance, de Lourdes Marques et al. (2018) report little sustainable progress in high-rise construction in Brazil, while in Colombia, Vázquez et al. (2012) describe a lack of knowledge and high costs as barriers to the adoption of sustainable practices. Torres-Guevara et al. (2021) highlight the importance of management commitment in Colombia to implement the circular economy in the industry.

Chile is no exception to the limited literature existing in Latin America. Some of the few studies on this topic have emphasized that Chile is in an incipient stage towards sustainable construction, attributing this situation to scarce regulations and little implementation of sustainable practices (Serpell et al., 2013). Also, large infrastructure companies are leading the adoption of these practices; however, this is not yet reflected in smaller buildings (Giannoni et al., 2017). Ossio et al. (2019) mention waste problems due to fragmented regulations and a lack of policies. More recently, Tori et al. (2022) examined nearly zero-energy buildings in Chile, noting a lag in public policies that promote this type of construction, pointing to a lack of regulations and government support.

3. Methods

This study uses a qualitative approach to explore the level of preparedness for climate change in construction projects in Chile, including multiple stakeholders. Qualitative methods are a good fit when developing an exploratory study that seeks to understand the problem and its context (Spearing et al., 2022).

In our case, the qualitative analysis is performed on interviews that were conducted with multiple stakeholders relevant to the problem of climate change in the construction sector in Chile. The interviews were divided into two sections: one to characterize respondents' role and awareness of climate change, and the other to assess their perceptions of the construction industry's preparedness and obtain recommendations for addressing this challenge. In the following subsections, we provide some description of the context of Chilean construction, the data collection process, the Qualitative analysis, and we discuss the limitations of our study.

3.1 Chilean context

In the Chilean context, it is fundamental to highlight the existence of legal aspects and strategic programs of national relevance that will be of interest in later sections of this research. For example, Law 19.300, known as the "Law on General Bases of the Environment", establishes principles for environmental protection in Chile. On the other hand, there are key technical regulations, such as 3562/2019, which regulate construction waste management, and 835/2007, which addresses thermal conditioning in buildings. These regulations are fundamental to guiding the industry towards more sustainable and environmentally friendly practices. International standards such as ISO 14001 and national programs such as Construye2025, “Compromiso Pro”, “Hoja de Ruta RCD Economía Circular en Construcción 2035”, and “Acuerdo de Producción Limpia (APL)” promoting sustainable practices, circular economy, and environmental impact mitigation are addressed. In addition, certifications such as CES, CVS, and LEED are mentioned, assessing and certifying the environmental performance of buildings and dwellings in terms of energy, water, materials and waste, health, wellbeing, environmental impacts, and sustainable design.

3.2 Data collection

The data for this study were collected through 16 semi-structured interviews with stakeholders in the Chilean construction industry between December 2022 and May 2023. A qualitative research approach was used; the literature indicates that in these cases, a common guideline is followed to determine the sample size, which is approximately between 9 and 17 interviews. A sample within this range is suggested to reach

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what is called the saturation point, in which additional interviews tend to provide little or no new information (Kvale and Brinkmann, 2009). Other qualitative studies in construction management have been carried out with a similar number of respondents. For example, n=8, Spearing et al. (2022); n=12, Yang et al. (2018); n=15, Zuo et al. (2012); n=15, Vásquez and Araya (2022).

As this study is exploratory in nature, convenience sampling (Stratton, 2021) and snowball sampling were used (Parker et al., 2019; Etikan et al., 2016). While the use of these types of sampling may restrict the generalizability of the results to the entire population, it also allows us to reach the specific profile of interviewers that was set for this study (i.e., Stakeholders relevant to the problem of climate change in the construction sector in Chile). Most of the interviewees were contacted via email. Of the sixteen interviews, fourteen were conducted via video call, while the remaining two were conducted by telephone. The interviews were conducted in Spanish, and informed consent was obtained from the participants before recording the interviews, ensuring the confidentiality of the data collected. The duration of the interviews ranged from 10 to 30 minutes.

In the framework of this research, interviewees were required to have experience in the industry, either being directly involved in construction projects, as architects, engineers, managers, or being professionals with specialized and relevant knowledge in the field of construction and its environmental impact, such as researchers, teachers, consultants, and governmental entities. The years of experience of the interviewees vary from 4 to 25 years, with an average of 14.25 years. Table 1 additionally shows the professional's field of work, degree, current occupation, gender, and years of experience.

Table 1. Characterization of the interviewees.

Number of interviewees	Field of work/ Professional qualification	Current position	Gender	Experience (years)
1	Project management /Environmental engineer	ITO	Woman	5
2	Environmental consultancy-Education/Risk prevention and environment engineer	Consultant in risk prevention and the environment - Teacher	Woman	16
3	Environmental management /Architect	Civil servant	Woman	25
4	Environmental Management /Geographer	Civil servant	Woman	20
5	Education-research /Architect	Research-teaching	Woman	11
6	Building/civil engineer	Head of Technical Office	Man	5
7	/Civil construction	Site Manager	Man	22
8	Public Building/Civil Construction	Project Manager	Man	20
9	Building/Architect	Head of Technical Office	Man	21
10	/Civil construction	Subcontract Analyst	Woman	5
11	/Environmental engineer	Address of waste management company	Woman	15
12	/Construction engineer	Environmental management advisor	Man	5
13	Academy/Civil construction	Research/ teaching	Man	15
14	Building/Architect	Technical site inspector	Man	16
15	/Architect	Sustainability manager	Woman	23
16	Road/Civil Construction	CChC Roads	Woman	4

Examples of some questions that were asked during the interviews are presented below:

- What information do you know about the construction industry's preparedness for climate change?
- What measures have you seen implemented in the construction industry to address climate change?

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• Who do you think should be involved in taking action on climate change?

3.3 Qualitative Analysis

The present research adopts an exploratory approach based on the qualitative analysis of the results. To this end, all audio interviews were transcribed, reviewed, and then coded. In terms of the coding process, interview excerpts were analyzed using the live coding method, where text segments were labelled in real time during data analysis (Saldaña, 2021). This approach allowed for a flexible and dynamic exploration of emerging themes, without prior bias, which facilitated the identification of categories and subcategories in an iterative manner. Coding consisted of highlighting excerpts from the interviews at the sentence level, then sorting them into multiple categories and subcategories, providing a robust analytical structure (Saldaña, 2021; Namey et al., 2008). Categories represented broad, general concepts, while subcategories reflected more specific themes that emerged within those main categories. Two coding dictionaries emerged from this coding process, which included the definition of the categories and subcategories. Tables A1 and A2 were located in Appendix A at the end of the document due to space limitations. Tables A1 and A2 show the coding dictionaries obtained from the qualitative analysis process regarding the level of development and recommendations to improve the preparedness of construction projects to deal with climate change.

Once coding was completed, frequencies were obtained for each category and subcategory to facilitate analysis. These frequencies were divided into two types: one indicating the number of times a theme was mentioned and the other revealing how many respondents mentioned that theme. Ultimately, to facilitate the counting of frequencies, the QDA Miner Lite software was used.

3.4 Limitations

Within the limitations of this research, it is important to highlight that the focus is on the context of the construction industry in Chile. Consequently, the results and conclusions obtained may not be directly generalizable to other regions or countries, but it provides some results that can be compared with other countries in the Latin American region. Another limitation is related to the fact that the life cycle of a construction project involves a wide variety of stakeholders. This analysis focuses on expert opinion, and while an effort was made to include diverse voices in this research, it does not include all potential stakeholders. Ultimately, another limitation is related to the sample size of the study. While with 16 interviewers we reach the saturation point during the analysis, it is hard to argue that these 16 people might represent an entire construction industry. However, it is still valuable as it provides a first approximation of how the sector may look and think about climate change.

4. Results

Our results showed that all 16 interviewees recognized the existence of climate change and its anthropogenic origin. Similarly, when exploring the role played by the construction industry in the context of climate change, all interviewees agreed that the industry is a significant factor in dealing with climate change. Table 2 shows the four categories and corresponding subcategories related to the level of development in the preparation of construction projects to face climate change, each with its corresponding frequencies. Similarly, Table 3 presents the five categories and their subcategories that make up the experts' recommendations for preparing construction projects to cope with climate change, with their corresponding frequencies.

Based on our results from Tables 2 and 3, we propose a summary to illustrate the relationship between the level of development of construction projects regarding climate change, recommendations made by interviewees, and the stakeholders associated with said recommendations (see Figure 1). Figure 1 shows a clear relationship between the recommendations provided by the participants and the issues addressed at the development level of the construction projects. In turn, the recommendations seek to address the problems and constraints identified at the development level.

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Table 2. Frequency of responses on the level of development of construction projects on climate change preparedness in Chile.

Category	Subcategory	N° of extracts (Number of interviewees)	Percentage value	
Regulatory framework	Laws and regulations	23(10)	36%	77%
	Guidelines/strategies/ initiatives	19(7)	30%	54%
	Regulatory constraints	22(11)	34%	85%
	Total	**64(13)**	**43%**	**81%**
Education	Research/innovation	10(8)	67%	89%
	Environmental education	5(3)	33%	33%
	Total	**15(9)**	**10%**	**56%**
Construction	Certifications	14(6)	33%	46%
	Waste management	16(9)	38%	69%
	Resources/materials	12(5)	29%	38%
	Total	**42(13)**	**28%**	**81%**
Barriers/challenges	Costs	13(7)	46%	70%
	Training	2(2)	7%	20%
	Level of awareness	7(4)	25%	40%
	Planning	3(2)	11%	20%
	Social projects	3(3)	11%	30%
	Total	**28(10)**	**19%**	**63%**
	Total	**149(16)**	**100%**	**100%**

Table 3. Frequency of responses on recommendations for climate change preparedness of construction projects in Chile.

Category	Subcategory	N° of extracts (Number of interviewees)	Percentage value	
Regulatory framework	Regulatory aspects	19(10)	61%	77%
	Public policies	4(4)	13%	31%
	Subsidies/incentives	8(6)	26%	46%
	Total	**31(13)**	**20%**	**81%**
Education	Academic background	4(3)	25%	33%
	Training	6(4)	38%	44%
	Awareness raising	6(3)	38%	33%
	Total	**16(9)**	**10%**	**56%**
Pre-construction	Design	16(8)	80%	89%
	Planning	4(2)	20%	22%
	Total	**20(9)**	**10%**	**56%**
Construction phase	Materials/resources	12(9)	31%	60%
	Waste	15(8)	38%	53%
	Industrialization	10(4)	26%	27%
	Digitization	2(2)	5%	13%
	Total	**39(15)**	**25%**	**94%**
Stakeholders	State	24(14)	48%	88%
	Private/companies	9(7)	18%	44%
	Clients/users	8(7)	16%	44%
	Professionals	4(3)	8%	19%
	Academy	4(3)	8%	19%
	Total	**49(16)**	**32%**	**100%**
	Total	**155(16)**	**100%**	**100%**

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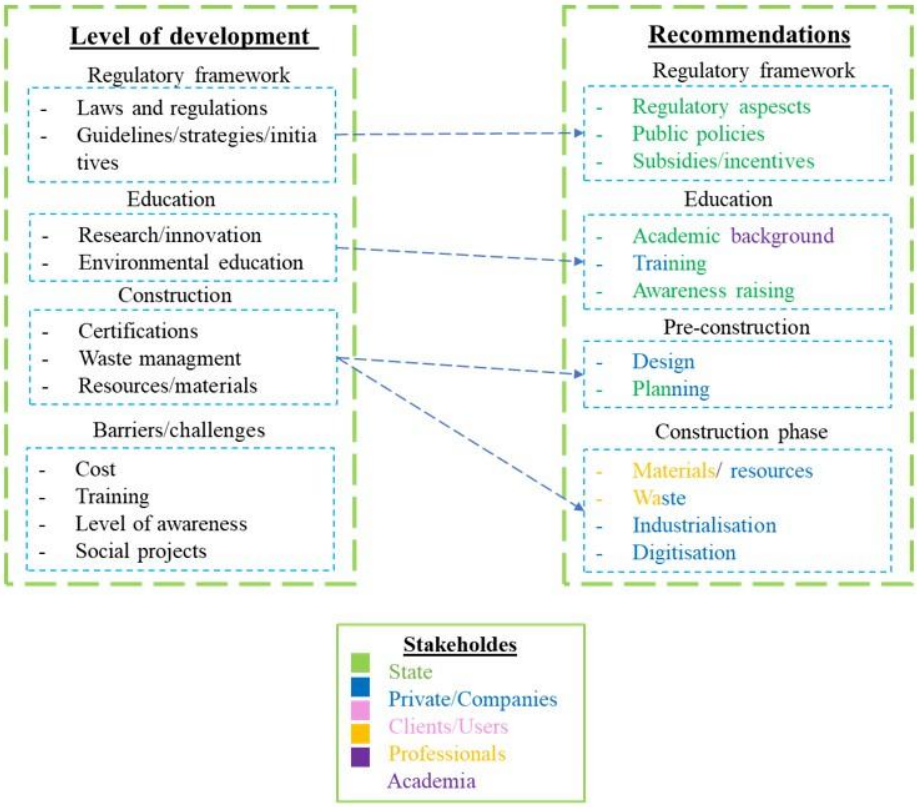

Figure 1. Summary of the relationship between participants' recommendations, the level of development of construction projects, and the stakeholders involved.

5. Discussion

In here, we discuss the most relevant categories and subcategories found in the qualitative analysis previously shown. We organize the discussion into two main areas: the level of development of construction projects and recommendations for climate change preparedness of construction projects.

5.1 Level of development of construction projects

Regarding the level of development of construction projects in Chile, we found four categories with their corresponding subcategories. The category with the highest frequency was regulatory framework (see Table 2). In this category, interviewees highlighted the importance of the subcategories of laws and regulations and regulatory constraints, with the highest frequencies in both the number of extracts and interviewees that mention them (see Table 2). These findings might suggest a high level of awareness of existing regulations governing construction in Chile. These regulations help to mitigate the environmental impacts of the sector, although some are perceived as insufficient, impractical, or limited.

Respondents pointed to limitations in specific laws, such as Law 19.300, which only applies to certain types of projects, in certain locations and of certain volumes, which aligns with previous literature from Chile by Serpell et al. (2013), who emphasized the lack of applicability of climate change regulations to the construction of smaller projects. Another interesting point made by interviewees referred to the lack of clarity in regulations, for example, the one related to greywater recirculation, which has generated doubts about its effectiveness.

Our findings reinforce the idea that the existing regulatory framework is a relevant aspect to account for in the Chilean context, which is aligned with international literature, for instance, in Australia and Sweden (Hurlimann et al., 2018). Moreover, interviewees reported that there exists a gap in current regulations, mentioning that although regulations exist to address climate change, these are too general or even optional. The

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absence of mandatory codes and regulations is cited as a common barrier (Al Sanad, 2015), and the lack of environmental regulations and laws hinders the implementation of the circular economy in developing countries (Bilal et al., 2020).

The subcategory *Guidelines/strategies/initiatives* was mentioned by 54% of the interviewees (see Table 2). Interviewees discussed multiple programs, such as "*Construye 2025*", which seeks to transform the construction industry from productivity and sustainability, or the "*RCD Roadmap, circular economy in construction 2035*". Also, public-private collaborations were discussed, such as the *Clean Production Agreement*, a voluntary agreement that seeks to reduce waste and improve the use of construction materials, or the "*Compromiso Pro*" from the Chilean Chamber of Construction (CChC). Although some interviewees express concern about the lack of effectiveness of some of these programs, in general, our results indicate that there is a high level of awareness of initiatives to adapt construction and reduce environmental impacts.

The second category, with the most frequencies, was construction, with the subcategories *waste management* and *certifications* leading with the highest frequencies (see Table 2). Regarding the subcategory of waste management, the interviewees mentioned their concern about the large amount of waste generated by industry, but they perceive improvements in waste management in recent years, especially in areas where proximity to companies or recyclers facilitates waste management. In this area, one interviewee commented that, "*In an urban project, the implementation of recycling systems benefited from the proximity to companies interested in such waste*". Another relevant issue addressed by the respondents was the lack of authorized waste disposal sites. Despite the fact that regulations establish that construction and demolition waste (CDW) must be taken to authorized landfills, 9 of Chile's 16 regions do not have sites for the legal disposal of solid waste (Minvu, 2019). This means that around 24% of the CDW produced lacks an authorized disposal site in its region of origin (Ossio et al., 2019). Although several of the interviewees mentioned having worked on projects where some type of waste management, such as waste separation, was carried out, they stated that it is not a widespread practice, and one of them even said "*Our innovation department promotes waste separation on construction sites. Although the intention is positive and beneficial, not all the company's construction sites are currently implementing it*".

The subcategory *certification* was the second most mentioned subcategory after waste management, with 46% of interviewees discussing this topic (see Table 2). We can understand these results as indicating that a high level of awareness exists about certifications, and they are thought to be related to dealing with climate change. Among the participants who mentioned this subcategory were those who had worked directly on projects with some kind of certification, such as LEED, the CES certification for sustainable buildings in Chile, the CVS certification for sustainable housing in Chile, and the ISO 14.001 standard for the environmental management of an organization.

Regarding the subcategory related to existing barriers/challenges, the main issue revealed by the subcategories was the costs that were reported by 70% of respondents who discussed that subcategory (see Table 2). This result emphasizes the importance of cost in transitioning toward a more sustainable construction and, therefore, higher climate change preparedness. Although the initial costs of certificated construction projects are higher, several interviewees highlight the long-term savings, especially when considering sustainable certifications. Hurlimann et al. (2018) explain that builders focus on short-term gains and, by working for others, avoid expenses without immediate benefits, fearing loss of competitiveness. One participant argues that sustainable construction implies additional costs, which some companies see as a threat to their competitiveness.

Ultimately, when it comes to the category of *education*, the subcategory *innovation/research* was the most mentioned (see Table 2). In general, the construction sector in Chile is perceived as not very prone to innovation, especially in environmental research. Nonetheless, an increase in some research on construction and climate change is noted by interviewees, mainly at the academic level. This change is supported by the perception of greater involvement in academia in these issues. Cooperation between universities and governmental organizations drives innovative projects against climate change and improved building practices. Collaboration between the public, private, and academic sectors is seen as crucial to progress towards sustainability in the construction industry.

5.2 Recommendations for climate change preparedness of construction projects

Regarding the recommendations, we found five categories with their corresponding subcategories. The category with the highest frequency was stakeholders (see Table 3). The subcategory with the highest frequency was state and was referred to by 88% of respondents (see Table 3). This subcategory refers to the role of the government as a stakeholder involved in taking measures for the industry to face the climate change scenario. Interviewees highlighted the state/government as the main actor with the responsibility and power to guide the industry towards sustainability. They see the government as the key driver of change, both through the development of regulations and educational programs. Moreover,

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interviewees emphasize the government's ability to mobilize the construction industry through laws and regulations, positioning it as a key leader in addressing the challenge of sustainability in construction. In turn, the government has the capabilities to create or modify laws and regulations that will allow progress to be made in combating climate change and achieving adaptation. Interviewees insist on regulatory reforms to drive changes in construction. They highlight the need for regulations that transform practices by providing mandatory guidelines and standards. They see this as key to balancing the industry, overcoming financial barriers, and promoting the widespread adoption of sustainable practices. They seek to standardize regulations to scale up sustainable buildings and ensure fair competition. These findings are aligned with existing literature; for instance, Darko and Chan (2017) point to government involvement as key to establishing effective evaluation mechanisms and incentives.

The second most frequent category was the construction phase, with the subcategories waste and materials/resources leading as subcategories (see Table 3). The waste subcategory refers to recommendations focused on solving the current waste problems in the construction sector. The interviewees suggested improvements to the current waste management through different strategies, for example, estimating the amount of waste generated per item. Additionally, a recurrent recommendation was to promote the separation of waste through separate containers, thus facilitating their reuse and recycling. Interviewees mentioned that it is crucial to avoid accumulating everything in one place and then taking it to a landfill. They add that success in waste management is directly related to the education of professionals and workers in the construction sector. Education, training, and awareness of those working on construction sites are fundamental to having proper waste management practices. Another issue discussed by interviewees was the challenge of finding companies or recyclers willing to receive construction waste. It is suggested to create government incentives to promote the circular economy and to develop waste management companies around the country. This seeks to prevent the lack of such companies from being an excuse for not properly managing waste generated in construction, regardless of the location of the construction site.

The subcategory of *materials/resources* was mentioned by 60% of respondents, who advocate reducing the use of virgin materials to preserve non-renewable resources, supporting the idea of replacing them with secondary materials (Alsheyab, 2022). Along the same lines, one interviewee highlighted the need to include sustainability requirements in regulations, such as the use of materials with a declared environmental impact or with a certain percentage of recycling. Another interviewee emphasized the importance of optimizing water use in construction, pointing out the current inefficiency and the need to adopt more efficient methods. This concern is highly relevant in Chile, which has been affected by a drought for more than 14 years.

Ultimately, regarding the pre-construction category, the sub-category design was referred to by 89% of respondents. Interviewees stressed that design is crucial if you want a more sustainable project, generating less waste, being more energy efficient, and protecting resources. Interviewees emphasized the importance of considering climate change from the outset of design to create resilient and sustainable structures in the long term. For instance, accounting for the importance of materiality in reducing the carbon footprint of buildings. They recommended favoring domestic materials to minimize transport emissions. They highlighted how the choice of imported materials significantly increases the carbon footprint.

6. Conclusions

This study analyzed the level of preparedness of construction projects for climate change in Chile from the perspective of multiple stakeholders. To do so, 16 interviews with construction stakeholders were qualitatively analyzed. Our main results showed that all interviewees stated that they were aware of the existence of climate change and the fundamental role of the construction industry in its development. Furthermore, our study revealed that the development of construction projects in Chile in the face of climate change is at an early stage and lags behind developed countries. The construction industry in Chile still faces challenges in waste management, with intermittent and selective practices. Despite regulations, there is a lack of authorized disposal sites, coupled with a shortage of companies managing construction waste. Regarding the recommendations from interviewees to move forward. These were focused on improving regulations to promote more sustainable practices. They highlight the need for the government to modify regulations and promote metrics to address climate change. For instance, it is suggested to improve construction waste management, and it is proposed to implement government incentives to foster the circular economy and to promote the development of more companies specialized in construction waste management.

This study contributes to existing literature by providing in-depth insights into the interaction between the construction industry and climate change in the context of a developing nation in Latin America (i.e., Chile). In practicality, our fundings provide valuable background for future

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developments of environmental policies in the industry and serves as a guide for policy and decision makers. Ultimately, it is recommended in future research efforts to involve more stakeholders to enrich the analysis and aim for quantitative methodologies so results can be generalized.

7. Declaration of generative AI and AI-assisted technologies

In preparing this manuscript, AI-assisted technologies (i.e., Grammarly) were used to support the structuring of the text and improvement of clarity, readability, and presentation. All outputs generated with the assistance of these technologies were carefully reviewed and edited by the authors, who take full responsibility for the content of the manuscript.

8. Notes on Contributors

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10. APPENDIX A

Table A1. Coding dictionary on the level of development of construction projects on climate change preparedness in Chile.

Category	Definition	Subcategory	Definition	Example
Regulatory framework	Refers to the set of legal provisions or regulations, as well as guidelines established at the governmental or sectoral level that guide and regulate practices related to sustainability and climate change in industry.	Laws and regulations.	Mentions related to regulations and provisions established at the governmental or sectoral level that seek to promote energy efficiency, more sustainable practices, and address climate change in the construction industry	“Law 19.300 requires an environmental assessment, but only for a certain type of project, in certain places, and of a certain volume”.
		Guidelines/ strategies/ initiatives	Refers to mentions of initiatives, programs, and strategies established by relevant bodies, entities, and actors in the field of construction, to promote sustainable practices	"In Chile, a work program has been in place for a couple of years now, called Construye 2025".
		Regulatory constraints	It refers to mentions related to the restrictions, inadequacies, and difficulties present in the existing regulations and laws in the field of sustainable construction.	"In the past, a law related to greywater recirculation was issued. However, there is no clear definition of how to implement it".
Education	Refers to mentions related to the promotion of awareness, sensitization, and knowledge on the sustainability of the environment and climate change in the field of the construction industry.	Research/ innovation	Mentions related to the development of academic and scientific research and innovations, or lack thereof, in the field of sustainable construction and climate change.	"Today, in the construction sector and in academia, there are more thesis students, more students, linking the environmental issue".
		Environmental education	Mentions related to the level of education or the development of educational programs linked to the environment, climate change, or sustainable construction.	"Environmental education today, at the school level, is very scarce, and may only appear at the university level and only in a few careers".

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Table A1. Coding dictionary on the level of development of construction projects On climate change preparedness in Chile (Continued).

Category	Definition	Subcategory	Definition	Example
Construction	Refers to the stage comprising the activities and processes that are executed during the development and materialization of a construction project.	Certification	It refers to mentions related to obtaining and adopting national and international certifications in the field of sustainable construction.	"For example, obtaining CES certification is an effort to mitigate the negative effects.
		Waste Management	Statements related to waste resulting from construction activity, including aspects such as management, disposal, reduction, recycling, and reuse.	"The company promotes waste separation at construction sites. Although the intention is positive, not all of the company's construction sites are currently implementing it".
		Resources/ materials	It covers subjects related to the use and handling of materials in the construction industry, as well as the extraction of natural resources.	"The environmental footprint generated by the resource extraction phase causes the most damage".
Barriers / challenges	Mentions indicating identified challenges, constraints, or difficulties that represent an obstacle to the development and progress towards sustainable construction and/or towards the industry's preparedness for climate change.	Cost	Mentions related to economic and financial aspects that represent a challenge or a difficulty for the implementation of more sustainable and environmentally friendly practices in construction	"It is often perceived that the adoption of measures is linked to increased costs, which leads the industry to avoid taking responsibility for them.
		Training	Mentions related to the need for training and skills development in professionals, to provide them with the knowledge and competence to perform in the environmental field.	"There are very few LEED certified professionals in Chile. There were few professionals with the years of experience that the project required".
		Levels of awareness	Refers to mentions related to the lack of knowledge and awareness of the importance of sustainability and environmental care in the construction industry.	"I also think that the level of awareness in people is not that deep."
		Planning	Mentions related to adaptation and lack of adequate urban planning, and the absence of long-term considerations in the development of projects and constructions.	"Urban planning plays a key role in the impact of climate change".
		Social projects	Mentions related to the lack of environmental and sustainability requirements in social projects, especially those promoted by the state.	"When the state commissions construction companies to carry out social projects, it often does not set stringent requirements from an environmental perspective.

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Table A2. Coding dictionary of interviewees' recommendations for improving the level of preparedness Of construction projects for climate change in Chile.

Category	Definition	Subcategory	Definition	Example
Regulatory framework	Refers to recommendations related to the development of regulations, laws, and policies that promote sustainability and a shift towards more environmentally responsible practices to prepare the construction industry for climate change.	Regulatory aspects	Recommendations related to the creation, revision, improvement, or updating of specific rules and regulations addressing environmental, social, and efficiency aspects of construction projects	"It is the regulations that must impose on construction companies the need to make substantial changes in their working methods".
		Public policies	Recommendations related to improving or formulating government policies and strategies that address the sustainability of the construction sector and improve its preparedness for climate change.	"It is essential to have public policies that foster market maturity. In the current market situation, this is an unavoidable necessity."
		Subsidies/ incentives	Recommendations are linked to the creation of support programs and/or implementation of economic stimuli, either fiscal or financial, in order to motivate and facilitate the adoption of better environmental practices in construction.	"The state should provide incentives for companies or individuals to opt for better environmental conditions in their homes, such as solar panels or heating."
Education	Refers to recommendations related to the education and learning of knowledge, skills, and values at academic, professional, and public levels on the awareness and understanding of sustainable and environmentally responsible practices in general, and in the field of construction	Academic background	Recommendations related to the inclusion of environmental and sustainability content in curricula at all levels of education to raise awareness of climate change.	"This implies that the state plays a fundamental role in conveying the existence of a problem through universities and schools.
		Training	Recommendations related to the generation of training and skills development programs for construction workers and professionals to improve knowledge and competencies in sustainable construction practices	"The key thing is education. This covers 100 per cent of the population, from the leaders of the companies to the workers and the lowest level of the workforce".
		Awareness raising	Recommendations related to raising awareness through information and education of the community at large by promoting the adoption of more environmentally responsible practices.	"Generating awareness on the environmental issue, educating the population, is also an important issue".

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Table A2. Coding dictionary of interviewees' recommendations for improving the level of preparedness Of construction projects for climate change in Chile. (Continued)

Category	Definition	Subcategory	Definition	Example
Pre- construction	It relates to the set of activities and decisions involved in the stages before the conception and development of a construction project.	Design	Recommendations related to improvements or changes in project design, focusing on more efficient and sustainable solutions	"I think we would have a change when the architect involves 100% the environmental issue, because a lot of the criteria depend on the design of the project".
		Planning	Refers to recommendations related to the organization and long-term projection of constructions, considering the implementation of adaptation measures to face the challenges of climate change.	"It is important to start construction with a focus on adaptation, and to renovate and upgrade infrastructure in line with adaptation.
Construction phase	Recommendations that refer to the activities and processes involved during the execution and materialization of a construction project	Materials / resources	Recommendations related to the selection, use, and handling of matercials and resources used in construction.	"In terms of materials, use those that have a significant amount of recycling, basically look for materials that have recycling, that have less impact.
		Waste	Recommendations related to the proper management of waste generated, the reuse of materials, and the recycling of construction waste.	"The first thing is to generate waste management systems in the different companies, so that we can reduce the amount of waste generated".
		Industrialization	Recommendations aimed at promoting technification and the implementation of industrialized processes in construction to improve efficiency, productivity and quality of projects.	"Continuing on the path of industrialization is something that can really help in reducing the use of fossil fuels".
		Digitization	Recommendations aimed at the improvement, incorporation, and use of digital technologies.	"Hopefully, we will try to incorporate digitization of processes well, e.g., BIM modelling".
Stakeholders	Refers to identified stakeholders who participate and have the capacity and power to influence the adoption of measures and policies related to the construction industry and climate change	State	Refers to government agencies and public bodies in charge of establishing policies, regulations, and standards related to the construction industry and climate change.	"The state, setting stricter standards for the rationalization of constructions".
		Private / companies	Includes private sector companies or bodies involved in the construction industry.	"The private entities that have to do with big business".
		Clients/users	This includes owners, developers, and end-users of construction projects	"It is also the people who should be demanding better standards".
		Professionals	It encompasses the experts, architects, engineers, designers, and other key specialists involved throughout the project life cycle.	"I think we would have a change for the better when the architect is 100% involved".
		Academy	Refers to educational institutions, universities, and research centers that contribute to the training and generation of knowledge on sustainable construction and climate change	"The educational world, everything to do with the university, the schools.

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