ORGANISATIONAL READINESS FOR BIM, LEAN AND SUSTAINABILITY ADOPTION: A CONCEPTUAL SELF-ASSESSMENT FRAMEWORK FOR CONSTRUCTION SMES IN CHILE.

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Declaration

I declare that no portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

Copyright statement

Abstract

The construction industry in Chile is currently experiencing a process of change and accomplishment of efficiency, productivity and sustainability goals that require the effort of the companies that encompass the construction sector in the country. These companies are comprised mainly of SMEs that are the ones that move the industry forward not only in Chile but also in most of the construction industries around the globe. For this reason, the government is promoting new initiatives to accomplish those goals and move the industry forward, including the use and application of BIM, lean and the focus on sustainability. The government has recognised these initiatives as a way to move the industry to the desired targets. In addition, the literature suggests that BIM, lean and sustainability (BLS) are synergistic because they have similar goals and should work better in combination rather than treated in isolation. The literature also suggests that most of the work in these areas focuses on specific aspects and larger organisations with little consideration and focus on SMEs. Moreover, the literature explores BLS integration with authors focusing on these aspects. However, the focus on the organisational part, which is essential to drive their use, is missing. In addition, there are no current frameworks to promote their use and application.

This thesis examines the integration of BLS at the organisational level to promote their use and produce improved results at the project levels as suggested by the literature, establishing that the organisational maturity in BLS aspects is essential to meet the targets of the construction industry in Chile. For that reason, three case studies were selected and analysed by conducting semi-structured interviews with members of the organisation to determine the factors that promote maturity, so SMEs in Chile can establish their maturity and focus their efforts on specific areas that need addressing. After this process, the factors were found by cross analysing the data from the case studies to later validate it during a focus group session with eight experts. The results show that 69 factors divided into five categories are the ones that are essential to assess maturity and compare the organisation's current status to the desired level of maturity. This way, more organisations can use this framework to reach the construction industry goals in the future and aim for improvements to deliver more efficient, productive, and sustainable projects.

Chapter 1 Introduction

Improving the construction industry remains a major challenge for industries around the globe, even at present times, where the levels of innovation and technology application have increased and have been made a priority for long term organisational success (Gambatese and Hallowell, 2011). However, for the construction industry, this increase in innovation and technology has remained a major challenge in which the full benefits have not been reflected in improvements in construction projects (Aziz and Hafez, 2013). In addition, efforts have been made to strategically improve the management of construction but still failing (Nguyen and Chileshe, 2015).

The industry's inherent characteristics have been acknowledged as a barrier to improving performance, namely fragmentation, lack of research and development, low profitability, and dissatisfaction from clients, which have been identified as some of the reasons impacting directly on how the final product is delivered (Demirkesen and Ozorhon, 2017).

These and other problems have also been acknowledged as barriers to improving the Chilean sector (CChC, 2020). Studies from Alarcon et al. (2002), Gonzalez et al. (2008), and most recently, Serpell and Ferrada (2020) have shown the inefficiencies of the Chilean sector, which are similar to the problems found in the worldwide construction industry.

In this sense, information and communication technologies (ICTs) have been used to tackle the complexity of the construction industry, which has been reflected in the development of a set of innovative tools and methods called Building Information Modelling (BIM). BIM is viewed as the new Computer-Aided Design (CAD) paradigm (Succar, 2009), which can contribute to the reduction of costs and errors, improved communication, and performance (Elmualim and Gilder, 2014). Furthermore, it is seen as an enabler to adopt other practices due to its strong synergy with performance improvements (Horta et al., 2010). This major cultural, organisational change related to innovation and collaboration is a key indicator of change in the industry's complex nature, aiming to improve productivity, efficiency, and sustainability (CChC, 2020).

Consequently, due to the nature of the industry and the problems encountered, the Chilean government has turned their attention to ways to increase performance and, most importantly, to face the challenges the sector has ahead in aspects such as digitalisation, sustainability, and productivity (CORFO, 2016). For this reason, the Chilean government has developed an ambitious strategy aiming to improve the productivity of the construction sector by using methodologies and information and communication technologies (ICTs) aiming to promote the use of Building Information Modelling (BIM) capabilities in organisations (Briones and Soto, 2017).

The adoption of these initiatives by the Chilean construction industry has been acknowledged and suggested to improve the sector's efficiency, particularly the adoption of BIM as a catalyst for change (CChC, 2020). In 2016, a national initiative from the government was born aiming to work on a national BIM standard, developed and presented to the audience in 2019. The idea and objective behind this standard are to position the country and the organisations in the construction industry to comply with the government's requirements and to open new opportunities to position the country at the highest level in terms of internationalisation of services and industry development. However, in practical terms, it is also acknowledged that the country is still not ready and the transition to comply with these objectives is still a significant challenge (Briones and Soto, 2017).

In addition, in the latest official government productivity report, the government sets guidelines to promote the use of BIM and lean practices to increase productivity and efficiency, aiming to boost the productivity levels along with increasing the GDP the sector produces from USD 19,760 million to USD 32,600 million (CChC, 2020). This strategy also aims to comply with the global environmental requirements in terms of buildings and infrastructure with sustainability considerations; energy consumption reduction of 12%; greenhouse gases reduction of 20%; and commitment by the construction sector to contribute 10% of the energy generated by unconventional renewable sources by 2024 (MOP, 2013).

1.2. Problem statement and research justification

BIM processes have been accepted as an enabler by the construction industry to improve performance but have not reached their full potential yet (Arrotéia et al., 2021; Doan et al., 2020; Cao et al., 2019; Chan et al., 2019; Charef et al., 2019; Zhou et al., 2019). In Chile, this situation is not an exception. A study from Loyola (2019) of BIM uptake in construction organisations in Chile shows that the number of BIM users has increased; however, the focus is on the software aspect in visualisation tasks, project coordination and documentation. In addition, the study shows that there is no progress in collaboration and communication, meaning that the users do not share their models and do not use a standard collaboration method. The study concludes that the number of users has increased because of the requirements imposed by the government, but the use and potential are still fundamental. Therefore, the challenge is to reach higher maturity levels by integrating it with other practices to make the process more efficient and compliant with the sector's requirements.

On the other hand, lean methodologies are used to produce safer, faster, and cost-effective projects to reduce waste and maximise effectiveness (Koskela, 1992). Chile is one of the pioneers of lean construction application in the region, with positive results in its application, and it is considered a central focus of the development and efficiency of construction organisations (CChC, 2020). However, despite those results, the uptake has been low, and most importantly, no current standardised frameworks to support implementation and integration of the philosophy exist, highlighting the lack of implementation alignment with organisation strategy (Salvatierra et al., 2015).

In addition, the construction industry has targeted reducing carbon emissions and becoming more environmentally friendly (MOP, 2013), which is synergistic with the BIM and lean principles objectives (Saieg et al., 2018; Koskela et al., 2010). These initiatives are trying to promote excellence in the whole supply chain through integration and collaboration supported by transformation and digitalisation to urge key industry players on the application of digital technologies and the use of tools and systems to enhance productivity to reach for higher standards and achieve sustainability (CChC, 2020).

These key players are, in their majority, small and medium-sized organisations (SMEs) which play an essential role in the economy and efficiency of the sector because the Chilean industry is comprised mainly of them (Nuñez et al., 2018). The issue is that in Chile, SMEs do not possess a proper organisational structure and are understaffed at the professional level (Serpell et al., 2002). Therefore, applying new practices such as BIM, lean and focusing on sustainability as suggested by the strategy is challenging, and proper guidance for complying with the new construction requirements is a complete challenge (Briones and Soto, 2017). In addition, much of the attention is usually paid to other industry participants, and the focus on SMEs needs to be explored in more detail (Dainty et al., 2017), establishing a clear gap that needs to be addressed.

The attention towards BIM, lean and sustainability has come to the attention of researchers in the literature due to their common shared goals of maximising performance outcomes and sustainability throughout the entire project life cycle (Ahuja et al., 2018). However, the way these practices are commonly treated is in isolation or pairwise, therefore missing the opportunity to enhance the strong synergies towards performance improvements between them (Koskela et al., 2010). As a result, some authors such as Mellado and Lou (2020), Sacks et al. (2010), Mahalingam et al. (2015), and Tauriainen et al. (2016) have proposed the integration of BIM, lean, and sustainability to promote performance improvements in the construction industry and to reach for the desired goals of improved productivity, efficiency, and sustainability, similar to the goals stated by the Chilean strategy.

The problem is that the application requires a proper strategy lacking in the existing literature on the BIM, lean and sustainability aspects applied in conjunction (Saieg et al., 2018). There have been attempts to study the integration of these aspects, such as Enache-Pommer et al. (2010); Koskela et al. (2010); Sacks et al. (2010); Ahuja et al. (2018) and Saieg et al. (2018), but no application frameworks were identified. The question arises then on how SMEs can apply BIM, lean, and focus on sustainability with no existing frameworks and how they can identify their organisation's readiness and maturity to implement them and comply with the industry's requirements. It has been shown in the literature that SMEs have struggled with the application of BIM (Vidalakis et al., 2020; Makabate et al., 2021), lean (Almanei et al., 2017) and, at the same time, focusing on sustainability considering the environmental, economic, and social aspects (Chowdhury and Shumon, 2020).

In this sense, Al-Balushi et al. (2014), Sarhan and Fox (2013), and Radnor et al. (2006) have discussed in the literature the significance of organisational readiness prior to lean implementation. Still, frameworks of this kind are not found, especially in the Chilean SMEs context (Salvatierra et al., 2015), representing a clear gap in the literature and the demands of the Chilean construction industry requirements (CChC, 2020). The same situation occurs regarding the importance of organisational readiness for BIM adoption (Vidalakis et al., 2020) and sustainability uptake (Agebsi et al., 2018).

The construction industry in Chile is trying to improve its performance, and for this to happen, organisations play an essential role (CChC, 2020). Gudergan et al. (2015) suggest that the organisations' efforts may be hindered due to an inefficient preparation and readiness to achieve maturity to commit to change. Therefore, assessing organisations' maturity is paramount before adopting new practices (Akunyumu et al., 2021).

This research aims to address those issues by proposing an integrated approach to assist SMEs in establishing their organisational readiness and maturity to comply with the challenges the industry is facing. For that reason, a framework is proposed considering elements in established categories in the process, human and attitudinal, technology, management, and economic aspects for construction SMEs in Chile that were identified as key elements when studying existing frameworks.

In addition, the exploration of BIM, lean practices, and sustainability (BLS) integration as a single approach is still in the early stages, and there is an absence of a proper strategy to promote their integration at the strategic organisational level (Saieg et al., 2018).

1.3. Research aim and objectives

Construction industry SMEs in Chile need support in their BIM, lean and sustainability implementation efforts. Therefore, this research aims to develop an organisational maturity framework to assess BIM, lean, and sustainability (BLS) implementation in construction SMEs in Chile. This way, they will be able to evaluate and learn their maturity towards BLS adoption and establish their current capability level.

To achieve this aim, specific objectives are identified as follows:

1. Critically review the concept of BIM, lean, and sustainability in the existing literature, focusing on synergies and linkage between BIM, lean, and sustainability
2. Critically review existing maturity frameworks to understand their concepts, usage, and components.
3. Explore the BLS implementation efforts in SMEs in Chile
4. Identify the maturity factors to enable BLS implementation.
5. Develop a conceptual framework derived from the results derived from objective 4.
6. Validate and refine the conceptual framework from objective 5 to establish the organisational maturity BLS framework.

1.4 Scope of research

It is crucial to have a scope to delimit the research area and narrow down the studied aspects.

The focus of this research is on contractor SMEs. The reason for selecting contractors for this study is because in Chile, specifically in the promotion of the BIM application, its use is low and immature, and it has been reported that most of its use is focused on the design stage (Loyola, 2019), leaving aside other project stages, other essential activities such as planning, and other project stakeholders such as contractors, establishing a gap that needs exploring (CChC, 2020). In addition, it has also been reported that the BIM application facilitates the application of lean (Sepasgozar et al., 2021) and sustainability (Olawumi et al., 2018). Therefore, BIM application enables lean and sustainability (Ahuja et al., 2018; Mellado and Lou, 2020). The rationale for focusing on SMEs is because the Chilean industry is mainly comprised of them (Nuñez et al., 2018).

On the other hand, the focus of this research is on the organisation rather than the project because, as explained in section 1.2 (Research justification) of this chapter, the success in the long run in the application of new practices lies on the organisation maturity to implement them (Akunyumu et al., 2021). Since the Chilean industry is moving towards the application of BIM, lean, and the focus on sustainability (CChC, 2020), and there are no indications of maturity assessment either in the literature or in the Chilean case, the approach taken is considered to be the right step to fulfil the industry objectives and contribute to the body of knowledge.

In this sense, the responses provided come from upper, middle, and supervisory organisational levels to reflect SME members' views encompassing the entire organisation. The reasoning behind this choice is that the researcher aims to explore the level of application of BIM, lean and sustainability and how the SMEs are addressing their implementation levels to follow the strategy proposed by the government encouraging the use of BIM, lean and sustainability. For that reason, it is necessary to explore where the SMEs currently are, and for those purposes, the upper levels are the ones that make the decisions and lead the organisation in terms of strategy adoption (Carmeli and Halevi, 2009). Given that the BLS application would promote changes in strategy and business decisions, the views from the upper levels are the best way to describe these issues. Then, the view of the other levels is to obtain their experiences in terms of the application and how the BLS introduction to the organisation's way of working would impact other areas. The middle and supervisory levels are more involved in the application and day-to-day use (Ateş et al., 2020), so for that reason, they are also considered part of this research. Finally, in terms of practicality, once the framework is developed, assessed, and validated, it is thought to be used by the upper levels at the start of the implementation process to assess maturity and address the factors that need evaluation.

1.5 Research methodology

This research engaged mainly a qualitative and inductive approach. The first step was to conduct a literature review to understand the topics, gain knowledge on the subjects under study, and identify the problems and gaps to develop the aim and objectives stated in section 1.3 of this chapter. After that process, a more in-depth literature review took place by analysing the BLS literature and the maturity concepts and existing frameworks to use them as a foundation for developing the BLS framework presented in this study. The literature review was a key aspect of this research because it was also used to justify and make sense of the responses provided in the case studies. This part was carried out when the answers were provided and were used to theoretically validate the findings presented in chapter 5 with the literature. Chapter 4 presents the factors that are required to ensure a proper BLS integration at the organisational level to comply with the Chilean industry requirements and enhance the knowledge of the BLS integration into a framework. The purpose of identifying factors is to populate the proposed identified areas from the literature with aspects concerning the Chilean case related to the scope of this study. The proposed BLS framework can be seen at the end of chapter 5.

At the end of the literature review, the analysis of existing frameworks and models was discussed to explore the areas that the BLS framework would develop and guide the researcher in exploring the line of investigation. Different models and frameworks were explored, which can be seen in table 2.2 in chapter 2, and the areas to be explored were identified, namely, processes, human and attitudinal aspects, management, technology, and economic categories. The initial conceptual framework is then proposed based solely on the identified areas and with no information at this stage on the factors to populate them. This conceptual framework is presented at the end of chapter 2. The researcher then developed the questions to be asked, and the research moved to the data collection process. In this stage, the researcher identified SMEs that fulfilled the aim and objectives of this study. This process was carried out with the help of key industry and government contacts to quickly define and commit the participants and define available dates for them to collaborate. The researcher proposed SMEs which were identified from the main construction industry website partners, the Chilean Construction Chambers, which were contacted and engaged with the help of these key contacts. As a result of this process, an initial number of seven SMEs were identified and asked to participate in the study, but three of them did not reply, and from the ones that answered, only three were the ones that committed and participated in the final study. Before commencing the study, the questions were piloted to assess their suitability, find any inconsistencies, and determine the length, quality of the questions and refine them if required, basically to assess whether they measured what the study needed to achieve the objectives.

After this process, the case studies took place which consisted of semi-structured interviews to determine the BLS factors. The data analysis was done first by transcribing the responses, and after that, content analysis was carried out to find patterns among the data and presented in a table shown in chapters 4 and 5. The data patterns led to organising the factors into subcategories linked to the main areas of study and were arranged based on that exercise. The subcategories are then presented in chapter 5 along with the discussion of findings. A literature review was performed to justify the responses, make sense of the data, and theoretically validate the factors found in the case studies. An initial total of 78 factors were found distributed in the proposed areas. The BLS framework is then presented pending validation, a process that is shown in chapter 6. The framework factors were proposed based on three case studies; therefore, a focus group was engaged to generalise and validate these results to a broader population. This focus group was also qualitative in nature, in which 8 participants collaborated to validate the findings by first filling out a questionnaire form to score the factors. This technique was used to quantify the responses and ease the data acquisition due to time constraints and the availability of the participants. After that, the participants discussed their findings and provided their insights to refine the initial framework to the final version shown at the end of chapter 6. The qualitative part of the focus group was analysed by engaging content analysis, the average and relative importance index. The discussion led to reducing the number of factors from 78 to 69 presented in the final BLS framework. For more details, see figure 1.1, where the research process is presented.

1.6 Contribution to construction management knowledge

This research's contribution has two elements, namely theoretical and practical. The theoretical view is to contribute to the development of an organisational framework that enhances the body of knowledge and can be referred to by organisations and analysed to their case. In terms of the practicality of the framework, SMEs in Chile can apply it, and other SMEs from other parts of the world can use it to gain knowledge about the implementation and compare it to their case. The framework is developed based on the views of SMEs contractors' organisations therefore, these kinds of organisations can develop strategies to integrate BLS practices in their organisations, and finally, the literature based on the Chilean sector and context is enhanced and enriched because studies like the one developed in this research are difficult to find in the context of the construction management area.

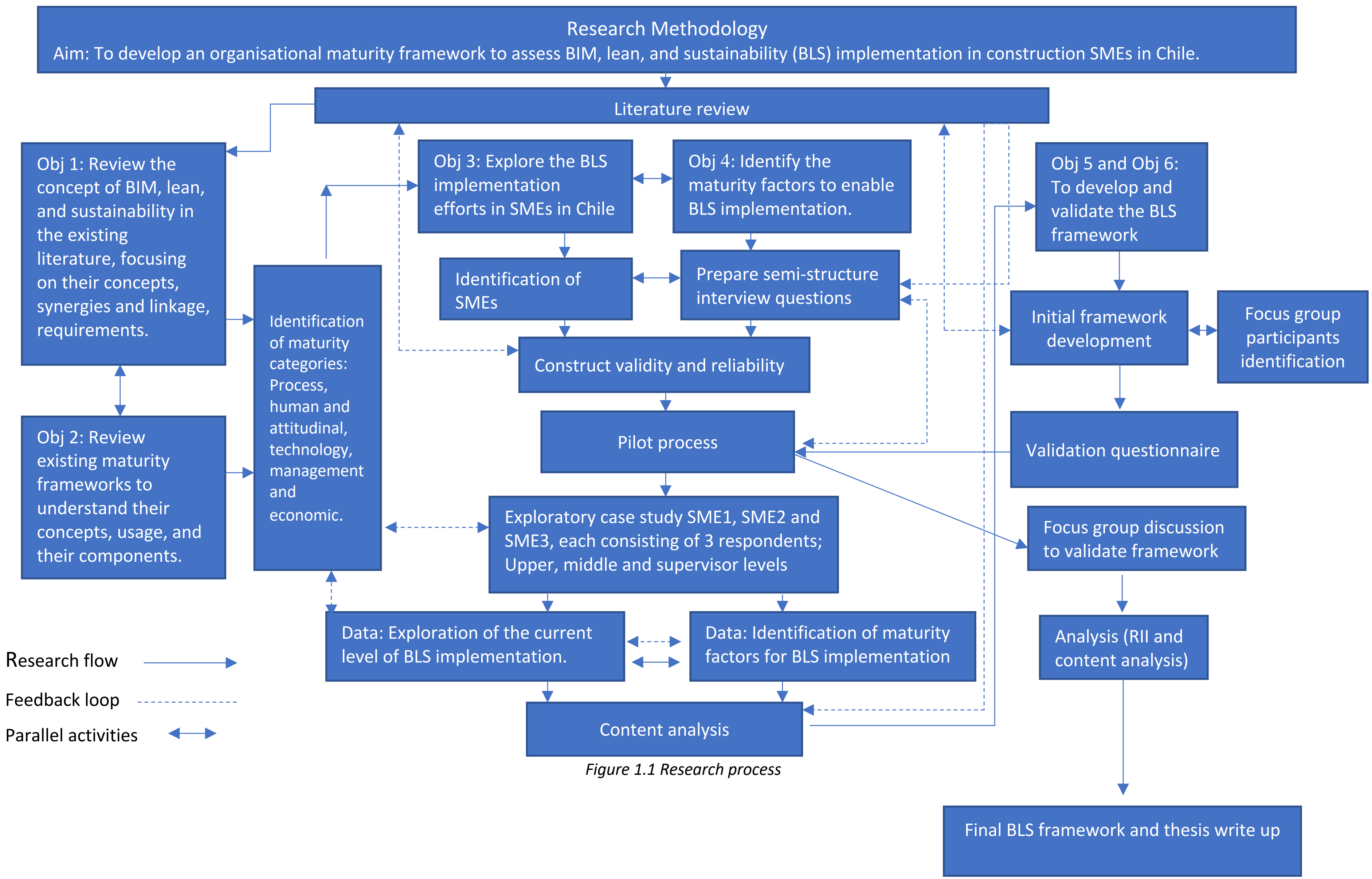

Figure 1.1 Research process

1.7 Overview of the chapters

This thesis comprises seven chapters that are written showing the best logical path to present the subject under research and to reach the objectives set in this study. The research process is shown in figure 1.1 and the thesis chapters are also presented reflecting the path taken. The overview of the chapters is shown below to provide the reader with a brief description of the covered topics.

Chapter 1 is the introduction of the subject, stating the rationale for this research and identifying the gap in knowledge this project intends to fill. A brief description of the topics under study is also presented as well as the objectives, research questions, aim, scope, research methodology, and contribution to knowledge.

Chapter 2 is the literature review covering the topics of BIM, lean, and sustainability (BLS) and the approach in the Chilean construction industry, explaining concepts and application as well as characteristics of the industry aiming to introduce the reader to the Chilean context of the topics under study as well as introducing BLS concepts to set the scene for the following chapters. This chapter also covers existing frameworks from which the BLS framework takes inspiration in its development

Chapter 3 presents a comprehensive research methodology for this study as well as the different philosophical approaches of carrying out research. Research logic, design strategies, and processes are also part of this chapter in which the best research option for this study is selected and presented.

Chapter 4 presents the results of the case studies where the factors that need to be considered for a proper BLS implementation are identified by nine different respondents who provided their views on the subject based on their experience.

Chapter 5 shows the discussion of the results from chapter 4 supported with the literature review to make sense of the responses provided in the previous chapter with findings from the literature review.

Chapter 6 presents the development and validation of the factors presented in the BLS framework. Discussion of the process is presented in this section and the final framework is presented after the validation process that involved a focus group.

Chapter 7 presents the conclusions and recommendations of this research and directions for future work in the area.

Chapter 2 The construction industry in Chile

This chapter presents the context of the Chilean construction industry and the application of the drivers under study. It provides BLS concepts to clearly understand the topics and set the scene for the following chapters in this research.

2.1 The need for better approaches in the construction industry

In the current global market, construction organisations are under constant pressure to manage their resources to improve their business operations in environmental, societal, and economic terms, which are not competitive advantage features anymore but a necessity to reduce the impacts the construction sector produces in these areas (Kuckukvar and Tatari, 2013). The complexity of the construction business in Chile and globally has increased, and so have the problems the industry has been known for a very long time, such as fragmentation, poor performance, and negative impacts on the environment (CChC, 2020). In addition, new requirements in the industry have made organisations consider adopting new practices to improve their business operations (Peansupap and Walker, 2006). In recent years, BIM, lean principles, and sustainability (BLS) features have emerged as trends in the industry to improve how buildings are delivered throughout their entire lifecycle (Saieg et al., 2018). Value aggregation and efficiency in operational and environmental terms are major concerns by stakeholders and the wider society, so better project outcomes can be achieved by integrating these practices (Koskela et al., 2010; Saieg et al., 2018; Enache-Pommer, 2012). However, BLS adoption and application are still at the early stages, and organisational management approaches towards their integration are missing in the literature, and their combined effect is also unknown (Saieg et al., 2018). Therefore, by committing organisations to include BLS in their practices, the industry can deliver better project results, and in consequence, its overall performance can also be increased (Mellado and Lou, 2020).

2.1.1 Background of Chile

Chile is in South America between the Pacific Ocean and the Andes mountains, and its location is next to the fast-moving Nazca plate. It has a high and constant tectonic activity, which has caused some of the strongest earthquakes recorded in history (Luo et al., 2020). The Chilean construction industry is internationally known and well recognised because of its infrastructure and resilience to earthquakes and other natural disasters (Siembieda et al., 2012). In addition, the country has a diverse range of climates due to its long geography, and diverse methods of construction are adopted depending on the area in which the facility is built (De Solminihac and Thenoux, 2017).
The north part of the country is mostly desert, which means that insulation and roof slopes are different from the southern parts, which are more rainy and wet, requiring different methods (De Solminihac and Thenoux, 2017). Given this complex nature in the more than 4,500 km long territory, the industry requires more sustainable and efficient designs and, therefore, efficient methods not only in the technical aspect but also in terms of strategy and proper management which are necessary to improve how the building products are delivered (CChC, 2020).

Furthermore, compared to other construction industries from more developed countries, the Chilean industry still relies intensively on the use of labour, whose training and educational levels are low and less skilled in the use of machinery and equipment (Fuenzalida, 2010). The industry is mainly composed of small and medium-sized organisations (SMEs) (Nuñez et al., 2018), and especially the small organisations do not possess a proper organisational structure and are understaffed at the professional level (Serpell et al., 2002). Therefore, applying new practices is difficult to accomplish, and proper guidance for complying with the new construction requirements is a complete challenge (CChC, 2020). It is not surprising then that research and development investment levels are deficient compared to more developed economies, and in consequence, the industry must rely on developments from other countries (Serpell et al., 2002).

The main construction sectors in the country are housing and infrastructure; while the first classifies all the buildings whose purpose is to accommodate people for housing purposes, the second is about all the necessary elements or services to allow the operation of a city, including transportation, energy, etc. (Switzerland Global Enterprise, 2020).

Buildings in Chile are mainly reinforced concrete structures because of the seismic nature of the country (Ugalde and Lopez-Garcia, 2017). In terms of high-rise buildings, these can be classified depending on their usage as residential and office buildings. Office buildings differ from residential as they require more open spaces, while residential buildings require more partitions for private occupancy (De Solminihac and Thenoux, 2017). High rise buildings have increased in the past years (Lagos et al., 2012). For example, according to the last census in 2017, high rise buildings accounted for 1,138,062 buildings, representing an increase of 552,678 buildings from the 2002 census. This growth of 4.9% shows that more buildings of this type are being demanded, and the forecast is that this number will increase in the future (Lagos et al., 2012). It is worth mentioning this tendency because it has been suggested that nearly 64% of the total construction investment is shared by construction and engineering works, housing, and non-residential construction, whilst the remaining 36% corresponds to equipment and machinery (Switzerland Global Enterprise, 2020).

Traditional buildings have decreased from 82.1% to 79.7% representing a 2.4% drop from 2002 to 2017 (INE, 2018). From this data, people are living and working in these kinds of facilities, and the numbers are and will continue to increase in the future due to constant demand and the increase in population. The possibility for people to live closer to the city where work locations are concentrated and the chance to reduce the impacts of travelling to and from work, fuel consumption are one of the advantages of this kind of buildings as well as placing shops, restaurants, cafes, in one single location (Kalcheva et al., 2016).

In this sense, the exponential increase of population in urban areas and the scarcity of land have made governments reconsider how their cities are organised in which high rise buildings play an essential role in avoiding horizontal overcrowding (Ahmad et al., 2017). On the negative side, high rise buildings contribute to the called "urban heat island", which brings negative consequences to the environment and, most importantly, people (Mohajerani et al., 2017). For the reasons previously mentioned, the government is demanding the application of sustainability features to building designs to make buildings more efficient and promoting the use of BIM, which is in accordance with the current construction industry scenario (CChC, 2020)

According to De Solminihac and Thenoux (2017), the main characteristics of the construction industry in Chile are:

- Construction is carried out in different stages with different specialised teams.
- Short life cycle in terms of execution processes causes high variability and high pressure leading to poor decision making and planning.
- High workforce mobility.
- Subject to location conditions.
- Overcrowding of the workplace in reduced spaces.
- Subject to high risks to processes and people.

Compared to other industries, the construction industry is highly variable due to the variety of teams working on a project, which leads to high fragmentation (Planbim, 2019). Despite this importance in contributing to the economy, the construction industry is still one of the low-rated industries in terms of performance, productivity, and efficiency (CChC, 2020).

2.1.2 Characteristics of the construction industry in Chile

The construction industry worldwide plays a vital role in a country's economy, employing people and creating other industries' infrastructure. The industry is known for high competition levels in which projects are usually granted at the lowest price, complex processes, and high-risk conditions, which can detriment the increase of efficiency because of the misalignment of incentives and potential benefits that can be shared throughout the supply chain, discouraging collaboration and the alignment of goals and objectives (De Solminihac and Thenoux, 2017; (CORFO and PMG, 2016).

The construction industry is one of the most critical activities in the economy of the country, with a contribution of USD 18 billion each year which is around 7.2% of the gross domestic product (GDP) of the country and 10.6 % of the national employment, estimated around 870,000 jobs, representing 64% of the total investment of the economy (CChC, 2020; Planbim, 2019). (Figure 2.1 and Figure 2.2)

The sector is made of 30,000 organisations, of which 98% are small and medium-sized organisations (SMEs), creating around 81% of the jobs in the industry and contributing 34% of turnover (CORFO and PMG, 2016).

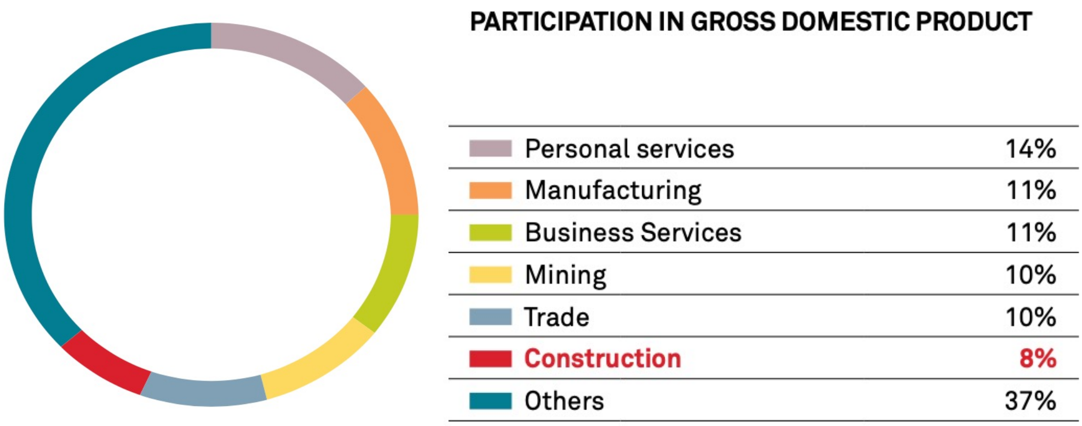

Figure 2.1 Construction industry participation in GDP (Switzerland Global Enterprise, 2020).

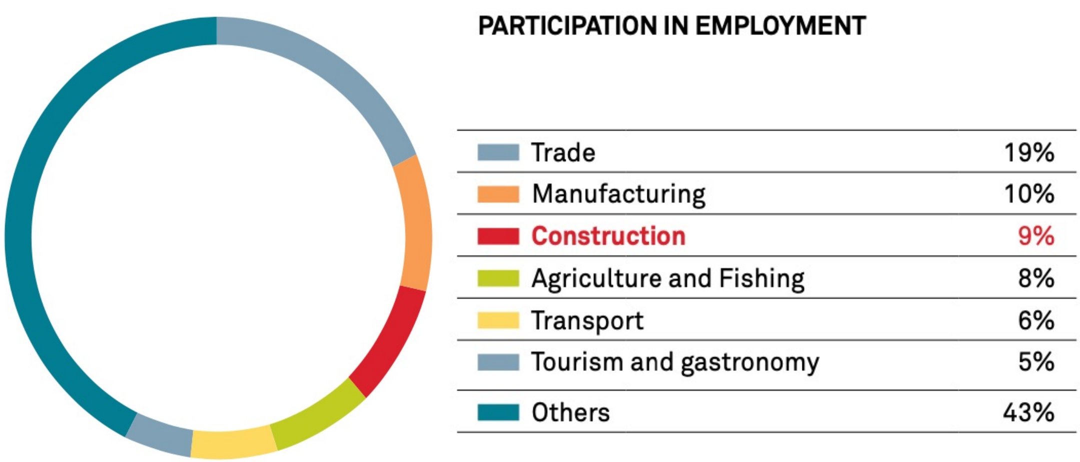

Figure 2.2 Construction industry participation in employment (Switzerland Global Enterprise, 2020).

Francis and Thomas (2020) suggest that the construction industry will globally contribute to around 15% of the global (GDP) by 2020, and the projections show that the sector will grow at a rate of 4 % annually, showing its fast progression not only in Chile but also globally. Data shows that the construction industry in Chile in terms of productivity has increased by 20% between 2000 and 2018; however, the construction industry has presented no variation, falling behind the general economic indicators and other countries from the OECD (CChC, 2020). The reasons found for these low productivity levels include low adoption of advanced management practices, fragmentation between stakeholders in the project life cycle, lack of standardisation, common use of prefabrication, and lack of training (Planbim, 2019).

For this reason, the Chilean government highlights the need for improving efficiency and identifies issues leading to low productivity levels. These issues include problems in the supply chain (design, planning and execution of works), adoption of new technologies, skill levels in people, regulations, and sustainability (CORFO and PMG, 2016). To improve those issues and lead the industry to global requirements, the government has developed the National Strategic Programme on Productivity and Sustainable Construction (Construye2025). This programme aims to increase productivity by identifying and tackling these challenges and the National Strategy for Sustainable Construction, whose goal is to promote sustainable development in the construction industry (Construye2025, 2019).

The strategy identifies and addresses key areas that need to increase productivity levels and accomplish the objectives to put the country at the productivity levels of OECD countries. These areas include supply chain excellence, collaboration and integration, digitalisation, industrialisation, technologies adoption, sustainability, competencies development, advanced human skills, and efficient regulations (CChC, 2020). The strategy encourages the promotion of BIM, lean, and sustainability to promote these improvements as key drivers. Still, their use and integration are not mentioned, creating a gap between theory and practice. This research intends to fill that gap by finding factors that need to be addressed by SMEs to promote their use to reach the established targets consistently. The same strategy mentions that lean tools such as the Last Planner system play an influential role in planning detailed activities, coordinating tasks, and preventing unexpected changes. However, it has not been consistently implemented. In this sense, the strategy also highlights that 71% of building projects and 72% of infrastructure projects experience delays and are not delivered according to the original schedule. In addition, only 34% of the whole population of organisations in the construction industry uses specialised software, and only 40% assess the reasons for non-compliance, showing that organisations do not consistently plan their efforts, causing inefficiencies and lack of trust in the system due to the lack of consistency and standardisation in its use. A clear example is that construction projects in Chile depend on the use of Excel (85%) over specialised software (CChC, 2020).

In addition, it is highlighted in the strategy that in terms of technologies, specifically the use of BIM and compared with countries in the OECD, the Chilean industry is still very immature in its adoption, showing low rates. Despite the need of improving productivity levels, the reality is that Chile is still plenty of steps behind, and the industry must be ready to take the initiative in establishing long term goals and consider other areas because it is shown in the government report that most of the BIM users are focused on the design stage (Loyola, 2019), leaving aside other project stages, other essential activities such as planning, and other project stakeholders such as contractors, establishing a gap that needs exploring (CChC, 2020).

2.1. Building information modelling (BIM) concept

The BIM concept was first introduced to the world in 1978 (Eastman et al., 2011), and since then, it has evolved to become the set of concepts and methods it is known for these days. Eastman et al. (2011) describe the BIM concept as “a verb or adjective phrase to describe tools, processes, and technologies that are facilitated by digital machine-readable documentation about a building, its performance, its planning, its construction, and later its operation”. The concept definition from international standards is a “shared digital representation of physical and functional characteristics of any built object […] which forms a reliable basis for decisions” (ISO, 2010).

Performing BIM means that a representation of a real building will virtually be produced over the whole life cycle. Software tools are used to build virtual models of buildings using parametric data showing objects' attributes and information. An example of functional attributes can be installation duration or costs, semantic information store, e.g., connectivity, aggregation, containment or intersection information and topologic attributes. e.g., information about objects' locations, adjacency, coplanarity or perpendicularity (Volk et al., 2014).

BIM promotes a more integrated approach when appropriately implemented, improving the construction project life cycle in aspects such as facilitating a more integrated design in the pre-construction phase and improved quality, lower costs, and reduced project duration in the construction process, among other benefits (Figure 2.3).

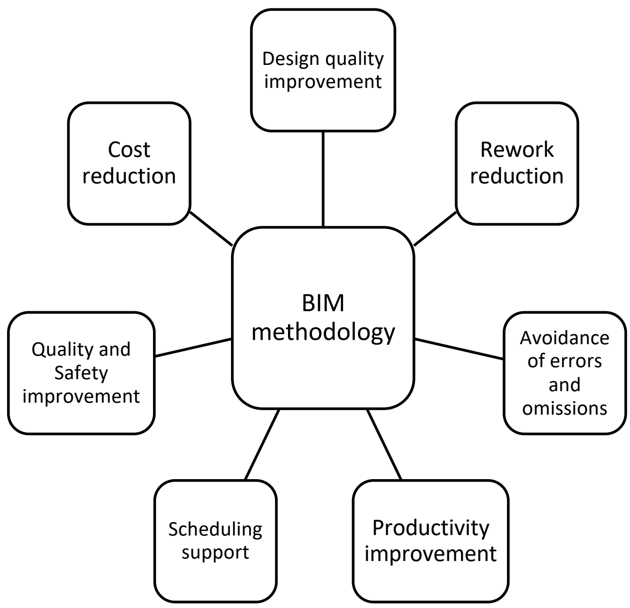

Figure 2.3 Benefits of BIM methodologies (Chen and Luo, 2014)

Without a doubt, BIM has brought plenty of attention in recent times in both industry and research. For example, a study by Santos et al. (2017) on BIM in the literature comprising ten years from 2005 to 2015 found that the topic has risen exponentially, and the most common subjects are BIM adoption, laser scanning and literature reviews. It was also found that collaborative approaches and interoperability are one of the emerging areas of interest, along with sustainable construction and standardisation. On the other hand, the training and education subjects, BIM-GIS and quantity take-offs are the gaps encountered.

2.2 BIM levels

The BIM process is divided into different stages or maturity levels to provide a roadmap for BIM implementation and the requirements for every stage. It has been acknowledged that the BIM process is a progressive path with milestones in every stage. There are four maturity levels as established by the BIM Task Group, starting from zero to three (BSI, 2014), as shown in figure 2.4.

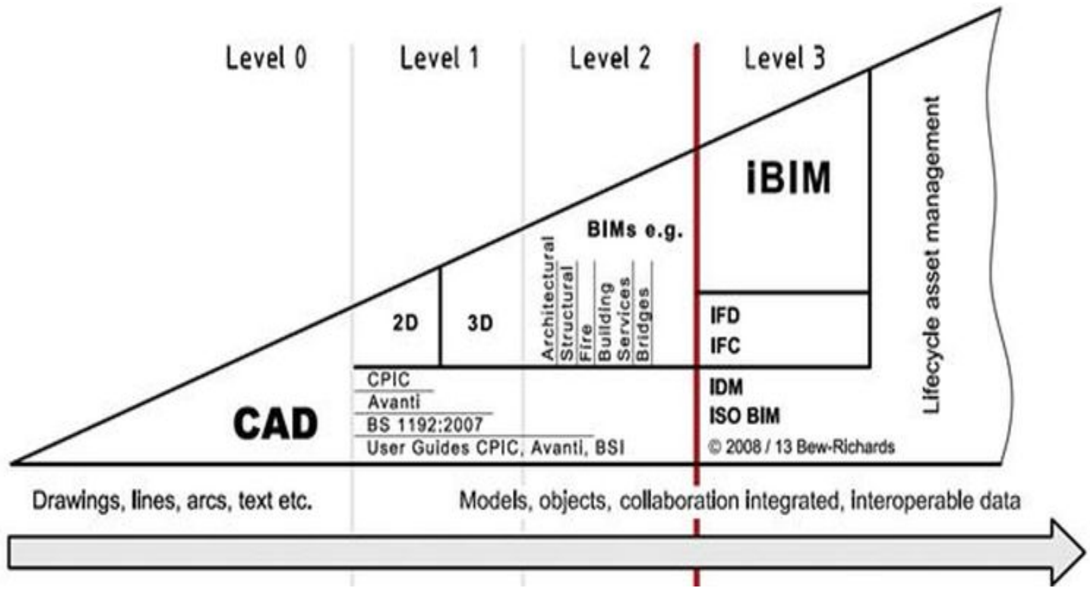

Figure 2.4 BIM maturity levels (BSI, 2014)

Level 0: The lowest and most basic BIM level comprises the use of unmanaged CAD, most likely with the management of information being shared based on paper drawings and PDFs shared electronically.

Level 1: The second maturity level is often called lonely BIM because the models are not shared between project team members. It is a mixture of 2D for drafting statutory approval documentation and production information and 3D for concept work (Eastman et al., 2011). CAD standards are managed to BS 1192:2007, and electronic sharing of data is carried out from a common data environment (CDE), often managed by the contractor.

Level 2: The main feature of BIM level 2 is collaboration; despite this, the parties involved are not working on the same shared model, but they use their 3D models. Collaboration comes to the scene in how the information is exchanged. At this level, the information of the design process uses a common file format for sharing, which allows any organisation participating in the project to combine that information with their data to make what is called a federated BIM model. This process allows performing checks on the information once it is shared, and it must be capable of being exported to a common file format such as IFC (Industry Foundation Classes) or COBie (Construction Operations Building Information Exchange).

Level 3: This level, known as "Open BIM", is about a full collaboration between all the disciplines involved using a single shared model stored in a centralised repository accessible to all the parties that can access and modify it. This level has not been fully defined yet, but it is the goal organisations should be aiming for in the foreseeable future.

2.3. BIM application in Chile

The use of BIM has been mandated in different countries, supported by governments to improve efficiency in the construction industry (Charef et al., 2018). In Chile, this situation is not an exception since the government has also mandated organisations to comply with BIM requirements based on the British model (Figure 2.4) to transition towards a more digital industry; and recently, training schemes to aid the industry moving toward the mandated requirements are appearing (Briones and Soto, 2017).

In Chile, the use of BIM in Chile has increased lately but is still experiencing a maturity process, meaning that organisations wanting to work on governmental projects should adopt BIM in their processes in 2020 (Rubio-Bellido et al., 2018). However, current policies established by the government focus primarily on quantity rather than quality, so it will be interesting to see when the benefits of promoting BIM will be tangible (Rojas, 2016). The mandate does not cover social housing (Gonzalez-Caceres et al., 2019), which is an integral part of government projects, so there is still plenty of maturities to reach before assessing the efficiency of the application in the Chilean construction industry. Also, organisations that have applied BIM have done it for their initiative (Loyola and Lopez, 2018). Just a few years back, a BIM committee was created that followed the UK framework to establish the Chilean mandate, and more work forums are taking place along with universities and institutes offering courses mostly based on the application of BIM software (Planbim, 2019).

2.2.1 The Chilean BIM plan

The Chilean BIM standard (Planbim, 2019) is developed by people in the industry and governmental institutions to promote productivity, efficiency, and sustainability. A government initiative was formed in 2016 called Planbim to promote incorporating information and communication processes, methodologies, and technologies to encourage modernisation in the Chilean construction sector. The goal is a 10-year plan that starts with using BIM to develop and operate public infrastructure and buildings by 2020 (CChC, 2020). This effort is supported by different governmental institutions, as shown in table 2.1.

Table 2.1 Chilean institutions supporting BIM (Planbim, 2019)

Chilean institutions supporting BIM	Corfo
	Chilean Chamber of Construction (CChC)
	Construction Institute
	Codelco
	Civil Registration and Identification Service
	Chilean Police
	Chilean Investigation Police
	General Civil Aviation Authority
	Ministry of Finance
	Ministry of Public Works
	Ministry of Housing and Urban Development
	Ministry of Social Development
	Ministry of Interior and Public Security
	Ministry of Transportation and Telecommunications
	Ministry of Health
	Ministry of Education
	Ministry of Economy, Development and Tourism
	Administrative Corporation of the Judiciary

Planbim (2019) describes that the standard aims to establish a consistent BIM requirement for the public sector so organisations tendering for public projects can follow a standardised procedure, ensuring that the process and requirements are always clear no matter the type or size of the project. The focus is on the exchange of information between involved parties during the tendering and development stages and the flow between the appointed organisation and the organisations providing services for the development projects through the BIM Execution Plan (BEP), described in the standard. The document includes geometric and non-geometric information that must be exchanged in a public project between the parties. It also establishes the incorporation of information in the parameters of COBie and the BIM Basic Information Delivery Manual in BIM models. Although the standard is developed to be used in public projects, private organisations can also benefit from it, and it is encouraged to do so if required.

2.3 Lean thinking characteristics

Lean production can work at a strategic level where the principles (Figure 2.5) are used to understand customer value and identify the value stream. At the operational level, the concepts are used to apply practices and tools to eliminate waste and promote continuous improvement (Gao and Low, 2014).

Lean has five distinctive fundamental principles that should be followed to reach maximum gains when implemented. These principles are described below.

1. Specify value: It refers to specifying what creates value for the client by identifying activities that generate value.
2. Identify value stream: Identify all the necessary steps in the productive process (value stream) required by the client and remove all the non-adding value activities. This means that everything must be stopped and immediately changed when things go wrong. In terms of processes that need to be avoided are miss and overproduction, storage of materials and unnecessary processes, transport of materials, movement of labour and products and unnecessary waiting time.
3. Flow: In this step, it is necessary to guarantee that the processes and value chain run in a continuous flow. The efforts must focus on the process rather than the end product. The customer value must be specified, and the value stream identified to obtain an optimal flow.
4. Pull: This step means that only what the customer requires should be produced when they need it. The aim of this step is to minimise unnecessary production and is encouraged to use the management tool “Just in Time”.
5. Perfection: The final step is to reach for perfection and continuous improvement. The product delivered must comply with customer expectations, within schedule and with the desired quality. To accomplish that goal, communication with the customer, managers, and employees is vital.

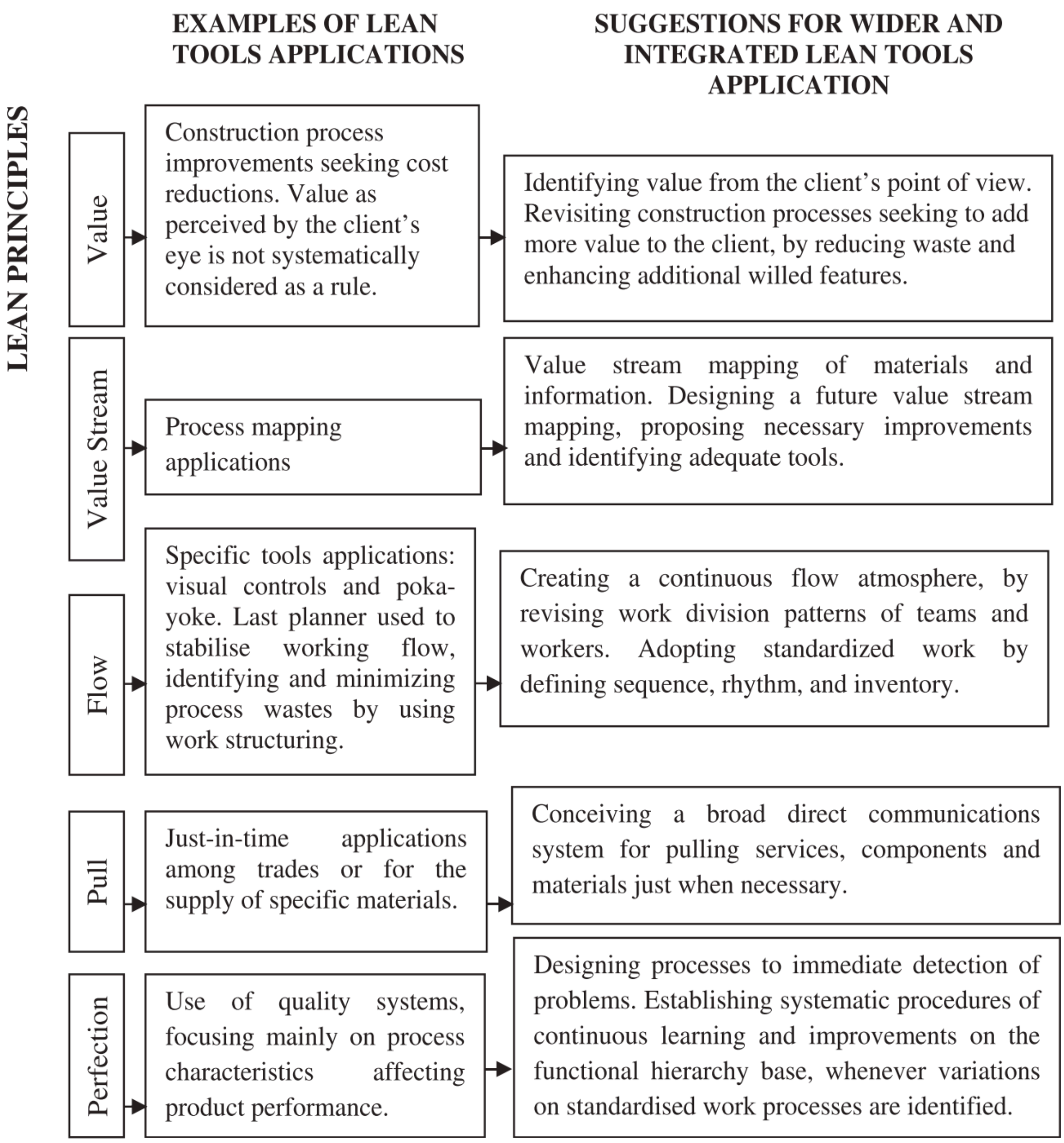

Figure 2.5 Lean tools reported in construction implementation (Picchi and Granja, 2004)

Moreover, Koskela (1992) established eleven principles summarised as follows:

1. Reduce activities that do not add value (waste)
2. Increase the value of outputs through systematic consideration of customer requirements
3. Reduce variability
4. Reduce cycle times
5. Simplify by minimising the number of steps, parts, and linkages
6. Increase output flexibility

7. Increase process transparency
8. Focus control on the complete process
9. Build continuous improvement into the process
10. Balance flow improvement with conversion improvement
11. Benchmark has fourteen principles organised in four categories: Philosophy, Process; People and Partners, and Problem Solving.

These principles have been successfully implemented in the construction industry. The Egan report (1998) identified measures to improve the construction industry in the UK, but applicable to almost every construction industry in the world, including the Chilean sector, which has no official reports, adopted the core of lean thinking and made recommendations along the following lines: Elimination of non-adding value activities which can take up to 95% of time and effort; waste removal of all the activities that take place in delivering a product; improvement of communication among the supply chain and removal of delays in the design and production process using "just in time management".

2.4 Lean construction concepts

Implementing lean principles in the global construction industry is gaining momentum because it can bring innovative changes (Babalola et al., 2019). This momentum has been gained because traditional project management approaches, namely the Work Breakdown Structure (WBS), Critical Path Method (CPM), Earned Value Analysis (EVA), have failed to deliver projects fulfilling the minimum performance parameters (Ballard and Howell, 2003).

The term coined by the construction industry is lean construction, derived from the principles established by the Toyota Production System (TPS); applied to the construction industry. The focus of lean construction is the same as the TPS of waste reduction, added value to the customer and continuous improvement by making the processes leaner being the removal of waste one of the key features because it is considered to be an activity that does not add value (Koskela, 2000). There are other principles that are different from the ones established by the TPS and vice versa (Sacks et al., 2010), which is understandable given the different nature of the industries.

As previously mentioned, the lean construction principle is derived from the lean production theory. Whilst the conventional production theory focuses on the transformation view; this is the transformation of inputs into outputs, the lean theory focuses on the activities that do not add value to the product/process. Koskela (1992) suggests that in the lean production concept, conversion and flow processes are present in the production process, thus, creating the transformation-flow-value concept introduced later to the lean construction philosophy. Some criticism has come from this view due to the project-based nature of the construction industry (Abdelhamid, 2004); however, research and practice have shown benefits when applying lean principles (Khalife and Hamseh, 2019).

2.4.1 Lean application in Chile

The application of lean principles in construction organisations in Chile has been documented and has increased, but mainly promoted by academia, lacking information from real cases regarding a full transformation. However, this issue seems to be changing lately since some organisations are realising lean construction potential and have started to consider it from the competitive advantage point of view (Salvatierra, 2021).

Studies are difficult to find in the literature based on the Chilean context. Alarcon et al. (2002) applied the Last Planner System (LPS) in twelve construction organisations with positive results in performance improvements. However, these improvements have not been sustained through time, as found by Salvatierra et al. (2015) in a diagnosis of implementation efforts in construction organisations based on the Last Planner System (LPS). Despite the country being one of the pioneers in lean construction that has led to the development of the Building Excellence group of companies that work closely with the Production Management Centre of the Catholic University of Chile (GEPUC), the results show a lack of alignment between the implementation efforts with strategy. This finding supports the findings from Barros and Alves (2007), who identify that the application of lean tools from organisations is promoted mainly from the operational level, ignoring critical aspects, namely a solid foundation from the strategic point of view aligned with organisational goals. Finally, Salvatierra's study also shows that organisations apply the LPS. Still, they did not identify other tools (Figure 3.3), and the results, such as analysis of reasons for incomplete assignments and constraint management, are very basic. In addition, the study does not determine whether the organisations that took part are SMEs or large.

2.5 Sustainability concept

Sustainability has become one of the major concerns and gained attention in practice and academia over the last decades. A study from Araujo et al. (2020) shows that the first study of sustainability in the construction industry dates back to 1993 and has risen from 2005 onwards, showing that it is still a new domain in the industry and undertaking a process of maturity. The most common definition is the one provided by the World Commission on Environment and Development, which defines sustainability as "development that meets the needs of the present without compromising that ability of future generations to meet their own needs" (WCED, 1987). Kibert (1994) was one of the first authors to work with the sustainability concept saying that the construction industry needed to move towards more sustainable practices to promote a healthy environment and preserve scarce resources (Figure 2.6).

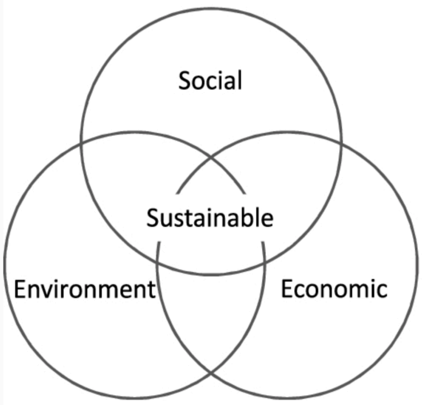

Figure 2. 6 Modern view of the sustainability pillars (Kibert,1994)

From figure 2.6, sustainability is understood as a balance of three aspects, namely social, economic, and environmental. Social sustainability is about the considerations of user comfort, health and safety, equality, diversity, and activities involving the wider public (Goh et al., 2020). Economic sustainability is related to stakeholders' financial gain from taking part in a construction project (Abidin, 2007). Economic sustainability is one of the most central sustainability themes because, for example, in a construction project, a proposed alternative for a particular construction method can be the most environmental and social friendly solution that can be applied. However, if not economically viable, these ideas are usually not considered. Finally, environmental sustainability refers to the maintenance of natural capital related to the consumption of renewable and non-renewable resources whilst minimising contamination and waste. It involves providing a better world to future generations by protecting the planet's ecology from destruction. It is essential to consider when using natural resources not to exceed their natural renewal rate. Environmental sustainability considers sustainable use of resources, harm to the environment and living species, protection of cultural and historical environments, among other aspects (Yilmaz and Bakis, 2015). Therefore, environmental sustainability aims to promote the harmony between nature and the construction activity throughout the entire life cycle of the constructed structure (Goh et al., 2020).

2.5.1 Sustainability application in Chile

In terms of the sustainable construction approach, construction organisations in Chile are still in the early stages of application and attainment; and the maturity levels are unknown (Serpell et al., 2013). Serpell et al. (2013) carried out an initial study on sustainable construction in Chile and argued that there is still little knowledge in Chilean construction organisations on the factors that would drive sustainable construction, especially in building organisations that have lower levels of expertise and interest in sustainability, creating a gap that needs to be explored further. In that study, it is found that larger organisations are the ones that are more aware of sustainability requirements and considering that the most predominant organisations in the country are SMEs (CORFO and PMG, 2016), the sustainability issue focused on these types of organisations is still an unexplored area. One of the key issues facing sustainability application in the country is the lack of integration in the process, which causes a disconnection between stakeholders and decision-makers, and contractors are involved only in the construction phase (Serpell et al., 2013). The same authors suggest that although organisations need to create profit from their projects, sustainability application within organisations should be an opportunity to create value. The suggestion is that more research is needed to evaluate the economic impacts of sustainability application, so organisations are well informed on how to balance the environmental and social issues pertaining to sustainability application.

Recently, a strategy called the National Strategy for Sustainable Construction (NSSC) has been supported by the Public Works Ministry, Housing and Urbanism Ministry, Energy Ministry and Environment Ministry to promote sustainability in the Chilean sector, aiming to establish sustainability in the construction industry (MOP, 2013). This strategy aims to establish guidelines to promote the concept of sustainable development in the construction industry to position the country at the regional level in 2025. The strategy also integrates other attempts developed by other agencies in one single national strategy, attempting to coordinate actions, goals, and objectives in the short, medium, and long term.

The objective of the NSSC is to accomplish sustainability goals in four key areas, namely: Buildings and infrastructure with sustainability considerations to 2020; energy consumption reduction of 12%; greenhouse gases reduction of 20%; and commitment by the construction sector to contribute 10% of the energy generated by unconventional renewable sources by 2024 (MOP, 2013).

The goals for sustainability in construction in the country are still very new, and more assessments and studies are needed in the area. Recently, the Chilean government presented their sustainability plans at the COP26 conference in Glasgow, establishing the guidelines and objectives of the sector (Hernandez, 2021). A long path is still ahead to reach these targets in which SMEs play a considerable role.

2.6 Organisational BLS assessment

The BLS framework that is proposed in this study is about measuring maturity in construction SMEs to make them aware of the factors that need to be assessed prior to the adoption of BLS practices, so they can be prepared to integrate these initiatives into their operations and thus, comply with the industry requirements. According to the literature, achieving maturity allows organisations to measure their capability when implementing change or improvement initiatives in a systemic manner (Röglinger et al., 2012) and can also determine developments in terms of people, process, and technologies (Nesensohn et al., 2014). Usually, the assessment of maturity can be done by analysing levels in which organisations can measure the adoption of initiatives from an initial maturity state, so evolution and transformation can be foreseen based on the maturity levels determined (Becker et al., 2009).

Maturity assessment has been researched in the literature; for example, De Carvalho et al. (2016) studied maturity models in information systems applied to hospitals. Knowledge transfer in the construction industry by Forstner et al. (2014). Albliwi et al. (2014) focused on a literature review in business process management. The BLS framework presented in this research suggests a similar maturity process following steps and an assessment to establish where the organisation is and the steps to move forward to achieve better results. This part is shown later in the following sections of this chapter. In addition, these kinds of models/frameworks are scarce in the construction industry, especially those focusing on small and medium enterprises, as studied by Omotayo et al. (2019).

The same author suggests that the BIM and lean implementation process can be facilitated by establishing a maturity model explaining the steps from an initial state to full maturity. A similar situation happens when trying to establish sustainability principles (See table 2.2 studied Maturity models). Therefore, by achieving BLS maturity, the benefits of the integration are more likely to be obtained.

2.7.1 Capability maturity models

The capability maturity model (CMM) is a process improvement framework that originated in the quality management field (Crosby, 1979) and was later adopted in the software industry and developed by Carnegie Mellon University. This model comprises self-assessment that organisations can use to assess best practices in key areas (capabilities), and in the process of transitioning to a more mature state, the model shows organisations how they can redefine their capabilities (Paulk et al., 1993). In addition, the CMM has served as the foundation for the development of several maturity models across other industries (Succar, 2010).

The advantage of the CMM is that it allows process improvement because it identifies a set of standardised processes allowing to obtain business benefits, including productivity improvements and Return of Investment (ROI) and reduction of costs and sustained process improvement (Hutchinson and Finnemore, 1999).

Maturity models are usually comprised of many levels made of different components whose processes, when satisfied, provide stabilisation of the whole system and provide a basis for continuous improvement, so by achieving maturity in each level, a different component is established (Paulk et al., 1993). In addition, the application of maturity has a direct correlation with business performance (Lockamy III & McCormack, 2004). In this sense, Renken (2004) argues that organisations that want to improve their capability should have a clear scenario of what they want to achieve and for that to happen and obtain consistent results, it is necessary to focus on improving the process, and that is exactly what maturity models do to achieve better results.

According to Succar (2010), available CMMs are more applicable to the software industry and focus mostly on implementation procedures. In addition, Sarshar et al. (2000) argue that the capability maturity model in its original form does not consider both supply chain issues and the different project life cycle phases; therefore, it cannot be applied to the construction industry. Even though more efforts have been developed with the construction industry in mind (See table 2.6 for examples), there is a lack of comprehensive maturity models/frameworks with an integrated BIM, lean and sustainability application developed for SMEs.

2.7.2 Theoretical elements of the BLS framework: Influences shaping the BLS framework

When developing the BLS framework, it is essential to acknowledge work from existing frameworks, even those unrelated to the construction industry, to gain knowledge and learn from the experience of other more successful sectors. Table 2.2 below shows existent published attempts from researchers that have influenced the BLS framework presented in section 2.7.6. It is worth mentioning that table 2.2 is a list of non-exhaustive maturity models in the BLS field, and table 2.3 illustrates some of the different performance excellence models that have somehow influenced the development of the BLS framework.

Table 2.2 Studied models

Model	Characteristics	Components/maturity
Capability maturity model integration (CMMI) (SEI, 2008)	CMMI is a process improvement approach that aims in helping organizations to improve their performance.	Initial, Managed, Defined, Quantitatively Managed and Optimising.
BEACON (Khalfan, et al, 2001),	Concurrent engineering readiness assessment model for the construction industry.	Process, People, Project, Technology.
VERDICT (Ruikar et al.,2006),	E-readiness model that assess the readiness of organisation to adopt e-commerce tools.	People, Process, Technology, Management (top level)
BIMMI Maturity Matrix (Succar, 2010)	Conceptual model to measure the maturity, capability, and organisational scale of BIM. Key areas: People, process, policy	Initial, Defined, Managed, Integrated, optimised.
NBIMS Capability Maturity Model (NIBS, 2007)	Measurement tool of a BIM organization’s maturity. It presents eleven categories of maturity (also called areas of interest) that are weighted according to importance and that can be scored from 1 to 10	Data Richness, Life cycle views, Role or disciples, Change management, Business process, Timeless response, Delivery method, Graphical information, Spatial capability, Information accuracy, Interoperability/ IFC support
Lean Enterprise Self-Assessment Tool (LESAT) (Nightingale and Mize, 2002)	This model assesses the organisation maturity in terms of the use of lean principles and practices within three Assessment Sections: Lean Transformation/ Leadership, Life Cycle Processes and Enabling Infrastructure	Awareness/Sporadic, General Awareness/Informal, Systemic Approach, Ongoing Refinement, Exceptional/Innovative
Lean Construction Maturity Model (LCMM) (Nesensohn et al., 2014)	It provides organisations with an assessment of the current state of their Lean Construction journey	(1) Lean leadership, (2) customer focus, (3) way of thinking, (4) culture & behaviour, (5) competencies, (6) improvement enablers, (7) processes & tools, (8) change, (9) work environment, (10) business results, (11) learning and competency development
Lean Production check- list (Sánchez & Pérez, 2001)	integrated checklist to assess manufacturing changes toward Lean	(1) elimination of zero-value activities, (2) continuous improvement, (3) teamwork, (4) JiT production and delivery, (5) suppliers’ integration, and (6) flexible information system

SPICE (Hutchinson and Finnemore, 1999)	Framework for continuous process improvement for the construction industry	Initial/Chaotic, Planned & Tracked, Well Defined, Quantitatively Controlled, Continuously Improving.
Lean Manufacturing: Performance Evaluation Audit (Urban, 2015)	A checklist for the assessment of an organization's current status and on- going progress in adopting Lean Manufacturing criteria	Process planning and control, management and leadership, quality control and planning, TPM, suppliers, Lean techniques, customer focus, performance improvement
The 4P Lean Model (Liker, 2004)	The model provides a picture of the values that constitute the foundation of the Toyota Production System and how these principles are applied in practice	Philosophy, Processes, People and partners, Problem solving
The Lean Project Delivery System (LPDS) (Ballard, 2000)	Conceptual framework to guide the implementation of lean construction on project-based production systems.	Project definition, Lean design, Lean supply, Lean assembly, Use.
Sustainability engineering and manufacturing SMEs (Burke and Gaughran, 2007)	framework for sustainability management, taking an incremental approach in moving from environmental management, using ISO 14001 as a foundation, to sustainability management which will contribute to an annual sustainability report which is currently only undertaken by large corporation	Environmental awareness program; Initial environmental review; Strategy development; Environmental policy; Environmental aspects and legislation; Objectives, targets, and programmers; Implementation and operation; Monitoring, auditing, and reviewing
Sustainability terminology (Glavič and Lukman, 2007)	framework for improved, coherent, and sustainable terminology	Triple bottom line (environment, economy, and society); Sustainability policy, systems, sub-systems (strategies), approaches (tactics), and principles
Sustainability transformation (Loorbach et al., 2010)	strategic perspective for business to contribute to the innovation of societal systems	Transition management levels: Strategic; Tactical; Operational
Sustainability reporting (Ahmed and Sundaram, 2012)	sustainable business transformation roadmap supported by a framework and architecture for integrated sustainability modelling and reporting	Discover and learn; Strategies; Design; Transform; Monitor and control
Corporate sustainability Implementation (Hahn et al., 2015)	systematic framework for the analysis of tensions in corporate sustainability. The framework is based on the emerging integrative view on corporate sustainability, which stresses the need for a	Analyse; Design; Implement; Monitor and control

	simultaneous integration of economic, environmental and social dimensions without, a priori, emphasising one over any other	
Global sustainability implementation (Laurenti et al 2016)	planning framework that connects material flows and socio-economic drivers	1. Plan: defining, forecasting, organizing 2. Do: demanding, executing 3. Check: controlling, coordinating 4. Act: standardizing, correcting
Sustainability management (Panagiotakopoulos et al. 2016)	Model to base the analysis of organisational sustainability (long-term viability).	Operations; Management; Environment
Corporate sustainability implementation (Gallotta et al., 2016)	conceptual framework based on Business Process Management to support organisations implement sustainability practices in its business processes	Sustainability dimensions; Systemic; Organizational; Individual

Table 2.3 Performance, Excellence and Quality Management frameworks influencing the BLS framework

Model/Author	BSC, The Balanced Scorecard (Kaplan & Norton, 1992)	EFQM Excellence Model - European Foundation for Quality Management (EFQM, 2008)	The Malcolm Baldrige National Quality Award (MBNQA) (NIST, 2008).
Features	Performance management tool and a strategic management system	management framework that supports organisations in managing change and improving performance.	Self- assessment process conducted by evaluating/scoring organisations against 7 Categories of Performance
Components	Learning and Growth, Business Process, Customer Financial Perspectives	Leadership, Policy & Strategy, People, Partnerships & Resources, Processes, Customer Results, People Results, Society Results Key Performance Areas	Leadership, Strategic Planning, Customer/Market Focus, Information & Analysis, Human Resource Focus, Process Management, and Business Results

After analysing the models presented in table 2.2, it is seen that they follow a similar structure, but the difference is in their depth, terminology, audience, and their industrial focus. These patterns are also highlighted by Succar (2010), whose BIMMi follows a similar composition in its analysis.

Regarding the performance management models presented in table 2.3, the literature shows that they positively impact business results (de Leeuw and van den Berg 2011; Qureshi et al. 2009) because they support continuous improvement through self-assessment and benchmarking (Niven 2006). The rationale for using these models as inspiration for the initial BLS model presented in section 2.7.6 is because they allow the use of a scoring system for self-assessment of maturity and capability (Vukomanovic et al., 2014).

2.7.3 Focus of the BLS framework.

Given that the BLS framework aims to assist SMEs in establishing their maturity levels in terms of BIM, lean and sustainability, the focus of its composition should consider these efforts. The above models (Table 2.2) show different attempts by researchers, and the common subjects that they explore are analysed by analysing patterns among them (Sinkovic, 2018) and extracted, adopted, and modified (Alshawi and Arif, 2012) to suit the aim of this study.

BIM/ICT/digital attempts are led by process, people, and technology aspects (Succar, 2010; Lou and Goulding, 2010; Khosrowshahi and Arayici, 2012) reflected in the BIM/ICT frameworks presented in table 2.2. Similarly, lean attempts are led by people and continuous improvement, establishing lean as a management philosophy (Koskenvesa & Koskela, 2012). In addition, Womack et al. (1990) suggest that organisations attempting to embark upon a lean journey should consider three fundamental issues: purpose, process, and people. On the other hand, when transitioning to sustainability in their operations, organisations should consider environmental, social, and economic aspects (Elkington, 1994, 2004). Similarly, Chofreh and Goni (2017) suggest that organisations should consider the social, economic, and environmental considerations and decisional aspects such as strategic, tactical, and operational levels for the successful adoption of sustainability principles in organisations. Most of the studied models (Table 2.2) consider the economic, social, and environmental aspects, but not all consider these decisional paradigms. The same authors suggest that any comprehensive framework should consider sustainability and decisional aspects.

For that reason, it is suggested that the BLS framework proposed in section 2.7.6 should also consider its composition Process, Human factors (people), technology, managerial and economic aspects. The models studied in tables 2.2 and 2.3 are used as inspiration, summarised, and integrated into these areas. Exploring these topics will give a foundation to SMEs on how to manage these requirements and give them ways to be prepared to adopt them.

In terms of maturity, most of the models presented in table 2.2 assess maturity based on five levels. For example, the CMM has five distinctive maturity levels: Initial, Managed, Defined, Quantitatively Managed, and Optimising. The BMMi also shows five levels: Initial, Defined, Managed, Integrated, optimised, which is understandable given that it is based on the CMMi as one of the frameworks that shape the BMMi (Succar, 2010). The same situation happens when analysing the Lean and Sustainability frameworks with 4 or 5 levels, depending on the model (See Table 2.2).

Additionally, existing attempts of integrating these practices have been studied by researchers, as shown in table 2.6 (BLS integration attempts).

2.7.4 Existing BLS frameworks and applications.

The literature shows existing attempts to study the application of BLS practices due to their synergistic nature, as explored by Koskela et al. (2010) and shown in table 2.5.

Table 2.4 Synergies between BIM, lean and sustainability (Koskela et al., 2010)

	Effect		
Driver	BIM	Lean	Sustainability
BIM		Promotes waste reduction and value creation.	Promotes the evaluation of sustainable

		Examples are: coherent design information, clash detection, visualization and evaluation of proposed design solutions, among others.	solutions such as simulations of energy consumption and CO_2 footprint
Lean	It aids in the BIM implementation journey through systematic approach; adds the necessary integrating process layer; and promotes collaboration between the parties.		Reduction of waste means that a higher resource efficiency can be obtained. Due to its focus on higher operational and product reliability, the reduction of harmful emissions can also be reduced. Due to its aim of adding value, it promotes the achievement of sustainability targets.

Sustainability	Sustainability requires complex simulations, so the use of BIM is strengthened in the analysis of such calculations.	Reinforces lean efforts through partial alignment of purposes and methods.	

Koskela et al. (2010) argue that change in the construction industry is needed and long-awaited, and the synergistic aspects between BLS provide a huge chance to achieve change. Still, it will only happen with visionary and decisive action and persistence. The author also acknowledges the difficulties that any change would imply and that it would be an error to position these changes as just a fad, outsourcing implementation hoping for the best, but involvement, insight, and championship are key to obtaining profound change. As mentioned before, the Chilean construction industry has identified BLS as critical aspects to improve the construction industry (CChC, 2020). Therefore, the challenge is to embed change in the industry in which construction organisations play a huge role that needs to be addressed and has been proposed in this study.

Another important study found in the literature on BLS integration is the one carried out by Enache-Pommer et el. (2010), who argues that the integration of BLS practices would yield better projects outcomes focused on healthcare facilities. Due to the specificity of requirements for healthcare facilities and the rise in demand for these facilities, efficient measures need to be taken to ensure clinical outcomes, low operating costs, energy consumption, and water use. The authors argue that customer value must be increased and that the whole system can benefit from applying lean principles to reduce waste, enhance collaboration and promote continuous improvement. In the study, the authors also add that healthcare facilities require complicated processes and that the inclusion of BIM to improve delivery and promote sustainability outcomes is needed; therefore, the authors propose a conceptual model including BLS to achieve these targets.

Ahuja et al. (2017), based on the synergistic features between BLS, suggests and proposes the use of BIM as an enabler for lean and green project outcomes. The authors found that the combination of four BIM capabilities, namely MEP system modelling, energy and environment analysis, constructability analysis and structural analysis, can lead to green and lean outcomes. In the study, the authors suggest that combining lean and green practices is possible and that the application in conjunction leads to better results in construction projects.

Finally, Saieg et al. (2018) took a different approach and carried out a systematic literature review suggesting the lack of studies integrating BLS concepts and found that most of the synergies occur in the construction stage and project process, especially during conceptual design and decision making, enhancing the opportunities to improve the overall construction industry in terms of the economic and environmental impacts caused by the lack of efficiency that characterises the construction industry worldwide. The study concludes that the application of BLS can help organisations and governments to achieve their sustainable development targets by implementing management strategies that include BLS. However, the review did not find any frameworks suggesting BLS, especially focused on SMEs and maturity towards the application. The question of how resource-constrained organisations such as SMEs can implement BLS and what aspects they should consider so the application is made correctly has been identified as one of the critical aspects of the present research.

In addition to the studies mentioned above that explicitly include BLS in conjunction, many researchers have focused their efforts on studying the integration of BIM, lean and sustainability either in conjunction or pairwise. Table 2.6, shown below, describes attempts in the use of these practices in the existent literature.

Table 2.5 Examples of existent BLS attempts

Reference	***Type of model/framework***	***Industry***	***Main Contribution***	***Validation Method***
Khanzode et al. (2006)	Conceptual B/L framework	Construction	Virtual design and construction (VCD) improve the lean project delivery system (LPDS) when applied at the correct stages. A set of guidelines on linking BIM and lean construction is proposed.	-
Toledo et al. (2016)	B/L planning framework	Construction	The use of Last Planner System (LPS) and BIM generates an increase in Percentage plan completed (PPC), a decrease in reasons for non-compliance, a shortening of the meeting durations, and a decrease in	Case study

			the total number of designs RFIs.	
Alwan et al. (2017)	B/S framework	Construction	The results show how ineffective strategies, policies and leadership have prevented full exploitation of the potential of BIM and modern methods of construction (MMC) towards sustainable production.	Case study
Nascimento et al. (2017)	B/L methodology	Oil/Gas	Methodology proposed to improve the production planning and control of pipe-rack modules. Results show improvements in prefabrication and preassembly planning. Reductions in welding-time.	Case study

Ilhan and Yaman (2016)	IFC based B/S framework	Construction	Results show that the proposed tool can be automatically process green data for BREEAM certification which can be used to aid the design process.	Sample project
Ng et al. (2015)	L/S methodology	Metal	Integration of lean and green manufacturing by introducing a metric called Carbon Value Efficiency to integrate L/S implementation metrics	Case study
Gan et al. (2018)	B/S framework	Construction	B/S framework to enhance the sustainable low carbon design of high-rise buildings.	Case study
Banawi and Bilec (2014)	L/S framework	Construction	Two types of waste were identified: materials which	Survey

			contributed the most in environmental impact, and time. “Changes in design during construction” was identified as a potential cause for waste.	
Mollasalehi et al. (2018)	B/L maturity model	Construction	It is proposed an integrated B/L maturity model to assess and analyse the performances of the projects that are implementing BIM and Lean together.	-
Wong and Wong (2014)	L/S framework	Manufacturing	Model promoting human integration in sustainable operations.	Case study

2.7.5 Factors affecting the adoption

Integrating BLS in SMEs will inevitably require organisations to commit to change or adapt the way they are working to promote these initiatives and, thus, comply with the requirements set by the Chilean government (CORFO and PMG, 2016). For this reason, it is vital to understand the factors that would enable such process to fully understand how to promote BLS in the Chilean construction industry, specifically in SMEs.

In this sense, studies found in the literature focused on finding key aspects to develop different frameworks also included the analysis of key elements in their development. Cherrafi et al. (2017) also explored the proposition of a framework integrating lean manufacturing principles, six sigma and sustainability, which included the analysis of critical success factors, barriers, tools, benefits, and drivers. Siegel et al. (2019) state that SMEs need guidance when implementing new practices, so in this process, the identification of challenges, benefits, success factors, tools and techniques, and barriers is fundamental. Demirkensen and Bayhan (2020) suggest that to convince implementers in the case of lean adoption, a guidance model is needed, and an important part is to identify factors enabling such process. Cherrafi et al. (2021) also focus on the critical success factors (CSFs), barriers and key elements when developing a readiness self-assessment model for assessing organisational readiness to adopt sustainability and lean initiatives. Lou et al. (2020) developed a self-assessment framework focused on SMEs to quantify and measure e-readiness from an organisation, technical and process perspective for building services providers in the UK. This framework was developed based on potential critical success factors which shaped the final version of the readiness assessment framework.

Lee et al. (2011) focused on the development of a self-assessment framework for Chinese companies, and the criteria to explore included critical success factors and challenges for implementing organisations. Juan et al. (2017) focused on analysing factors to develop a BIM self-assessment framework, including the BSC (See table 2.3) for inspiration.

Liao and Teo (2019) focused on critical drivers for the implementation of BIM in Singapore to develop their framework based on the idea that organisational change is key to the implementation process.

Finally, this study takes as inspiration these authors' studies to explore the factors impacting the application of BLS practices in SMEs in Chile. These factors along with the models studied in table 2.2 give a foundation for the issues to explore and the areas of coverage that the BLS framework should have in its development.

2.7.6 Theoretical BLS framework.

Based on the reviewed models, the theoretical BLS framework presents the following categories to be explored: Process, Human and attitudinal, technology, management, and economic aspects, and the exploration is also based on the factors that would enable those categories (Table 2.7). There was a consideration of proposing an environmental category as well to analyse environmental factors and comply with the social (People), economic and environmental aspects of the sustainability concept since, as Goh et al. (2020) imply in their study; there is a lack of integration of these three areas in sustainable construction. However, after consideration, environmental outcomes such as water improvement, energy efficiency, lighting analysis etc., are factors that are seen and can be measured at the end of, in this case, construction projects. As pointed out by Häkkinen and Belloni (2011), sustainability in construction is not hindered by a lack of assessment methods or technologies but is affected by the procedural aspects in organisations to promote the adoption of new methods. Therefore, by tackling the organisational aspects, positive environmental outcomes are more likely to happen, and that also highlights the importance of the procedural elements that organisations should consider before embarking upon the application of BLS in this case. For this reason, the consideration in this research was to analyse how Chilean SMEs can obtain those results from the organisational perspective, and the reasoning after analysing the models in table 2.2 was that other procedural aspects must happen so organisations can later get results in the environmental area.

The proposed maturity levels will follow a similar view as mentioned in the above paragraphs, moving from one to five levels of maturity, and the assessment carried out by SMEs will be based on the above categories.

Table 2.6 BLS theoretical framework initial proposition

BLS framework areas to explore	
Category	**Factors**
Process (P)	To be explored
Human and attitudinal (H)	To be explored
Technology (T)	To be explored
Management (M)	To be explored
Economic (E)	To be explored

2.8 Summary

The main objective of this research is to develop and validate an organisational framework to assess maturity in SMEs to achieve BLS objectives as proposed by the Chilean strategy and as identified in the literature due to the BLS synergistic characteristics but with no organisational frameworks to assess SMEs. For that reason, this chapter presents the literature review to support the study, starting with the Chilean context and moving toward the BIM, lean, and sustainability concepts and their reality in the Chilean scenario. The chapter also presents and discusses existing maturity frameworks that support the proposal of the BLS framework and existing attempts regarding the integration of BLS practices. Finally, the chapter presented the topics explored in the BLS framework, explained in-depth in subsequent chapters.

Chapter 3 Research methodology

This chapter aims to present the philosophies and methodological approaches and the research design and processes of the method approach chosen to achieve the aim and objectives of this research.

This study is based on the opinions and behaviours of people from SMEs in Chile, so the best way to describe the ideas proposed in this study is to consider a multi-method approach of case studies and expert validation. The considerations of the selection of these methods are discussed in this chapter.

The research methodology is an integral part of any study because it goes through the entire research project cycle, giving a snapshot of the activities to be carried out and the methods to collect data to reach the aim and project objectives. It follows a systematic, logical path of thought processes applied to perform scientific analysis to reach new conclusions (Fellows and Liu, 2015). According to Sutrisna (2009), when talking about research methodology, three prominent aspects need to be considered: the research philosophy, reasoning of the research, and data.

3.1 Research methodology employed

The research methodology to be employed in this research project is based on the Saunders et al. (2008) method, where the research is classified in layers moving from philosophies to strategies, techniques, data collection and analysis. This process provides a structured guideline to be adopted in this research allowing to narrow down the different steps to be used, which is consistent with Sutrisna's (2009) view.

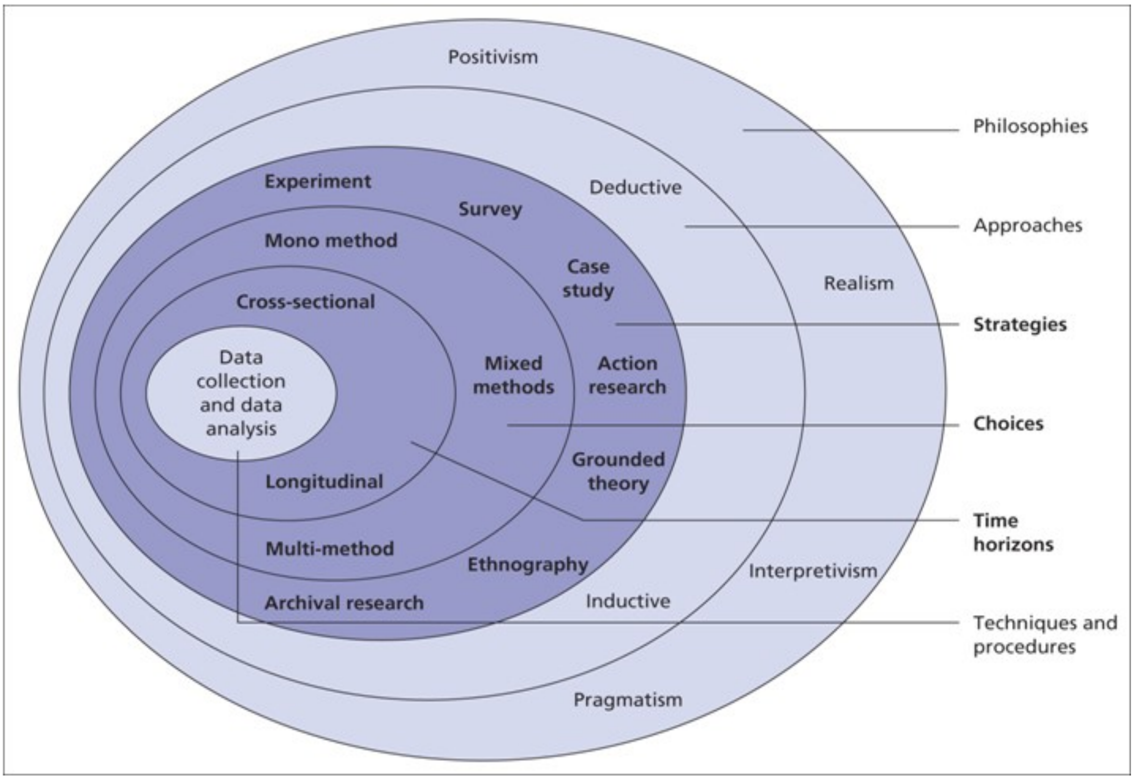

Figure 3.1 Research methodology (Saunders et al., 2008)

Figure 3.1 shows the research onion methodology employed in this study.

3.2 Research philosophy

Research philosophy refers to the development and nature of knowledge, which means the development and interpretation by researchers who also need to know what philosophy they belong to and what research group they are part of. Saunders et al. (2008) and Fellows and Liu (2015) suggest that epistemology and ontology are the two main research philosophy types.

Creswell (1994) suggests that epistemology refers to the branch of philosophy related to human knowledge's origins, nature, methods, and limits. In other words, it is the researchers' knowledge of what they know and how knowledge should be acquired and accepted. In addition, Easterby-Smith et al. (2002) argue that two philosophical paradigms are the most predominant in this area: Positivism which is characteristic of natural and physical science and it is more likely to be adopted by researchers; and

interpretivism, where researchers need to understand differences between humans in their roles as social actors.
Creswell (2009) also argues that the interpretivism paradigm aims to gain knowledge and understanding of a particular topic by collecting data that will allow inducing new ideas. Easterby-Smith et al. (2002) say that in the inductive stance, people try to make sense of the world by sharing experiences with others via the use of language.

This research is exploratory in nature, so by following the research onion presented in figure 3.1, the process starts with the interpretive philosophy because, as Fellows and Liu (2015) suggest, the reality is relative and therefore varies according to the participants' perception. It is the task of the researcher to interpret and understand those realities. In this research, perceptions will be collected from interviews and experts' opinions who respond according to their current reality regarding the subject. The main objective of this project is to establish a framework to assess SMEs' maturity in the adoption of BIM, lean and sustainability in conjunction, which are synergistic but lack maturity models (Enache-Pommer et al., 2010; Koskela et al., 2010; Sacks et al., 2010; Ahuja et al., 2017).

On the other hand, according to Saunders et al. (2008), ontology refers to the nature of reality. It questions the assumptions researchers have about the way the world operates. The same author suggests that there are two different branches in this area: Objectivism, which says that social entities exist, external to social actors, and subjectivism, which is created from the perceptions and actions of social actors. In other words, Cresswell (1994) describes this phenomenon as the explanation of "what" knowledge is and assumptions about reality. In the case of this research, it is considered necessary also to adopt this philosophical position since it is essential to explore the level of BLS implementation in the SMEs under study because the maturity framework is built from the reality of the organisations that took part in this process.

3.3 Research approach

In this part of the process, three different elements are analysed by following figure 3.1. The decision to opt for quantitative, qualitative, and mixed methods is also known as the strategy of enquiry (Creswell, 2009). The other element to be considered is the research reasoning which Sutrisina (2009) defines as “the logic of the research, the role of the existing body of knowledge gathered in the literature study, the way researchers utilise the data collection and subsequent data analysis”. The final part of this process is the data collection, analysis, and interpretation of results (Creswell, 2009).

3.4 Strategy of enquiry

The strategies of enquiry are classified as quantitative, qualitative, and mixed methods that provide specific directions for procedures in a research design (Creswell, 2009). Some authors, such as Saunders et al. (2008) and Jankowicz (2000), have different opinions. The first author suggests that one approach is better than the other, whilst the second author states that choosing one strategy depends on what is being studied and the stated objectives. Despite this lack of concordance, quantitative and qualitative methods focus on exploring certain phenomena (Mack et al., 2005) and should not be viewed as opposites or dichotomies (Newman and Benz, 1998).

Quantitative research refers to the measurement of quantity, which means that it is applicable to phenomena that can be expressed in terms of countable terms. It is explanatory in nature given that it adopts the scientific method, comprising an initial literature review, establishment of aims, objectives, and proposition of hypotheses to be tested (Creswell, 2009; Fellows and Liu, 2015).

In contrast, qualitative research refers to qualitative phenomena such as quality or kind, which means that an exploration of the subject is undertaken, sometimes without prior formulations (Fellows and Liu, 2015). According to Harrison et al. (2007), the qualitative research approach is better when formulating new theoretical ideas and making interpretations of a theory. On the other hand, quantitative methods are best when research is leading towards identifying general patterns and making predictions.

Research in the construction industry is classified as emerging or intermediate in maturity. According to Edmondson and McManus (2007), appropriate methodologies exist depending on the field of study and the development of research in each discipline. The construction discipline leans towards exploratory studies by using qualitative methods rather than quantitative ones by using hypotheses that are more suitable to disciplines with a higher level of maturity.

Although, there is also the possibility of using a mixture of both qualitative and quantitative methods to carry out research which is a powerful combination to gain an understanding of the subject and draw conclusions, better known as triangulation (Jick, 1979). Authors such as Faules (1982), Kaplan and Duchon (1998), Gable (1994), and Yin (2003) describe the use of combination and surveys and case studies to describe phenomena. The mixed-methods approach is a solid approach to potentially reduce the disadvantages of either quantitative or qualitative methods applied alone and reinforce each other (e.g., qualitative quotes support statistical results; Creswell and Plano Clark, 2007).

Since the premise of this study is that BLS work better combined than treated in isolation and because in the Chilean case, the government is requiring and promoting the use of BIM, lean and with a focus on sustainability, and the lack of guidance and maturity in this area, the idea is to collect perceptions from real experiences to have a better understanding and to reflect the reality of SMEs that are in/or transitioning towards the adoption. Due to the nature of this study, experiences from people in BLS topics is required; the best way to approach it would be by applying a qualitative instrument.

The selection is also justified because, in the case of quantitative approaches, despite its advantages such as generalisation of results, the method is seen as inflexible, and depth is also an issue because the questions are predetermined, and more insightful content is challenging to obtain (Weisberg, 2008). For that reason, to solve that issue and add more depth to the subject, Weisberg (2008) suggests the use of case studies, and Yin (2009) contributes to this matter by saying that case studies provide a more in-depth description of the events. As previously mentioned, in this research, the maturity concept is adopted to develop a framework to assess the implementation efforts of SMEs regarding BIM, lean and sustainability (BLS), so in depth-exploration is required.

3.5 Research reasoning

In this part, there are two methods: the deductive and inductive approaches (Saunders et al., 2008). Saunders et al. (2008) suggest that deduction is about testing a theory; therefore, it is subject to a thorough test, and it is the primary research approach adopted in the natural sciences where laws present the basis of explanation, allow the anticipation of phenomena, predict their occurrence, and thus permit them to be controlled. Deduction starts with a general idea which then evolves to a more specific approach, moving from theory to obtaining data through a process that involves theory, method, data, and findings. For this reason, it is known as a top-down approach.

On the other hand, induction occurs when the theory is developed after the data collection and analysis, focusing on the context where the events are occurring to understand what is happening. For this reason, smaller samples are more appropriate for this method than a large number. Researchers adopting this approach are prone to use qualitative data (Saunders et al., 2008).

The same author proposes that although the methods differ between them, the combination of both is possible and beneficial. In this sense, Creswell (2009) suggests that if the topic under investigation yields a vast number of previous literature from which hypotheses, research questions and theoretical frameworks can be obtained, the deduction approach is the most likely scenario because the topic has enough evidence in the literature to sustain and explain the content of a theoretical framework.

This research has both elements, topics specifically centred in the Chilean context where little literature exists which falls into the inductive category because data is generated and then analysed and reflected upon. On the other hand, literature on the specific BLS subject and maturity models, as shown previously in chapter 2, can be found in the existent body of knowledge. Therefore, a deductive approach can be taken in this part to develop the elements of the proposed BLS framework.

3.6 Research method

This research is based on a qualitative approach based on case studies to identify the factors that compose the BLS framework. The next part is the validation of the BLS framework, which is also a qualitative approach based on a focus group from a small sample of SMEs to determine the final version of the framework.

The research strategy is the general plan researchers must follow to answer their research questions. It is an orientation to carry out proper research (Bryman and Bell, 2011). In this sense, the appropriate research strategy must be set following the research questions and objectives, which also must consider the extent of the existing knowledge in the reviewed area, resources available such as time, cost etc. and the philosophical support the researcher has chosen. A different way of thinking proposed by Yin (2013) suggests that a specific research strategy must be chosen according to three points: The research question type, the extent of control the researcher has over behavioural events and the degree of focus on contemporary or historical events.

In this sense, Fellows and Liu (2015) suggest that five methods apply specifically to the construction field: ethnographic research, case studies, surveys, action research, and experiments.

Since this research positions in the use of qualitative methods, the selection was based on case studies and expert validation for the framework validation.

3.7 Justification for the selected research method (Case studies and expert validation)

Figure 3.2 shows relevant situations for different research methods in which the explanation for each method is given. This research stance lies in the qualitative approach; therefore, by following the approach established by Yin (2009), summarised in figure 3.2 below, the options that the researcher can choose from are case studies, action research and ethnographic studies. The researcher selected case studies as a research method approach because they answer the questions of how and why, which are consistent with the questions established in the objectives set for this study which is the development of a theoretical framework that is then modified according to the data obtained. In addition, it does not require control over behavioural events since the researcher has no incidence in the organisation's approach in the implementation of BLS. Finally, the topic follows and focuses on contemporary events by asking questions regarding the reality of SMEs in terms of BLS.

Method	(a) Form of Research Question	(b) Requires Control Over Behavioral Events?	(c) Focuses on Contemporary Events?
Experiment	how, why?	yes	yes
Survey	who, what, where, how many, how much?	no	yes
Archival Analysis	who, what, where, how many, how much?	no	yes/no
History	how, why?	no	no
Case Study	how, why?	no	yes

Figure 3.2 Relevant Situations for Different Research Methods (Yin, 2009)

Similarly, case studies are more effective than surveys in this case because the information presented is derived from a specific organisation with existent data fulfilling the characteristics of that organisation and when analysing criteria for assessment models, Saleh and Alshawi (2005) suggest that case studies are the most appropriate method when establishing new systems because it requires an understanding of the organisation processes, people and work environment, which is something that experiments and surveys cannot provide.

3.8 Pilot study

Yin (2009) promotes the use of a pilot study before the formal interviews to refine the data collection plans and strengthen the procedures so inconsistencies are not found later in the formal interviews and to familiarise and expose the researcher to the method. The same author also highlights that a pilot study can give more insights into methodological aspects such as research design. Given that in formal interviews, people take time out of their schedules to cooperate, assessing the instrument before being officially used is a necessary step to ensure that the right questions are asked and not discourage the interviewees with questions that are not relevant or useful.

The procedure for this pilot was to assess and simulate the questions with people from academia and industry to check the question's relevance and the length of the interviews. In total, four people were engaged through an academic contact who was the key connection to engage relevant industry participants who took an interest in the subject and were encouraged to participate. This preliminary session lasted around 2 hours, and the respondents gave insights on the questions and made suggestions on how the interview process should be carried out. These suggestions included examples of asking follow-up questions and digging for more details when people were providing an answer that needed more details.

The feedback provided helped the researcher in formulating the final set of questions which can be found in annexe 1 and were used to collect the data presented in Chapter 4.

3.9 Case study

In selecting case studies, Yin (2009) argues that the number of cases is not straightforward and can vary from a single case to multiple cases and that the selection depends on the research questions that need answering.

In this research, the case studies are used to find BLS factors to populate the framework. In this sense, Gerring and McDermott (2007), Lloyd-Jones (2003) and Yin (2009) agree that multiple case design is more advantageous than a single case and that in terms of the methodological approach, they are similar to carrying out experiments. For that reason, in this study, a multi-case study approach is selected in which three case studies are analysed.

The types of organisations selected for this study are contractors SMEs registered with the Chilean Construction Chambers (CChC) and are experiencing a transition toward implementing BLS practices to comply with the industry requirements. The selection of the organisations starts with the most important attribute: the willingness to cooperate with this study. The identified SMEs fulfil the objectives of this study, and the selection was made with this priority in mind. The organisations' engagement was through contacts made by the researcher to key people in industry and academia who helped identify the SMEs. An initial number of 7 organisations were identified and asked to participate in the study, but three of them did not reply, and from the ones that answered, only three were the ones that committed and participated in the final study. During that first initial contact, the researcher made the study's objectives clear and made sure that the SMEs were positive in the BLS process, either already implementing it or with a commitment to implement it in the near future. The strategy also helps to build a rapport with the organisations and show that the study can help them succeed in the transition. This way, it ensures their cooperation and commitment to help.

The identified SMEs are described as follows:

SME1, SME2, and SME3 are the codes given to the organisations in the case studies.

SME1: This organisation is a contractor that offers building services in both high rise and residential projects. The use and application of BIM are in their infancy, and the contractor has experience using lean tools, which have been applied to different projects with different levels of success. Sustainability is a priority, but they have yet to find and use methods to promote it.

SME2: This organisation is a building contractor focused on high rise services. The organisation has vast experience in high-rise construction and has recently used BIM in a pilot project. They have also appointed a BIM champion to promote its use throughout the organisation and their projects. The contractor has also consistently applied lean tools in their projects, and sustainability in their projects has been applied by using more prefabricated products.

SME3: This building and housing contractor organisation is transitioning to implementing BIM in their projects, but no projects have been developed yet using this methodology. In the case of lean tools, the organisation has used them in some projects but has not been consistent in the application. Sustainability is a priority, and they are implementing plans to adopt more sustainable construction methods.

3.10 Focus groups interviews

Many authors concur that focus groups are advantageous when collecting qualitative data because the method allows interactions between participants (Mc Lafferty, 2004). According to Ritchie and Lewis (2003), by applying this approach, different participants can exchange their views of the subject under study in a relaxing and unpressured way (Merton, 1987). This approach allows the researcher the chance of collecting data from several people at the same time (Robson, 2002), probing into the ideas developed by the participants at the desired level of depth, adding quality and richness to the collected data (Minichiello and Kottler, 2010).

This part of the research process aims to validate the proposed BLS framework from the view of key industry participants who can provide insights and key information regarding the BLS framework improvement and directions on how to apply it in the future. This method is considered the most appropriate way to collect opinions, experience, and knowledge from industry participants about the subject.

3.11 Research technique

3.11.1 Literature review

The research technique used in this study to accomplish the aim and objectives included an extensive literature review on the subject. The main source of information came from papers in journals, conference proceedings, and government reports. Also, as Kothari (2004) suggests, relevant references are checked from those reviewed papers to add more quality to the information.

The purpose of the literature review is first to gain a deep understanding of the subject and establish the foundation on which this research is based. This way, the proposed research questions have a strong foundation derived from current issues the construction industry faces, applied to the Chilean context.

Secondly, the literature review is also an ongoing process because the topics can evolve quickly, so checking the literature for updates is necessary. The literature also allows the researcher to gain knowledge and support the development of the BLS framework with the information identified by the respondents.

During the first part of the literature review, when establishing the aim and objectives, it is found that the Chilean construction industry is promoting the use of BIM, lean, and the reduction of the impact the construction sector produces. In the literature, BLS integration is being looked at as a potential solution to increase performance due to their synergies. However, the focus on SMEs' organisational maturity is not considered. This premise led to the objectives set in Chapter 1 and discussed there as a foundation for this study.

3.11.2 Data collection technique

Fellows and Liu (2015) suggest that there are different ways of collecting data, such as books, journals, and interviews. The features that need to be considered when choosing the data collection method depend on the research topic and how the method is appropriate for that purpose.

Kothari (2004) and Saunders et al. (2008) suggest that observation, interviews, documents, and surveys/questionnaires are the most common data collection methods. Yin (2009) says that the selected data collection technique depends on the level of assessment of the researcher in terms of the availability of the data since some data acquisition could be difficult to obtain or could not be in the researcher's control. For this reason, of all the mentioned methods and due to the use of quantitative and qualitative methods, the most suitable techniques for data collection for this study are the survey/questionnaire and the case studies that consist of interviews with people from the SMEs described in section 3.9.

Esterby-Smith et al. (2002) describe interviews as conversations where the researcher follows a structured procedure. Their findings are obtained from a set of pre-conceived questions where responses reflect the respondent's experiences, opinions, feelings, perceptions, and knowledge. In this method, the output depends on the ability of the researcher to get answers (Kothari, 2004). Interviews characteristics are their formality which can be classified as structured, semi-structured and unstructured, being the difference in the restrictions established between the respondent and the interviewer (Fellows and Liu, 2015). According to Esterby-Smith et al. (2002), the semi-structured format is the most important in the qualitative area because the researcher has some space to ask for more details and gain more knowledge or uncover new issues (Yin, 2009). The format of the semi-structured interview questions is usually based on a set of pre-determined questions, but it can vary because the researcher may feel the need to ask more details about a certain subject or, depending on the responses given by the respondents, the researcher may also pick up on certain areas that may need further exploring (Robson, 2002).

The interviews were held online due to the current COVID-19 situation. When the interviews took place, the researcher's country of origin was on the red list of countries; therefore, the option of travelling was considered but discarded. Also, the mobility issues in the researcher's country were also a factor that led at the end to choose an online option. In addition, since the world has gotten used to the use of digital tools for online meetings and due to the increased capacity of organisations in this aspect, online interviews were the best option. Confidentiality and ethical considerations were important for this part of the process; even though the option of recording the interviews has become widely acceptable (Lee, 2004), the respondents must agree to this practice (Fellows and Liu, 2015). In this case, not everyone felt comfortable being recorded, especially on video. Hence, the researcher decided to take notes using keywords and made sure to bullet point ideas so as not to lose focus on what the respondents were answering. Full notes were taken in some responses, and a protocol that included the review of the responses right after the interviews were finished was followed. This approach was taken by Burke and Gaughran (2007), who in their study's methodology, discussed the disadvantages of using recordings in interviews, being the tension and anxiety created during the process a leading factor to poor responses. Other authors such as Rutakumwa (2020), Bachiochi and Weiner (2002) have also discussed this issue when recording is not possible and highlighted that it does not impede undertaking quality research. Other than that, the interviews were held in a relaxed manner and lasted approximately 65 minutes to 90 minutes. The interviews were kept as short as possible so as not to make the process tedious and cause the respondents to lose interest and not give their best effort in the last set of questions. However, it was paramount that the duration of the interviews did not compromise the quality of the output, and the discussions extended the time interviewees deemed necessary.

In terms of the focus group to validate the BLS framework, the researcher had a time limit because it was challenging to gather all the experts at the same time, so after discussing with them and finding a suitable date and time, it was decided that the time to discuss the topic was a maximum of 2 hours with a 90-minute goal and 30 minutes in case the discussion extends. The rule of thumb with focus groups is between 1-2 hours (Ochieng, 2018), so in this case, the goal established by the researcher fulfilled that premise. A premise that is shared by Grudens-Schuck et al. (2004), who say that a significant focus group should comprise between 8 to 12 participants and should not last longer than 2 hours and that it should take, in some cases, more than one session to reach for a consensus on the topic. Only one focus group was needed in this research, made of 8 participants, and consensus and discussion on the framework validation were reached during the set time frame.

The framework was presented to the participants, and they had to provide scores in the form of a Likert scale type after discussion to assess the framework components and factors according to the importance level given. This is because it was essential to ascertain de validation framework in a simple manner, due to the potential problems that logistics and engagement of participants could cause, if another session had to take place. The use of a questionnaire in this scenario provided a clear way of collecting answers in a structured manner (Wilkinson, 1998).

The questionnaire was reviewed by four key construction industry practitioners who were engaged by approaching a key interested party in the project who assisted in approaching people to take part in this study. The aim of providing the questionnaire to be reviewed to people with experience in the subjects under study is to make sure the questions are relevant and easy to understand. The questionnaire was approved after minor changes were asked to be made, such as some wording and question order. In the process, the researcher took the place of moderator, and the respondents were asked to discuss the components and factors of the BLS framework and during the session, the findings were discussed and presented.

3.11.3 Data analysis technique

According to Fellows and Liu (2015), data analysis is a systematic process carried out to identify relationships and patterns, and Yin (2009) defines it as a process of examining, categorising, tabulating, testing, or otherwise recombining both quantitative and qualitative evidence to address the initial propositions of a study.

On the other hand, there are different methods to analyse qualitative data, such as phenomenology, grounded theory, ethnography, and content analysis (Burnard, 1995). This process usually starts when the data is collected, but in the case of qualitative studies, the analysis can start during the collection process (Silverman, 2004), which was the case for this research. The data was collected and analysed after the process because time was a massive factor in this study.

Bengtsson (2016) suggests using qualitative content analysis because it does not adhere to any particular science and because there are fewer rules to adhere to, so the risk of confusion in terms of the right philosophy to choose from is reduced. In addition, by using content analysis, different concepts can be used to achieve rigour and credibility, such as those used in quantitative studies, which is an option that is not possible by using other qualitative methods (Long and Johnson, 2000).

Krippendorff (1980) defines content analysis as a research method that provides a systematic and objective means to make valid inferences from verbal, visual, or written data to describe and quantify specific phenomena.

The use of content analysis allows the analysis of text into categories by applying coding, which has made the method to be considered a quantitative method. At the same time, other researchers view it as a mix of both qualitative and quantitative approaches (Neuman, 2006). Berg (1998) explains that this method allows the examination of communication contents such as documents and transcripts.

The choice of content analysis for the case studies is because it allows putting the words into groups and because it allows establishing patterns of responses that can be put into categories. Data coding is one of the key aspects of this method, as explained by Bernard (2000), who says that the identification of similar contents can be put into labels and identifies two methods in the coding process, namely deductive and inductive coding. Deductive coding is about generating themes supported by the literature, which is advantageous because the existent body of knowledge is used to support the research (Saunders et al., 2008) and provides the framework for the analysis (Yin, 2009). On the other hand, the inductive coding approach is used when there is no previous knowledge or studies about the subject being investigated, and the information is directly obtained from the data collected (Bengtsson, 2016).

Since content analysis is more reliable with the deductive coding technique (Catanzaro, 1988: Elo et al., 2014), this is the approach used because the BLS concepts to explore are gained from the review of the existent body of knowledge. The data coding process was done manually to make sure nothing important was left missing and because, as Carley (1990) suggests, it is more reliable.

Yin (2009) suggests the use of cross-case synthesis for analysis when there are multiple cases because it is necessary to compare the results from the different cases to obtain acceptable and valid conclusions and check the differences and similarities among the cases. In this research, the main content was deduced or extracted from the interviews with the case study participants, and the results are presented in a table which is a procedure suggested by Miles and Huberman (1994), who say that by taking this approach, the internal consistency and data triangulation of interviews is made possible.

Regarding the number of factors derived from the content analysis process, similar studies can be found in the literature. For example, Banihashemi et al. (2017), Sfakianaki (2018), Olawumi et al. (2018), and Liao and Teo (2019) assessed factors and analysed them, not giving much importance to the total number, but their effect was more important, similar to the present research. The focus group discussion intends to analyse the factors and validate them. In this case, as shown in chapter 6, not all the factors found in the case studies are valid, and the experts discarded several after discussion. In addition, a similar validation process to assess their framework was carried out by Succar (2014) and, most recently, by Lou et al. (2020) which suggests that the one adopted in this research is appropriate to answer the research questions.

In the case of the focus group, content analysis was also used along with the relative importance index (RII) to rank the aspects. The relative importance index (RII) was chosen because it provides a ranking of different options showing a more significant interpretation (Idrus and Newman, 2002). Holt (2014) suggests that in the construction management area, questionnaires are widely used and that they commonly employ Likert scale items to collect data and the analysis is performed by applying the relative importance index (RII) method. Likert scales are typically used to measure attitudes by presenting an array of responses to a given statement or question. Usually, Likert scales range from 1=strongly disagree to 5= strongly agree. Even though more scale levels exist; for instance, some authors agree on the seven-point scale or those with an even number of response categories; the 5-point scale is still one of the most popular because it allows a middle or neutral option and it yields better quality data (Revilla et al., 2014). Likert scales fall into the ordinal type, which means that the categories of the responses have a rank order, but the intervals between values cannot be considered equal (Blaikie, 2003). As Blaikie (2003) suggests, researchers generally assume that they are, which can cause problems when choosing the appropriate statistical tests. Selecting the correct inferential or descriptive statistics depends on the level of measurement, which is different depending on if the variables are ordinal or interval (Cohen et al., 2000); therefore, if the statistical method selected is not suitable for the type of variables, researchers may reach the wrong conclusions on their research (Jamieson, 2004). As Jamieson (2004) suggests, the mean and standard deviation are not appropriate for ordinal data, and the use of frequencies and percentages is the best way to describe it. Similarly, when it comes to inferential statistics, non-parametric tests are the best way to analyse the data because parametric tests such as ANOVA require the data to be in an interval or ratio level. For this reason, the relative importance index is selected to show the importance of the responses in the questionnaire provided in the focus group because parametric methods are not applicable for assessing respondents' preferences, so a non-parametric technique such as the RII was used to evaluate the responses from the questionnaire handed in the focus group to validate the maturity factors. Furthermore, there have been many studies applying the RII in construction management research, such as Okoroh et al. (2002); Zeng et al. (2005); Othman et al. (2005); Ribeiro and Fernandes (2010); Chileshe and Dzisi (2012); Aghili et al. (2019).

In this case, a questionnaire was provided to experts who had to choose a score from 1 to 5 or "strongly disagree" to "strongly agree" with an intermediate option.

The RII is calculated by ranking the options according to the frequency of occurrence as selected by the respondents rather than determining the mean score (Aibinu and Odeyinka, 2006). The formula used is shown below.

$$RII = \frac{\sum_{i=1}^{i=5} Wi\,Xi}{A \times n} \times 100$$

Where:

Wi = Weight given to the ith response: i = 1,2,3,4, 5

Xi = Frequency of the ith response

A= Highest weight (5 in this study)

n = the number of respondents.

3.11.4 Validity and reliability

In terms of case studies, they are prone to be criticised in terms of reliability and validity because of their weaknesses, such as lack of rigour, biased view, and problems with the generalisation of results (Gibbs, 2007). According to Yin (2009), there are two types of validity: namely external, which is about generalising the results, and internal, which is about establishing causal relationships. Reliability, on the other hand, is about assessing whether the approach taken by the researcher is consistent and can be applied to other different cases and projects (Gibbs, 2007).

Yin (2009) proposes a validation strategy that the researcher follows in this part of the study. This research uses construct validity which is about using the appropriate operational measures related to the study. This means that multiple sources of evidence are used, also it is important to have a chain of evidence, and finally, it is vital that other people review the draft.

In this research, multiple sources of information are used to construct validity, such as interviews, documents, reports, and journal papers. In addition, in developing the BLS framework, the focus group serves as a validation method by different respondents regarding the subject.

In terms of the reliability process, Yin (2009) suggests the use of a case study protocol to document procedures and steps used in the process.

3.12 Summary

The insights from SMEs in the construction industry are identified as the best way to provide the answers to the research questions stated in chapter 1. For that reason, the positioning of this research in a qualitative nature is explained in this chapter, along with the research methodology employed in this study and the philosophical research aspects. The chapter also discusses the selection of interviews and focus groups to accomplish this study's objectives. Data analysis techniques employed are discussed. The next chapters present the data obtained from the interview process, and the subsequent chapter discusses these findings. Finally, the framework is presented after that, and the validation process is shown to conclude and recommend new research areas.

Chapter 4 Results from the case studies.

This section presents the results from the case studies to assess the organisational requirements to establish the framework based on the most critical factors when considering the integration of BLS practices in SMEs. In this research, readiness is considered as the maturity organisations should reach to establish BLS practices.
As mentioned in the methodology chapter, three Chilean SMEs were studied. The results are obtained from interviews with key organisation members who provided their knowledge and experience in the subject.

4.1 Case studies results

SME1 is an organisation founded in 1993 that, at the moment of the interviews, employed 55 employees. The organisation focuses on providing high-quality, high-rise services for important clients, mainly in the country's central region. The interview process was performed on an online platform and carried out during two days with three different members. The first two sessions were held in the morning (Chilean time) and lasted around 90 minutes. The first interview started at 9:00 AM and finished at 10:35 AM, while the second one started at 11:00 AM and finished at 12:30 PM. The final interview for this SME took place in the afternoon, starting at 14:30 and finishing at 15:57.

The list of the respondents is provided below, along with the codes given to each participant.

SME1 (SME number one); R1: Respondent number one. Coded as SME1R1
SME1 (SME number one); R2: Respondent number two. Coded as SME1R2
SME1 (SME number one); R3: Respondent number three. Coded as SME1R3

4.1.1 SME1

Table 4.1 Interviewees for SME1

Code	Degree	Position	Experience	Category
SME1R1	Civil Engineer	Project Manager/BIM manager/Lean specialist	12 years	Middle Manager
SME1R2	Construction Engineer	Senior manager/Project manager/Lean specialist	25 years	Upper manager
SME1R3	Architect	BIM designer	4 years	Supervisor manager

This is an SME that has people with different expertise levels and backgrounds. They have applied lean in their projects with varying levels of success, but mostly with positive results. They have recently appointed SME1R1 as a BIM specialist to carry out the BIM implementation process.

4.1.2 SME2

SME2 is an organisation that started its business in 1990 and currently employs 70 employees. Their main business is high-rise building construction, and their business covers most of the country's central region. The interview process in this SME took part on an online platform and was carried out in 3 days. The first interview took part in the morning (Chilean time), starting at 10:00 am, lasting around 95 minutes. The second interview took place at 14:30, lasting 88 minutes, and the final interview took place in the evening at 15:00, with a duration of 92 minutes.

The list of the respondents is provided below, along with the codes given to each participant.

SME2 (SME number two); R1: Respondent number one. Coded as SME2R1

SME2 (SME number two); R2: Respondent number two. Coded as SME2R2

SME2 (SME number two); R3: Respondent number three. Coded as SME2R3

Table 4.2 Interviewees for SME2

Code	Degree	Position	Experience	Category
SME2R1	Architect	Director	32 years	Upper manager
SME2R2	Civil Engineer	Project manager	18 years	Middle manager
SME2R3	Civil Engineer	Project manager	7 years	Supervisor manager

This organisation has delivered a project with BIM protocols, and the use of lean is extensive, with different levels of success in their projects. The organisation is fully committed to the sustainability theme and has developed a plan to follow the strategy set out by the Chilean government.

4.1.3 SME3

This SME has more than 20 years of experience delivering high-rise building projects, employing 60 employees, and being present in Chile's central region. The interviews for this SME were held for one week in 90, 95, and 100 minutes interviews, respectively. All these interviews took part at 10:00 am (Chilean time).

The list of the respondents is provided below, along with the codes given to each participant.

SME3 (SME number three); R1: Respondent number one. Coded as SME3R1

SME3 (SME number three); R2: Respondent number two. Coded as SME3R2

SME3 (SME number three); R3: Respondent number three. Coded as SME3R3

Table 4.3 Interviewees for SME3

Code	Degree	Position	Experience	Category
SME3R1	Construction Engineer	Director	28 years	Upper manager
SME3R2	Civil Engineer	Project manager	13 years	Middle manager
SME3R3	Civil Engineer	Project manager	9 years	Supervisor manager

This organisation is transitioning towards adopting BIM, and in the case of lean, they have applied it in the past in a couple of projects, but it is not mandatory. Sustainability is a priority, and they are developing plans to deliver more projects with these characteristics.

4.2 BLS current state of uptake

4.2.1 SME1

In terms of the implementation process, SME1 is on the way to implementing BIM in its processes to comply with the government requirements. According to SME1R1:

"Looking at the bigger picture and not considering the cost barrier, BIM is the way forward and something all the organisations in the construction industry should commit to".

SME1 has purchased licences of Revit in their structure and architecture versions and a Navisworks license. They still use AutoCAD since they are still transitioning to promoting the use of BIM in their organisation.

In terms of the use of Lean tools, SME1 relies on the use of The Last Planner System in their projects. The use of this system has brought benefits in the last couple of years, but the uptake of this tool took effort, and it was a challenging task due to the commitment of the stakeholders, which was not clear from the beginning. It took a couple of projects to see benefits, but mainly because it was something other organisations were doing, so the application, in the end, was prompted by the fear of being left out of a trend and for strategic purposes such as competitiveness.

SME1R2 suggests,

“When we started the lean process, the first reaction was mainly negative, and there was reluctance from people. Luckily this perception changed, and now people have gotten used to working with this tool. I think the same will happen when we take on the BIM process, although it is a more complicated process than the application of lean”

SME1 has plenty of projects scheduled for the future, and it is committed to applying BIM and lean tools in most of them. They expect to deliver a full BIM project in the future, and the take on the application will be gradually done. The sustainability part is not the main priority just yet, but they think that the use of BIM and lean will indirectly help promote sustainability principles. Certainly, SME1 is aware of the commitment to reduce the environmental impacts that the sector produces, and it is committed to the government initiative. For that reason, they are preparing a plan to fulfil those requirements, and they are currently in that process of development.

4.2.2 SME2

This organisation has developed a BIM strategy, using it in one of its projects. They have people in charge with clear and well-defined roles for such purposes, leading them to commit their future projects to comply with the same strategy. The reason behind implementing BIM is because of the realisation of wasteful processes and repetition of information which caused them inefficiencies and problems with communication and collaboration in the past. After realising that the situation needed to improve, their attention turned towards using more sophisticated tools and methods to avoid and decrease their losses. For this reason, the application of BIM was considered due to the noise it was causing in the global construction scenario and even before the government's intervention, but as a new way of working and with little information at that moment in the national context the application was delayed. Soon after the news about the requirements established by the national construction industry, they decided that it was the moment to fully commit to the BIM trend, set up a team to deliver that process and commit resources to run the technical and technological part.

The use of lean has been extensive and has different levels of success, but most of the experiences are positive. The use of the Last Planner System is the main lean component. According to SME2R2, it has been easier to use in recent projects due to the knowledge gained by industry practitioners. The recent application in construction projects by different organisations means that subcontractors and other key players have adapted to its use and have become more knowledgeable in this area.

Finally, the application of sustainability has resulted in the development of plans to comply with the industry requirements, and the use of more prefabricated components is the main contribution in this area. In addition, SME2R3 adds that the application of BIM is already a contribution due to enhanced design leading to the reduction of errors. The use of lean is also mentioned because it is seen as a tool to improve efficiency, especially on the construction site, leading to optimising resources.

4.2.3 SME3

This organisation is transitioning to the application of BIM and is currently in that process. They are in the process of finding people with the required level of skills to undertake such tasks and have purchased software designed for such purposes. The transition has been slow, according to SME3R1, and it will take time to reach maturity in the area. The organisation acknowledges that there are benefits to applying BIM practices. Rather than deciding on using them due to the benefits found elsewhere, they are applying them because of the mandatory requirements imposed. As the technology and application become more mature, SME3R1 thinks it will be the way to score points in securing jobs for the company in the future and will allow them to stay competitive in the market.

The use of lean tools is sparse and has been applied in some projects in the past. Currently, the organisation is trying to find people with new skills, including lean methodologies, since they currently have only three people with experience in the lean area. For that reason, it is not possible to apply it consistently in every project.

On the other hand, sustainability plans are a priority area in the organisation, and the development of plans to commit to this area is currently underway. SME3R3 thinks that developing and delivering projects with sustainability features in mind is a way to differentiate from other companies and respond to new customers' demands. They acknowledge that customers' requirements have changed, and the construction industry is not an exception. Hence, environmentally friendly products are a huge opportunity to fulfil those needs and increase the company's profitability.

4.3 Readiness factors to BLS maturity

The following section presents the results classified in the categories shown in chapter 2 when analysing the types of different models to assess maturity. Table 4.4 below presents the content analysis with the identified aspects for each respondent.

Table 4.4 Process readiness factors to BLS maturity

	SME1			SME2			SME3			
Process factors	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**	**Frequency**
Alignment		✓	✓	✓				✓	✓	5
Business process reengineering	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
Change strategy plan	✓	✓		✓	✓		✓			5
Clear BLS policy		✓	✓		✓	✓		✓	✓	6
Client experience in BLS				✓		✓				2
Collaboration	✓	✓		✓	✓		✓		✓	6
Communication	✓	✓	✓	✓		✓		✓	✓	7
Continuous improvement					✓		✓			2
Controlling and monitoring	✓			✓						2
Culture change	✓		✓	✓	✓		✓			5
Early contractor involvement		✓				✓	✓			3
Focus on long run		✓	✓	✓		✓	✓	✓	✓	7
Government initiative	✓			✓	✓			✓	✓	5
Gradual change	✓				✓					2
Implementation strategy		✓		✓		✓		✓		4

Optimise resource allocation	✓			✓			✓			3
Strategic planning			✓						✓	2

Table 4.4 shows the identified factors by the three SMEs and the frequency of occurrence. The top three most repeated measures are the business process reengineering identified by every respondent, followed by the communication and the focus on the long-term aspects.

Business process reengineering is identified as a key aspect to prepare organisations to comply with the requirements established by the government. The respondents identify that the current way of working is obsolete, and adapting the organisation is a major but necessary challenge to keep existing in the competitive market. In this sense, SME1R2 shares that:

"Our organisation needs to adapt. We have been doing things the same way for a very long time, and we have been struggling to keep operating. We have had good years, but it is easy to focus on the negatives, especially when the finances are impacted. We realised that business as usual is no longer sustainable and change is needed. The government, in this sense, has guided organisations by promoting change, so it is known what areas we need to focus on, and we do not have to keep thinking about how to improve our business. The challenge is to rethink how to use that information to keep competitive since I believe many organisations are doing the same changes."

SME3R1 and SME1R3 have similar opinions when thinking about the need to restructure the process of moving away from traditional CAD drawings to comply with the information required in a BIM model. Therefore, a process redesign is required mainly because of people's current skills and the amount of information that needs handling. The same situation happens when trying to deliver more sustainable projects, which according to SME3R3, adds more pressure and difficulties to the process. The amount of data and extra requirements make the process more complex, and the current strategy of delivering projects is not suitable to fulfil those requirements.

SME1, SME2 and SME3 acknowledge that there must be a change in the current business processes to reach maturity in the BLS aspects, where communication plays an important part in the strategy.

SME1R2 shares that:

"Creating effective means of communication is an important part of establishing objectives towards adopting and implementing the proposed BLS practices in the organisation's core business. People need to be aware that a change is required and needed, so the clearer the message, the better, so they know what is expected from them."

Another focus on the importance of the communication process is a view shared by SME2R1, who says that,

"Communication to our people is important, but it is also important to communicate to our stakeholders the required approach so resistance can be identified early in the process and tackled appropriately."

The importance of having a clear message is paramount; SME3R1 shares an anecdote when a speaker went to talk about the importance of BIM implementation a few years ago:

"I remember a few years back when the BIM trend was being talked about a lot, so the company arranged someone to come and talk about the system to a diverse number of people in our organisation. The speaker was very knowledgeable, but the presentation was very technical and focused on applying fancy software and requirements. After the presentation and during the coffee break, everyone looked at each other, asking what it was that all about. People were left rather confused and were not engaged, so the importance of the application was not taken seriously, and people thought it was only a fad."

The focus on the long-run objectives is the third most important repeated measure among the three studied SMEs. SME1R2, SME2R1 and SME3R1 share the opinion that the long-term results and objectives should be a priority rather than focus on short-term goals. They also understand that short-term goals are important to boost morale and show people that the implemented changes show tangible results. However, as SME2R1 shares:

"The criteria to promote maturity in BLS applications in SMEs is to consider the sustainable implementation throughout time and measure results in the long term. There is no point in investing this time and effort to obtain immediate results considering that maturity is a process that takes time. The bigger picture should be looked at, but in many cases, the reluctance from senior managers, stakeholders etc., comes from the desperate need of seeing immediate results. As a result, the implementation of new initiatives tends to fail. People need to understand that implementing these practices would take time, and convincing people to get on board would have to be focused on how the systems can enhance business operations."

As for the rest of the process factors identified by the respondents, a clear BLS policy has been proposed to be a driver for process change. In this sense, SME1R2 and SME1R3 share that in their organisation, a policy for BIM is being developed to determine data ownership and how to share information and a policy in the application of lean tools in their projects and the areas of focus. SME2R2 and SME2R3 agree that the application of lean has been unmonitored, and it depends on the people working on projects. Although the application is encouraged, a clear policy does not currently exist, and they agree that in the future, organisations should follow a procedure on how to apply lean tools so everyone can do the same. Although projects are different, their business focus is on high rise buildings, so the processes are repetitive. Thus, the lean application can be standardised and modified accordingly, but with a foundation on how to be applied. A clear policy should help provide guidelines in the implementation efforts.

Culture change is another aspect that needs attention; as SME1R3 suggests, the success or failure of the implementation would depend on how well the ideas are embedded in the organisation's culture. Once the concepts and ideas are immersed and well accepted, culture change can happen. SME1R3 also suggests that aspects such as the government's initiative (Frequency 5 in the listed factors) have helped promote such culture change. This process must also be done gradually (Also listed in the factors, frequency 2). A change management plan (Frequency 5 in the listed table) is also related to this area, and it is supported by the respondents. SME2R2 states that a change management plan must be communicated effectively to work, and SME3R1 says that in developing a change management plan and strategy, a clear definition of roles and steps must be provided.

It is also acknowledged by SME2R1 that small organisations, in general, can struggle when determining and providing clear roles due to the lack of structure and the "day to day" management style focused on the short term.

According to SME1R2 and SME3R3, the organisation must develop a clear implementation strategy and plan to fulfil the application and achieve maturity. SME3R2 also suggests that the alignment of goals and objectives from the organisation should be reflected in this step and SME2R1 thinks these considerations should be one of the first steps before attempting the operations procedure to comply with BLS maturity.

4.4 Human factors

Table 4.5 shows the result of the human readiness factors to achieve BLS maturity. The most repeated measures among the SMEs are qualified staff, training, attitudes and behaviours, and understanding of the BLS concepts.

Table 4.5 Human readiness factors to BLS maturity

	SME1			SME2			SME3			
Human aspects	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**	**Frequency**
Attitudes and behaviours	✓		✓	✓		✓	✓	✓	✓	7
Awareness	✓			✓			✓			3
Champion	✓						✓	✓		3

Competencies of top staff	✓	✓		✓	✓			✓		5
Development			✓							1
Education		✓			✓	✓		✓	✓	4
Knowledge			✓	✓		✓				3
Motivation				✓		✓	✓			3
People management								✓	✓	2
Qualified people	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
Roles		✓	✓		✓			✓	✓	5
Skills		✓	✓	✓					✓	4
People support		✓			✓					2
Stakeholder engagement	✓		✓	✓	✓	✓			✓	6
Teamwork	✓		✓	✓		✓				4
Training	✓	✓	✓		✓	✓	✓	✓	✓	8
Understanding of the BLS concepts	✓	✓			✓	✓	✓	✓	✓	7

According to the response, each respondent identified the qualified people factor, and everyone agrees that this aspect is key to achieving maturity. As mentioned in the previous section, strategy and implementation plans are the first steps to moving toward BLS maturity. The next part of making that process reality is to count on qualified people to undertake such tasks. SME1R2, SME2R1 and SME3R1 agree that identifying the right people for the job is a real task since these skills are in high demand and the maturity in terms of BLS is not there yet. Hence, as a new way of working, the number of professionals is still low. SME2R3 thinks that as the process becomes more mature, so will be the people with these skills. SME3R3 agrees with this vision and shares a similar view, saying that the number of institutions, including higher education, institutes, and training providers, is important in helping people develop these skills.

Training is becoming more and more important to SME1R1, and it is reflected in the number of responses provided. In this sense, SME1R1 shares:

"People are required with different skill sets, that is not new, but currently it is seen more in younger professionals. Training becomes essential for people with more experience since they are new in the whole BLS area. The way they have been working has not changed much in the last decade, and the inclusion of new methods sometimes is a struggle. We must be very careful on how to deal with them because we do not want them to feel unwanted and unmotivated, which is directly related to the success or failure of the whole system."

This is also related to people's attitudes and behaviours, which also have a high number of responses. Attitudes and behaviours towards implementing and adopting BLS can directly impact organisation plans, especially in SMEs. According to SME1R3, it is either success or a failure because of the resources committed to adopting new practices.

SME1R3 shares that:

"For us, it is very important to make this right from the beginning, and the general feeling is that we have this shot at making it work. Resources are employed, and plans are developed. People play an important part, and the right attitude and change of behaviours are critical. Our SME is undertaking a transformation towards BIM application. Training is an important part because technological transformation is a tool that does nothing if people do not know what to do with it."

In addition, SME1R2 shares that:
"We are currently undertaking a couple of training programmes, and people are attending external BIM-related training. We have an in-house system delivered by the more knowledgeable people in our organisation to train our current staff in BIM more specifically. Our training covers the use of software and experiences such as success stories in its use. We also cover some standards, but the focus now is on using the software. Apart from providing software training, our main objective with this is to change people's minds and move slowly away from the usual way of doing things. Education and knowledge go hand in hand with training". Education and knowledge are also factors identified by the respondents, and it is linked with people skills and the development of qualified people.

The next high mentioned aspect is understanding BLS concepts to reach maturity. Certainly, people are more aware of the concepts and what they promote, according to SME1R2. That is due to the government initiative to promote BLS, as explained in chapter 2 in the literature review and nowadays due to the number of people taking training. SME2R2 argues that the lack of implementation of these concepts individually, especially BIM and sustainability, is related to a lack of understanding of what they try to promote. Given this lack of knowledge, reluctance has appeared impacting on the implementation efforts. In the case of lean, SME2R2 also argues its application has been around for longer, giving a certain advantage to the lean philosophy over the other two. However, the argument is that systematic methods on how to accomplish the best of the philosophy are still lacking, and the application is due to individual efforts from organisations. In this sense, SME3R2 contributes to this debate by saying that although individual application efforts are valuable when promoted to become more comprehensive, the standardisation of methods and applications is important and should be developed and distributed by, in this case, the government.

The rest of the factors deal with a clear definition of roles, so people know what is expected from them. Having clear roles will make the whole adoption more successful, according to SME1R3, who says:

"In our organisation, the development of BIM strategy comes with a clear definition of roles and responsibilities. Everyone knows now what is expected from every member, whom they respond to, and a clear line of communication. For example, our organisation has recently appointed a BIM strategist who will also act as a BIM manager, and we are in the process of appointing a BIM coordinator. The person's name in that position does not matter. We have written role specifications and what is expected from any person who comes to fulfil that role. We also have a BIM modeller, and we have found someone who will come in a role created specifically for the purpose of liaison between the lean strategy and BIM strategy. For that purpose, we found someone with skills in that area that we think can make the communication process even better when it comes to the application."

In this sense, it was mentioned among the factors the appointment of a champion to oversee the process, who, according to SME1R1 and SME3R1, must possess good leadership and knowledge skills to lead the change process. SME1R1, SME3R1 and SME3R2 agree that this champion must deliver the direction, management of resources, the appointment of roles, liaison between upper and lower levels in the organisation, and control the implementation progress. Here is when competencies of the upper levels, as identified by SME1R3, SME2R2, SME2R3, SME3R2, and SME3R3, are key since their capacities and leadership reflect on the lower levels. The reason is that the way they promote the implementation change is noticed by the people. SME3R3 says that people notice when people in positions of power know what they are talking about and judge the message based on who is delivering it. When the staff considers someone as incompetent and not good at their job and has the task to deliver an important message, people usually do not listen and focus their attention on something else. Therefore, the person in charge to promote the change must be competent, engaging, and willing to listen to people and be supportive of the other members. For this reason, people's support in the transition should also be considered.

4.5 Technology related factors

Table 4.6 shows the result of the technology readiness factors to achieve BLS maturity.

Table 4.6 Technology readiness factors to BLS maturity

	SME1			**SME2**			**SME3**			
Technology	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**	**Frequency**
Appropriate exchange of information		✓	✓	✓			✓	✓	✓	6
Appropriate hardware	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
Appropriate software	✓	✓		✓	✓	✓	✓		✓	7
Capacity to implement tools	✓	✓		✓		✓	✓	✓		6
Compatibility				✓		✓			✓	3
Constructability			✓			✓		✓		3
Data security	✓		✓	✓	✓			✓	✓	6

Design errors		✓		✓		✓	✓	✓		5
Efficiency		✓		✓	✓			✓		4
Infrastructure	✓				✓		✓			3
Interoperability			✓	✓			✓			3
Less paperwork				✓			✓			2
Policy		✓		✓					✓	3
Tech support	✓		✓		✓	✓	✓	✓	✓	7
Standards	✓		✓			✓			✓	4

The most important factor found among the studied SMEs in the technology category is the appropriate hardware. This item refers specifically to the BIM part, and every respondent mentions it. The respondents agree that having the proper hardware to implement tools is one of the key aspects of reaching technological maturity. SME1R2 believes that using the proper hardware will make software run more efficiently and enhance productivity and efficiency. SME2R2 also agrees with this statement by adding that there is no point in implementing tools that won't be running smoothly and will cause more trouble than providing solutions. SME3R1 adds in this discussion that the pressure of SMEs to constantly adapt their IT solutions to run software is something that needs to be carefully studied so that the systems can offer their true potential. SME1R1 says that the acquisition of new computers is part of their plans to run BIM software, and their SME has recently purchased equipment for such purposes. There also could be the chance of upgrading old hardware to make the new software run which has been the case for some equipment according to SME1R3. However, in their experience, it is better to get new hardware and new software. The recycling of old equipment should be done to run other less complex applications. In this sense, tech support is important, and it is also mentioned several times in the responses, along with the appropriate software. Having the right tools to carry out the job is a path towards achieving maturity, according to SME2R1, who also adds that the use of complex software should also come hand in hand with the right tech support from the specific software provider. Hence, the best and most updated versions are always available to perform the job.

The investment in equipment and software should be included in the SME policy to support the long-term investment plans as stated by the respondents.

The capacity to implement tools is an aspect that needs to be carefully assessed before committing resources to purchase technology. According to SME2R1, organisations, especially SMEs, should not commit their resources just for the sake of complying with requirements. First, an assessment of their capacity as an SME should be studied to focus their efforts on achieving objectives and goals. SME2R1 also argues that large organisations have a better capacity to commit resources to the implementation of new tools and the management of change, such as specialised people; on the other hand, smaller organisations must be smarter in their resource allocation. For that reason, SME2R1 also thinks that the success of the change efforts towards BLS will depend mainly on the SME's capacity to transform their tools and, most importantly, on the capacity of people to adopt and make the most of the technological tools that are provided.

SME3R1 argues that the adoption of sustainability features is strongly linked in the technological item with the capacity of the SME to perform calculations and present solutions that are well studied and supported by the right hardware and software applications. SME3 has also purchased the licence of a specialised sustainability solution software to offer better services to their customers.

The respondents have identified factors that are strongly linked with the application of BIM tools because they think that these tools can enhance the adoption of lean and mainly sustainability features.

SME2R1 suggest that efficiency can be enhanced by applying lean tools, and lean features will be achieved indirectly by using BIM. However, it is also acknowledged that lean tools are efficient as well on their own and can be applied indistinctively if BIM is being used. SME1R1 says that the application of lean tools can enhance the planning on-site by using the Last Planner System and can be used along BIM to reduce waste and enhance productivity. This respondent also suggests that the continuous improvement aspect of the lean philosophy can make BIM adoption less difficult because there is a culture already in place.

4.6 Management factors

Table 4.7 shows the result of the management readiness factors to achieve BLS maturity.

Table 4.7 Management readiness factors to BLS maturity

	SME1			SME2			SME3			
Management	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**	**Frequency**
Adaptability			√					√	√	3
Align (Organisation objectives)	√			√	√			√	√	5
Management of information	√	√		√			√		√	5
Bottom-up approach			√		√	√		√	√	5
Commitment to change from top management		√		√		√	√	√		5
Flexibility		√		√			√	√		4
Leadership	√	√	√	√	√	√	√	√	√	9
Management support			√			√			√	3
Motivation	√	√			√	√	√	√		6
Planning		√			√				√	3
Resistance to change	√	√	√	√	√	√		√	√	8
Risk Management		√	√	√		√	√			5
Subcontractors' commitment			√	√			√		√	4
Top-down approach	√		√	√	√		√	√		6
Vision	√			√			√			3

Leadership has been identified by every respondent, mentioning this factor as a key maturity enabler. SME2R3 argues that for their SME, the pressure to improve and differentiate from competitors played a huge role in adopting and moving to a different approach to managing their business. However, rather than imposing a system with which people were unfamiliar, the top management gradually suggested that a change may come, and people had time to adjust and adapt to that idea. SME2R3 describes this move as a perfect show of leadership because leaders did not impose the change and considered people's concerns.

SME2R3 shares:

"The move from the top management was key to successfully promoting the adoption of a new system that still is new for many of our members. People's fear of losing their jobs was never a problem because top leadership handled the situation with perfect timing and assurances that people are the most important asset."

SME2R3 also suggests that this lesson was learned when promoting the use of lean in the past because, on that occasion, resistance from people came when the opposite management style of imposing and not listening was adopted.

SME2R3 adds:

"The lean implementation in a couple of projects was not as expected. At that moment, we thought that making people adopt a system was going to make them more attracted to the idea because it was going to enhance their skills and aptitudes, but we soon found out that this show of leadership was the wrong approach because we did not consider their opinions regarding the subject."

SME3R1 states that resistance to change is a factor that should be closely followed. The right leadership skills from people should help change people's perceptions of the word "change", which usually has a negative connotation. Leadership and resistance to change are closely connected, according to SME3R3, who also agrees that when there is change coming, resistance is natural, and the people in positions of leadership should make people feel sure that they are part of the change and should embrace it. The worst thing that could happen is leaving people with the feeling of not belonging, undermining the whole process.

For this reason, motivation is another of the important factors identified by the respondents, which is linked to the leadership attribute mentioned in the above paragraph. SME1R2 adds that in their attempt to lead the transition toward BIM adoption, their organisation has encountered reluctance from some senior members who were unsure about the whole process. Therefore, SME1R2 had to take a more proactive approach. After consideration, these members were given key tasks in the process, so their perception changed, and they fully committed to the adoption. This is still a work in progress for this organisation, but the attitudes have completely changed, and the key was to work together to find a solution. For this reason, motivation is found to be an important factor in the whole change process.

SME1 is in the process of moving to a more integrated and sustainable way of carrying out its business. For that reason, they are moving to a BIM oriented organisation and are also planning to improve their operations by using lean tools with sustainability as the last huge objective to change their current way of doing things gradually. They have found that the management process driving the implementation from their upper levels and managing it down to the other levels is the best way to carry out this process. Therefore, the top-down approach has been identified as another factor that should be considered. This statement is supported by SME1R3, who thinks that involvement from the top chain of command is required to align the objectives of the implementation to the business operations, allowing the necessary allocation of resources to such purposes. Thus, the alignment of objectives is another factor identified in this research.

The interviewees have also highlighted the need to assess whether the implementation is needed by the organisation right away or not, this is despite the need to comply with the requirements of the government. This is mentioned by SME3R1, who thinks that despite the initiative from the government, SME3 and SMEs organisations, in general, should assess whether they have the resources to carry out this task and should not do it just because of the government goal. For this task, management commitment is essential, and in addition, this respondent also mentioned that there are high risks implied for their SME for SMEs in general due to the business characteristics they have. Therefore, an analysis of the pros and cons should be carefully carried out with all the risks implied. A well detailed and proper risk analysis is required, so risk management and management commitment have been identified as factors in the BLS implementation.

Management of information is among the most repeated measures as well. SME3R3 suggests that innovation is difficult for SMEs, and they rely on the successful application in larger organisations to consider the application in their own organisations. In this case, SME3R3 argues that the management of information is particularly attributed to the use of information and communication technologies (ICTs), which for SMEs, in general, is difficult to obtain the full benefits of the application. SME1R2 has a different view saying that management of information is key to any application process, not only ICTs, but if it adds value to information processes, the whole process will be more effective. This respondent also suggests that in the case of an effective BIM application process, if the information process is well organised and represented, it immediately will add value to the customer. Managing, sharing, and collaborating with the information process on its own qualifies as a lean view, so SME1R2 says that by applying BIM, organisations are also strengthening the application of the lean philosophy.

The feedback from employees and their contribution to the adoption is another mentioned factor. SME2R3 says that before they could deliver a project using BIM, a team was set up with employees that had regular meetings to assess the state of the implementation plan set up by the top management. This team had discussions and provided feedback to the top levels on how the tool would change their roles and responsibilities. Regular channels of communication were shared, and according to SME2R3, this process helped SME2 achieve an efficient project.

SME3R3 also adds to this discussion that when applying lean tools in one of the projects undertaken by their organisation when the Last Planner System was implemented, an employee form questionnaire was handed to them before starting the project asking for feedback about the use of the tool. The consideration from the top management towards their employees was seen as a "good move", as mentioned by SME3R3 in the application of the tool.

Flexibility and adaptability from the organisation to adapt to change, commitment from subcontractors to learn what the new requirements are about, and the conditions SMEs will be asking in the future from them are among the last set of factors encountered in the interview process for this category.

In this sense, SME2R1 comments:

"Subcontractors also play an important role in the construction industry, so they also need to adapt the way they work to commit to the new requirements. Certainly, this process will take time, but it is important that they are also included in this scheme."

Finally, the last factors found in the management category are management support, vision, and planning.

4.7 Economic factors

Table 4.8 shows the result of the economic readiness factors to achieve BLS maturity.

Table 4.8 Economic readiness factors to BLS maturity

	SME1			SME2			SME3			
Economic	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**	**Frequency**
Increased competitive advantage	✓	✓		✓	✓	✓		✓		6
Cost control		✓		✓		✓	✓			4
Cost reduction		✓	✓	✓				✓		4
Financial support	✓		✓		✓	✓	✓		✓	6
Implementation cost	✓	✓	✓	✓		✓	✓	✓	✓	8
Incentives	✓	✓		✓	✓			✓	✓	6
Increased economic performance		✓		✓	✓		✓			4
Increased value	✓		✓		✓			✓		4
Market demand for BLS deliverables	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
Productivity improvement	✓	✓		✓		✓	✓		✓	6
Quality improvement	✓	✓		✓	✓	✓		✓	✓	7

Resource optimisation	✓		✓	✓		✓	✓		✓	6
Return on investment (ROI)		✓	✓	✓		✓	✓	✓	✓	7
Subsidies	✓		✓	✓	✓		✓	✓		6

The most mentioned aspect in this category is the market demand for BLS deliverables. SME1R1 argues that:

"The market is changing globally not only in day-to-day aspects such as smartphones, computers, cars etc., but also in the construction industry with the application of new materials and technology to build better and smarter. The huge pressure from environmental and governmental agencies to comply with carbon emissions reduction has made SMEs consider their full operations. There is a market out there asking for products to be more efficient and sustainable, and in our case, that was a huge driver to commit to change. We think we can secure our position by applying BIM because we are likely to get more opportunities. However, we know that other SMEs are taking similar steps, so we need to add something extra. We really think that sustainable focused projects are a reality and something that we need to turn our attention to. Our organisation needs to be ready to meet the current market demands, and we need to take steps to ensure that we remain competitive."

In addition, SME2R1 suggests that,

"We noticed that clients are becoming aware of the opportunities that are out there, and in the case of BIM, many of them are requesting it in their projects. We have also found clients that are aware of the use of lean practices, and even though it is not mandatory, we have used it in the past in a couple of projects to highlight how our processes are less wasteful and more efficient."

As shown in Chapter 2, the BIM market in Chile is increasing. Therefore, as SME3R1 suggests, the number of SMEs that are applying it should increase as well, and guidance to apply it, other than the BIM mandate, should be provided to efficiently transition towards this change, something that is still missing.

In terms of the costs associated with moving to a BLS oriented organisation, SME1R2, SME2R1, and SME3R1 agree that the implementation cost is a factor that needs to be carefully addressed. This is because the uncertainty of obtaining projects, depending on the organisation's effectiveness in their costs from projects executed in the past and the number of projects projected in the future. SME3R1 says that when this item is well studied and sorted and all costs are accounted for, implementation of new practices can happen without impacting other areas.

SME1R1 suggests that the implementation cost is, of course, something that needs to be properly assessed, but the long-term benefit should be prioritised when making these kinds of decisions. The long-term cost reductions as supported by SME1R3 that can be reached by becoming more efficient and effective should come into consideration when analysing the cost and benefits of the implementation. In addition, cost control is mentioned by SME1R2 in this category as a factor in BLS terms because to achieve maturity and before the implementation of change, SMEs need to be able to study and control their current costs to be able to direct resources to the implementation process for a future BLS adoption without impacting everyday activities. Thus, financial support is seen as another factor in positioning organisations to achieve BLS objectives, as explained by SME2R2, who explains that this support was key to achieving and delivering a BIM project. SME3R3 and SME1R1 share the idea that appropriate incentives and subsidies from the government to help in the transition are a valuable aid to those organisations that may struggle in allocating resources towards the transformation process.

As shown in table 4.8, most of the respondents have also mentioned return on investment (ROI) connected to the implementation cost as per SME2R3. SME3R2 also adds that investment should not only be measured based on monetary terms, but also in terms of the effort and time spent on the implementation and application process, adding these dimensions to the financial factor to measure ROI.

SME2R3 has a very distinctive view in this regard by saying:

"Investment in our SME is most of the time attributed to the money spent on a certain application, software, etc., but other factors should be considered as well, such as the time spent or effort from our members to adapt and adopt new initiatives. We are certain that the cost of acquiring new software licences to comply with client requirements and compete in the market is high, and it would take a couple of projects to obtain the money back from that initial investment. However, if we could put a monetary value to the effort, time, and skills that our team is gaining, that will positively contribute to our organisation beyond the instant monetary return because their skills will be enhanced, and our organisation will become more adaptable and efficient, which is the long run is money saved."

The next set of mentioned factors, including quality and productivity improvements, optimisation of resources, increased value and economic performance and increased competitive advantage, are identified as benefits of the integration in economic terms rather than maturity factors towards BLS adoption. However, they are mentioned because the respondents were clear that to achieve these benefits, their SMEs need to reach a level of maturity that allows them to obtain beneficial results in those areas. In the discussion during the interview, SME2R2, for example, started responding to a question about their SME's economic factors, which led them to discuss the economic benefits of the application of mainly BIM and lean in their organisation.

4.8 Summary

This chapter presents the results of the case studies in which three SMEs were analysed, comprising a total of nine interviews whose purpose was to identify the factors that need to be considered when trying to implement BIM, lean and sustainability in SMEs in Chile. The results show factors from the processes, human and attitudinal, management, technology, and economic perspectives to reflect the reality of SMEs in the Chilean context. These factors are discussed in the next chapter, along with support from the literature to make sense of the responses and still pending validation, process that is presented later in chapters 5 and 6.

Chapter 5 Discussion and framework development

This chapter discusses the findings from the case studies and the development of the organisational BLS framework. The framework is developed based on the previous chapter's findings, in which the main factors were found and cross analysed in the different case studies. The data set the foundation for elaborating the BLS framework because the main factors to populate it were presented. This chapter also presents a literature review to support those findings and support the researcher in making sense of the obtained data. Table 5.1 summarises the findings showing the occurrence of the responses. As seen in the previous chapter, not all the respondents answered the questions in the same way; therefore, the purpose of Table 5.1 is to show the frequencies of responses of each studied SME. The framework development is composed of the factors found in the case studies, but they need to be validated to make the results more general and applicable to other SMEs. That validation process is discussed in the next chapter.

5.1 BLS state of uptake.

The BIM state of uptake was investigated to understand the organisational approach towards BIM adoption and the extent of the implementation. From the case studies results, SME2 is more advanced in applying BIM than the other two SMEs since they have completed a full project using the methodology. Despite completing this project, they acknowledge that they are still learning from the process and are becoming more mature in the adoption. The use of BIM in the project was done by applying the extraction of drawings, calculating materials, coordinating the different parties involved in the project, and clash detection activities. They also used the system to show progress to clients. They expect to move from this pilot project to keep working with the methodology in their future projects and gradually eliminate the use of CAD, which is still in use.

On the other hand, SME1 has appointed a BIM specialist to handle the transition process toward implementing and delivering a full BIM project in the near future. This appointment means that the organisation is tailoring their current activities to suit the BIM needs. The identification of suitable people to perform the BIM tasks is part of the process, and there are plans to start a BIM pilot project by gradually introducing its use. These plans include the calculation of materials for pricing, clash detection and coordination activities. The idea is to adopt more activities once they become more mature.

Finally, SME3 is recently transitioning to the adoption, and the levels of implementation are low compared to the other two studied SMEs. Plans are in the process to adapt their organisation to the new standards the industry requires. A pilot project is in the discussion, and the initial talk is to apply BIM with low levels of detail first and move from there to start reaching maturity.

In terms of lean adoption, SME1 has applied lean practices, specifically the use of the Last Planner System, in a vast number of projects with positive results. The application of lean has been straightforward and only found difficulties at the beginning of the implementation process due to the organisation's lack of knowledge and awareness of the tool, thinking that it would be more of the same and a waste of time. The meetings held weekly to assess the implementation and check for early results were not encouraging, but after the team members became familiarised with the process and the productivity levels were increased, the perception changed, and the application was made gradually in more projects.

SME2 has a similar experience in applying lean tools as SME1, and they share a variety of different success levels in the application. SME2 also relies on the application of the Last Planner System due to the simplicity in their application and lower implementation costs since, as reported by their respondents, it does not require the use of expensive and fancy software compared with the application of BIM.

SME3 reports that the application of lean has been sparse, and it depends on the people in charge of their projects. The organisation does not require its application, but it has been encouraged to reduce waste and avoid reworks which have been a persistent problem.

Finally, sustainability considerations are at a low level of adoption. The three cases show that they are in the plan development to implement these practices, but it is not a priority just yet. The general feeling is that the application of BIM and the use of lean practices to reduce waste will suffice to accomplish green targets.

Table 5.1 BLS factors from the case studies

Category	Factors	SME1	SME2	SME3
Process	Alignment to strategy	✓✓	✓✓	✓
	Business process reengineering	✓✓✓	✓✓✓	✓✓✓
	Change strategy plan	✓✓	✓✓	✓
	Clear BLS policy	✓✓	✓✓	✓✓
	Client experience in BLS	–	✓✓	–
	Collaboration	✓✓	✓✓	✓✓
	Communication	✓✓✓	✓✓	✓✓
	Continuous improvement	–	✓	✓
	Controlling and monitoring	✓	✓	–
	Culture change	✓✓	✓✓	✓
	Early contractor involvement	✓	✓	✓
	Focus on long run	✓✓	✓✓	✓✓✓
	Government initiative	✓	✓✓	✓✓
	Gradual change	✓	✓	–
	Implementation strategy	✓	✓✓	✓
	Optimise resource allocation	✓	✓	✓
	Strategic planning	✓	–	✓
Human and attitudinal	Attitudes and behaviours	✓✓	✓✓	✓✓✓
	Awareness	✓	✓	✓

	Champion	✓	–	✓✓
	Competencies of top staff	✓	✓✓	✓✓
	Development	✓	–	–
	Education	✓	✓✓	✓✓
	Knowledge	✓	✓✓	–
	Motivation	–	✓✓	✓
	People management	–	–	✓✓
	Qualified staff	✓✓✓	✓✓✓	✓✓✓
	Roles	✓✓	✓	✓✓
	Skills	✓✓	✓	✓
	People support	✓	✓	–
	Stakeholder engagement	✓✓	✓✓✓	✓
	Teamwork	✓✓	✓✓	–
	Training	✓✓	✓	✓
	Understanding of the BLS concepts	✓✓	✓✓	✓✓✓
Technology	Appropriate exchange of information	✓✓	✓	✓✓
	Appropriate hardware	✓✓✓	✓✓✓	✓✓✓
	Appropriate software	✓✓	✓✓✓	✓✓
	Capacity to implement tools	✓✓	✓✓	✓✓
	Compatibility	–	✓✓	✓
	Constructability	✓	✓	✓
	Data security	✓✓	✓✓	✓✓
	Design errors	✓	✓✓	✓✓
	Efficiency	✓	✓✓	✓

	Infrastructure	✓	✓	✓
	Interoperability	✓	✓	✓
	Less paperwork	–	✓	✓
	Policy	✓	✓✓	✓✓
	Tech support	✓✓	✓✓	✓✓✓
	Standards	✓✓	✓	✓
Management	Adaptability	✓	–	✓✓
	Align (Organisation objectives)	✓	✓✓	✓✓
	Management of information	✓✓	✓	✓✓
	Bottom-up approach	✓	✓✓	✓✓
	Commitment to change from top management	✓	✓✓	✓✓
	Flexibility	✓	✓	✓✓
	Leadership	✓✓✓	✓✓✓	✓✓✓
	Management support	✓	✓	✓
	Motivation	✓✓	✓✓	✓✓
	Planning	✓	✓	✓
	Resistance to change	✓✓✓	✓✓✓	✓✓
	Risk Management	✓✓	✓✓	✓
	Subcontractors’ commitment	✓	✓	✓✓
	Top-down approach	✓✓	✓✓	✓✓
	Vision	✓	✓	✓
Economic	Increased competitive advantage	✓✓	✓✓✓	✓
	Cost control	✓	✓✓	✓
	Cost reduction	✓✓	✓	✓

	Financial support	✓✓	✓✓	✓✓
	Implementation cost	✓✓✓	✓✓	✓✓✓
	Incentives	✓✓	✓✓	✓✓
	Increased economic performance	✓	✓✓	✓
	Increased value	✓✓	✓	✓
	Market demand for BLS deliverables	✓✓✓	✓✓✓	✓✓✓
	Productivity improvement	✓✓	✓✓	✓✓
	Quality improvement	✓✓	✓✓✓	✓✓
	Resource optimisation	✓✓	✓✓	✓✓
	Return on investment (ROI)	✓✓	✓✓	✓✓✓
	Subsidies	✓✓	✓✓	✓✓

Legend:

3 respondents: ✓✓✓; 2 respondents: ✓✓; 1 respondent: ✓; 0 respondents: –

5.2 Discussion of findings in the process category

After the cross-analysis process, seventeen factors were found across the three studied SMEs in this category. As shown in table 5.1, the frequency of responses varies, and every respondent mentioned only a few factors. The most dominant pattern of responses is the mention of the factors twice, followed by one mention, three mentions and no mentions at all in the last place.

After evaluation, the factors from table 5.1 can be further classified into subcategories. The subcategory, along with each factor, is shown below in table 5.2.

Table 5.2 Process factors subcategories

Category	Subcategory	Code	Factors
Process (P)	Business transformation (BT)	PBT1	Business process reengineering
		PBT2	Gradual change
		PBT3	Focus on long run
		PBT4	Change strategy plan
		PBT5	Continuous improvement
		PBT6	Government initiative
	Strategy (S)	PS1	Implementation strategy
		PS2	Strategic planning
		PS3	Alignment
		PS4	Resource allocation
	Culture (C)	PC1	Culture change
		PC2	Client experience in BLS
		PC3	Early contractor involvement
	Information (I)	PI1	Communication
		PI2	Collaboration
		PI3	Clear BLS policy
		PI4	Controlling and monitoring

5.2.1 Business transformation (BT)

Business process reengineering (PBT1) is the most frequent response in this category. This item refers to the transformation process that organisations, in this study, SMEs, should follow to transform their current way of doing things to apply new methods. In this sense, Crowe et al. (2002) argue that this process considers a total transformation or reshaping of all business processes, technologies, and management systems, including organisational structure and values, to achieve better performance levels throughout the business. In addition, a change strategy plan (PBT4) is required to establish a clear path to promote change. This way, the top levels can follow the plan to communicate the message down to the other levels with clear indications of what needs to be done, increasing the chances of a successful application which is the ultimate goal of the whole process (Ahuja et al., 2010).

This aspect is evident in the case studies and, as discussed in the results chapter, where SMEs are trying to move their way of working towards the achievement of objectives to comply with current Chilean proposals and regulations (PBT6). The studied SMEs are transitioning in becoming mature in the use of mostly BIM and lean. For those purposes, as Crowe et al. (2002) suggest, redesigning and reorganising internal processes to suit the needs of the BIM process and adapt or completely change the organisation's capability to commit to that process. The use of technology in the form of BIM to support that process is supposed to help achieve those targets because it enables the organisation with a tool to make better-informed decisions (Heaton et al., 2019). However, it should follow a review of the strategic change process beforehand undertaking that change (Soh and Markus, 1995). As studied by Vidalakis et al. (2020), BIM adoption in SMEs has been slow because the adoption of technologies does not, most of the time, align with their needs as SMEs, producing a problem with the capacity to adopt the technology.
This situation becomes evident when analysing the Chilean BIM survey (Loyola, 2019), finding that the maturity levels are low, and in the case studies, only SME2 has completed a project using BIM. For those purposes, SME2 had to change their processes to deliver the final product. These changes included the digital delivery of a 3D model at the end of the project, clash detection, calculation of materials, and coordination activities. The change process was done gradually (PBT2), meaning that BIM was used for that particular project, and they carried out doing business as usual with the other projects in their portfolio. In addition, the appointment of new roles and people was part of that process too. This change of processes in delivering projects is consistent with findings from the literature, such as Eastman et al. (2011) and Gu and London (2010).

Similarly, lean implementation is a transformation process that also requires a process change that needs to focus on supporting the organisation's development and promoting continuous process improvement (PBT5) (Pearce and Pons, 2013). In this sense, Singh et al. (2008) argue that lean implementation in SMEs has two sides: a positive side because of their less complex structure compared to larger organisations that allow flexibility to change and the simplicity of the dissemination of knowledge. The negative side is that SMEs have limited resources, such as financial and human, to carry out such transformation (Goodyer et al., 2011; Achanga et al., 2006). Examples of these statements are also encountered in the case studies regarding the application of lean practices, which is limited only to the application of tools, especially the Last Planner System. According to Pearce et al. (2018), the focus on applying tools is an outdated paradigm to comply with lean processes. This situation is reflected in the responses because the studied SMEs do not apply lean from an organisational transformation point of view, but the focus has been on isolated projects, which explains the variability of success in its application.

On the other hand, sustainability is the least considered process by the studied SMEs and the transformation towards adopting those practices. This finding is consistent with the literature in saying that the studies are mostly focused on large enterprises, with little input from studies focused on SMEs (Johnson and Schaltegger, 2016; López-Pérez et al., 2018). The studied SMEs are currently developing plans to embed sustainability in their respective organisations, and the priority is to establish the BIM and lean plans first. However, the literature mentions that to achieve sustainability and become a sustainability-oriented organisation, the aspects that can help achieve this process are focused on factors described in chapter 2, where the sustainability models are presented. These models focus on aspects that consider managerial and processual factors with the goal of achieving environmental benefits. Therefore, the factors that potentially enable sustainability are also the ones considered in the organisational approach toward BIM and lean (Saieg et al., 2018).

This transformation process is challenging and a long-term process (PBT3), and as argued before, it is not about the application of specific tools to achieve, in this case, sustainability outcomes, but it depends on organisational factors such as management commitment, proper strategy, and clear vision (Duarte and Cruz-Machado, 2019).

5.2.2 Strategy (S)

In this subcategory, four factors are included. The studied SMEs are all including plans to the extent of their capacity to promote BLS in their practices and are looking into the future, and have the vision to expand their business capabilities and competitive advantage by applying new methods. From the results in the previous chapter, the studied SMEs are identifying their goals and what they want to achieve and are taking steps to do so.

From the literature review in chapter 2 and the results from the previous chapter, the Chilean construction industry is slowly moving towards the adoption of BIM as the main way of working, but for example, the studied SMEs from the case studies are still using a mix of CAD and BIM and that transition is still in place (Loyola, 2019). The conversion process requires a smart allocation of resources (PS4). The respondents from the case studies also acknowledge that change won't happen overnight and for change to gradually happen needs proper strategic planning (PS2) to ensure that guidance on how to deal with change is provided to the organisation (Mihindu and Arayici, 2008).

In addition, top management must formulate an effective implementation strategy (PS1) which needs to be aligned to the organisation's goals (PS3), thus, ensuring continuous improvement and the promotion to a transformation including lean and green (Duarte and Cruz-Machado, 2019; Govidan et al., 2015), and BIM oriented objectives (Wu and Issa, 2014). This is consistent with the strategy to implement BLS according to the responses provided in the case studies. By having a closer look at the findings presented in table 5.2, these are not focused on tools to perform BIM, lean and sustainability, but rather on the components that would enable maturity to achieve those practices. SME1 and SME2 members mentioned that just because the organisation purchased a BIM licence and has applied lean tools in specific projects does not mean that they are a BLS-oriented organisation, and it would be very simplistic to think otherwise. The studied SMEs show a disparity in the BIM implementation, and the inconsistency of results in the lean area can be attributed to a lack of strategy because the previous projects where lean tools were applied were not aligned to the organisations' strategic goals creating a gap between goals and implementation. This finding is consistent with Antony et al. (2012), who highlights the importance of this link between organisational goals and strategy and argues that focusing on tackling existing problems is not sustainable in the long run. Missing objectives and strategies are common in SMEs and are one of the main reasons they fail and struggle to keep in the market (Siegel et al., 2019). As Albliwi et al. (2014) mention, focusing on short-term objectives and lack of or not planning put even more pressure on SMEs.

The studied SMEs also show that the formulation of strategic plans is reflected in SME1, where the top management is involved in the transition towards BIM adoption. The appointment of resources and key personnel for this task follows the strategic approach of upgrading their current processes to the adoption of BIM practices. Although the studied SMEs did not provide their detailed implementation plan, they acknowledged the importance of having one to identify the minimum requirements to fulfil the implementation. In addition, SME2 performed their pilot BIM project incorporating elements that included the evaluation of requirements established in their strategic assessment before committing to carrying out that first BIM project. SME2 also shares that by having a clear plan, the allocation of resources is simplified, allowing to follow the steps to comply with the current Chilean regulations and legislation. In this sense, SME2 claims that the government mandate has helped align the implementation efforts to the required standards.

In the case of SME3, the development of a strategy is currently underway, and the respondents also share the vision of the strategy to work, should follow a clear plan with clear roles and responsibilities.

5.2.3 Culture (C)

This subcategory is related to culture and how SMEs organisations should approach the BLS transformation from a cultural point of view. The transformation to a BLS culture would require a change (PC1) in people's attitudes and behaviours which is key for organisations to commit to change (Cherrafi et al., 2021). From the results, the studied SMEs are changing their cultural approach toward BLS initiatives by committing people to training programmes and including them in their decisions regarding the adoption. In addition, the promotion of a culture of doing things better and more efficiently has been highlighted by the application of BIM and lean, especially for SME2, which has had the most positive results in their implementation. BIM has received plenty of attention lately, and its implementation has been recognised as a top priority by many SMEs organisations (Vidalakis, 2020), including those in this study. Therefore, a culture change towards its adoption is more evident in the SMEs in this research that are in process or have elaborated plans to promote its implementation in the organisation culture. On the other hand, in the case of lean, the literature suggests that many organisations that have tried to implement it have not been entirely successful, resulting in a lack of trust in the system and even in total failure and rejection. Cultural factors are one of the aspects causing this lack of implementation (DeSanctis et al., 2018). Similarly, Shang and Pheng's (2014) study about lean construction implementation found that cultural aspects are one of the most important barriers.

This is consistent with a study by Alkhoraif et al. (2019), who highlight the importance of having a proper culture for the successful implementation of lean practices and that success will depend on how well the idea is embedded in the organisation. On the other hand, sustainability application has not been prioritised as high as the other initiatives by the studied SMEs. For that reason, it is seen that the uptake has been slow and still not considered by the organisation and their members. Organisational culture has a high impact on the application of sustainability considerations, especially for SMEs (Cambra-Fierro and Ruiz-Benítez, 2011; Uhlaner et al., 2012).

On the other hand, this subcategory also mentions the experience of the client (PC2) in BLS, which the responses from members of SME2 have highlighted. SME2 is the most experienced organisation in the use of BIM and lean compared to SME1 and SME3. They acknowledge that the culture of the client and knowledge of BLS aspects is a factor to consider when establishing project requirements and driving project deliverables. Although this is an external factor because the culture of the client is something that the organisation cannot control, it was still brought up to the researcher's attention.

The case of the integration of the contractor (PC3) has been discussed in the literature (Song et al., 2009) and, in practice, as mentioned by the respondents, as an aspect to consider when achieving maturity towards BLS. The construction industry in Chile uses traditional contracts in which a separation between design and construction still exists, reducing the contractor's input during these phases once selected through competitive bidding (De Solminihac and Thenoux, 2017). Bringing construction knowledge into the design from construction experts has been studied and concluded as an important step to avoid future errors and omissions (Arditi et al., 2002). As suggested by Song et al. (2009), the involvement of the contractor will only work under appropriate circumstances, which in this case would be the established BIM and environmental requirements. As previously mentioned, the case of lean has not been made obligatory, but it is a management practice applied with different levels of success in the studied SMEs. The same author concludes that the early involvement strategy to work would require a profound culture change, currently happening with the application of digital tools. A more recent study from Pheng et al. (2015) integrated lean principles and early contractor involvement strategy, whose results suggest that indeed by involving the contractor from early stages, productivity levels of lean construction principles are increased, especially variability. Therefore, it is not far from certain that this aspect can be applied so that contractors can have more input from the beginning.

5.2.4 Information (I)

This subcategory classifies the factors according to the management of information. In the case of the collaboration factor (PI2), SME1 recognises that the application of BIM will enhance this factor due to the benefits reported in the government initiative. However, He et al. (2017) argue that despite the advancements in the technical aspect of BIM, the managerial part is still a problem, and a lack of development in the management of BIM is still an issue. This idea is shared by SME1, providing a similar argument by adding that the collaboration factor will be enhanced with the application at a national scale of the BIM standards but that the management of information is still an issue due to the levels of maturity of the industry, and that collaboration aspects in terms of sharing of models, teamwork, etc. are still at early stages because organisations are still relying on the use of CAD. For that reason, SME1 believes that the term collaboration will take time to reach full maturity.

This is the view from SME1 from the application point of view, but in terms of the strategic perspective, collaboration has been identified as a factor that is dependent on the organisational and people/behavioural components (Allen et al., 2005; Patel et al., 2012). As per the results reported by SME2, the process of delivering a BIM project was a stepping-stone in the organisation's way of working because they are now looking forward to embracing it as a full way of delivering projects. However, the application of this methodology had many complications in terms of people rather than technological issues. Creating a collaborative environment was a difficult task because, according to the respondents, people, mainly external stakeholders, were not on the same page at that moment of executing the project. The SME had taken previous steps to achieve collaboration by enabling technology, but as Erdogan et al. (2014) suggest, that is not enough to reach for a collaborative working environment.
SME1 and SME3 have moved in their BIM implementation process by purchasing licences to use BIM software and are in the plan development process, but the expertise is not there yet. Organisations that adopt new processes supported by emerging technologies tend to fail their implementation process because they focus too much on the technical factors, ignoring the factors related to change, human aspects, implementation strategy, management, organisational processes, and end-users (Erdogan et al., 2008). This research has also found these reasons, as evidenced in the previous chapter.

In the lean case, the same situation happens. The implementation of the Last Planner in a couple of projects is viewed as a collaboration tool, and the aspects mentioned above are not considered in the application. The results show that the SMEs have different levels of success, and the implementation has not been embedded in the organisational culture to promote a collaborative working environment. Unless the change is well managed at the organisational level to promote collaboration (Erdogan et al., 2014), the full BLS benefits will not be achieved. This situation is the likely scenario since the studied SMEs are still in the process of change in which the focus is on the technology rather than the other aspects. In addition, as Loyola (2019) mentions in his national BIM survey, this situation is also the current scenario.

Communication (PI1) is seen as a factor to enable collaboration (Shelbourn et al., 2007). The way to convey the change process is important to obtain buy-in from members of the organisation and see a change in their behaviours towards the transformation process. This aspect is evidenced in SME1, which is transforming its business process by accepting the use of BIM. This transformation has allowed them to establish a strategic plan in which communication is a central part of that strategy. The constant flow of information and feedback is part of their strategy to communicate their vision and why change is required. This process adds transparency to the whole process and stability to the organisation (Halabi et al., 2017).

Clear BLS policy (PI3) and controlling and monitoring (PI4) are the final factors found in the information subcategory and the last couple of aspects to consider in the process category. A clear BLS policy must comply with the standards required in the implementation. The Chilean BIM mandate is a clear example for organisations to adapt their processes to comply with such policy. According to Eastman et al. (2011) and Succar (2009), the BIM process is seen as a set of interacting tools, technologies and processes guided by principles, norms, and policies. In this case, it is known what is expected from SMEs. In the case of sustainability, there is also a policy put in place that organisations in the construction industry must follow. Finally, there is a lack of clarity on the lean part since there are no current requirements to follow. The contradictory part is that it has been suggested to enhance the construction industry in Chile (CChC, 2020).

Finally, controlling and monitoring (PI4) the process has been identified as part of the implementation efforts that SMEs must adhere to ensure continuous improvement and to make sure that the pre-established requirements are closely followed and improved. As per respondents from SME2, the implementation plan is a way of controlling and monitoring the whole process to make sure every step is being followed and properly assessed.

5.3 Discussion of findings in the human and attitudinal category

In this category, after the cross-analysis process, seventeen factors were found across the three studied SMEs. As shown in table 5.3, the frequency of responses again varies. After evaluation, the factors from table 5.1 can be classified into a Human and attitudinal subcategory. The subcategory, along with each factor, is shown below in table 5.3.

Table 5.3 Human and attitudinal factors subcategories.

Category	Subcategory	Code	Factors
Human and attitudinal (H)	Expertise (EX)	HEX1	Competencies of top staff
		HEX2	Skills
		HEX3	Champion
		HEX4	Understanding of the BLS concepts
		HEX5	Qualified staff
	Education (ED)	HED1	Education
		HED2	Knowledge
		HED3	Development
		HED4	Training
	Attitudes (A)	HA1	Attitudes and behaviours
		HA2	Awareness
		HA3	Motivation
		HA4	Roles
	Engagement (EG)	HEG1	People management
		HEG2	People support
		HEG3	Stakeholder engagement
		HEG4	Teamwork

As previously discussed, organisations implementing new practices usually focus too much on the technology part and do not pay attention to other factors such as the human and attitudinal aspects (Erdogan et al., 2008).

In this case, the human element is of utmost importance to achieve maturity, as identified by the respondents.

For example, to enable the implementation of sustainability and lean, the main focus should be put on people to maintain results in the long term, and they should be well managed (HEG1) by people with strong competences in the area (HEX1) (Wong and Wong, 2014), and encouraged to learn and develop (HED3) to increase their skills (HEX2) (Ali et al., 2013, Glover et al., 2015) through the support (HEG2) from top management and a transformation culture (Alves and Alves, 2015).
It is evident from the case studies that SMEs are attempting the promotion of the aforementioned factors. Although the focus at the moment is the promotion of BIM outcomes, the SMEs count on people with experience mainly in the BIM and lean areas, especially SME1 and SME2. In this sense, the use of a "champion" (HEX3) to lead the implementation efforts (Smits et al., 2017) has also been identified as a BLS enabler. SME1 and SME3 agree that the appointment of this person to lead the change is required to deliver the whole process. For that purpose, SME1 has appointed a BIM specialist to deliver the strategy to identify the roles that the organisation needs to comply with that strategy in terms of qualified people (HEX5) or the assessment to provide training. The results also show that the availability of qualified and competent staff is essential for applying BLS, and higher levels of performance can be reached by having the right personnel for the job (Ozorhon and Karahan, 2017). For example, the availability of qualified people is essential to undertake tasks with the level of complexity sustainability requires and has been identified as one of the major issues when dealing with sustainability in construction (Choi et al., 2016).

The use of a champion has also been identified to promote lean (Mahalingam et al., 2015) and sustainability (Dhingra et al., 2014). The appointment of these people should be by selecting them according to their experience and understanding of the BLS requirements (HEX4) aligned to the organisation's goals. For example, to comply with the sustainability theme, this champion needs to understand the organisation's economic, environmental, and societal goals (Dhingra et al., 2014). The same understanding is required with the application of BIM and lean (Dave et al., 2013).
Kiviniemi and Wilkins (2008) suggest that the implementation of BIM practices requires a clear definition of roles (HA4), and the lack of this clarity leads to poor adoption (Gu and London, 2010; Sacks and Barak, 2010).

As previously mentioned, the studied SMEs are in the very early stages to reach sustainability outcomes, but the application of BIM and lean can indirectly enhance sustainability (Lu et al., 2017; Peng and Pheng, 2010). In this sense, the way to reach for BLS objectives is with training (HED4), education (HED1) and teamwork (HEG4) to develop knowledge (HED2), which the respondents have identified as key aspects to reaching for BLS maturity. Similarly, the lack of them is one of the reasons implementing new initiatives such as lean and sustainability tend to fail (Duarte and Cruz-Machado, 2013). The studied SMEs should also focus on this aspect when the strategy is developed and not only on the BIM training, which is the current scenario.

Garavan (1997) identified training at all organisation levels as one of the important factors, along with motivation (HA3) and employees' development to maintain competitiveness. Similarly, Sambrook (2004) states that the development of skills through learning supports the achievement of goals such as business strategies and performance improvements in both organisational and project terms. In addition, training programmes are relevant, especially in the construction industry, that is dependent on the skills of its workers (Durdyev and Mbachu, 2017).

SME3 identifies the need for training to reach maturity and has also identified that a selected number of members in their SME, based on their knowledge and experience, should be taking this training and then pass their gained knowledge to other members in the organisation. This way, resources can be better deployed, and savings can be made compared to sending all their staff to complete training courses. Bryde et al. (2013) identify the need for training to promote BIM along with stakeholder engagement (HEG3) activities to raise awareness (HA2) in the systems put in place to promote a change in the attitudes and behaviours (HA1) towards these new initiatives. Arayici et al. (2011) also suggest the use of a bottom-up approach and top management commitment to support engagement in the adoption of BIM and lean. This way organisation's competencies are increased, and strategies supporting change management are more effective (Pearce et al., 2018). The Chilean BIM and sustainability mandate are ways to encourage engagement from stakeholders. In this sense, governments are one of the most important drivers to promote engagement from stakeholders and organisations in the industry (Tsvetkova et al., 2020).

5.4 Discussion of findings in the technology category

In this category, after the cross-analysis process, fifteen factors were found across the three studied SMEs. As shown in table 5.1, the frequency of responses again varies. After evaluation, the factors from table 5.1 can be classified in a technology subcategory. The subcategory along with each factor is shown below in table 5.4.

Table 5.4 Technology factors subcategories.

Category	Subcategory	Code	Factors
Technology (T)	Infrastructure (I)	TI1	Appropriate hardware
		TI2	Capacity to implement tools
		TI3	Infrastructure
	Software (S)	TS1	Appropriate software
		TS2	Interoperability
		TS3	Tech support
		TS4	Compatibility
		TS5	Constructability
		TS6	Design errors
		TS7	Less paperwork
	Data (D)	TD1	Appropriate exchange of information
		TD2	Efficiency
		TD3	Data security
	Protocols (P)	TP1	Policy
		TP2	Standards

The subcategories for the technology part are infrastructure, software, data, and protocols. SMEs are usually constrained in terms of financial resources, which means that most of them do not have the capacity (TI2) to invest large sums in technology, infrastructure (TI3), and training at the same time, even if it is acknowledged that these are essential to implement new improvement initiatives (Antony et al., 2016).

Bryde et al. (2013) argue that the challenges in the implementation of BIM are focused mainly on hardware (TI1) and software (TS1) issues, which in the case of the studied

SMEs include interoperability (TS2) and compatibility (TS4) aspects. This is mentioned mainly by SME2, which has delivered a BIM project and shared that they encountered problems when working with other stakeholders in terms of shareability of models and compatibility of different software applications that was solved in the end, but the sharing of information was not as smooth as it was supposed to be. This is understandable and logical since the SME, and their stakeholders were new in the process, and it was the first project undertaking this methodology.

The cost of the BIM implementation is high and varies according to the different providers, and so do the hardware specifications. Therefore, depending on the selection of providers, the hardware requirements will change (Olatunji, 2011). This is something that organisations, especially SMEs, should consider and include in their strategy and IT policy (TP1) according to their goals, needs and how the market is moving and the consideration of maintenance and technical support (TS3) as well (McGraw Hill Construction, 2007). Studies from Arayici et al. (2011) and Eastman et al. (2011) highlight the need to have powerful workstations, IT infrastructure and solutions to support the BIM tasks. Policy (TP1) and standards (TP2) are also important because the organisations in their process should adapt their practices to the current BIM policy, which in this case is set by the government regulations and comply with the standards required by stakeholders and clients in their projects. Policy support in the acquisition of software, hardware, and training is key to the successful adoption of BIM (Song et al., 2017). This is the case for SME2, which adapted its BIM policy to suit the organisation's needs in terms of their IT restructuration and acquisition of new technology to satisfy their future needs in the procurement of new projects with the government, as well as planning future projects with the methodology. In this sense, the acquisition of BIM software is part of their commitment and strategy to develop more sustainable projects and comply with government regulations and requirements. The use of BIM software for sustainability purposes is an ideal tool that can integrate the assessment of sustainability and resource management efficiency, including energy-consumption analysis for a sustainable built environment assessment and benefit-cost analysis of economically sustainable design (Yuan et al., 2019). Regarding the hardware and software discussion, the addition of sustainability considerations makes this application an extra requirement when considering the purchasing of equipment because of the extra processes and additional tasks needed, which makes the files "heavier" (Al Hattab, 2021). In this sense, a study from Chong et al. (2017) about BIM adoption for sustainability highlighted the need for new BIM tools to assess sustainability and improved interoperability among the different available BIM software and energy simulation tools. This makes the consideration of sustainability practices a more difficult scenario for SMEs in Chile, as mentioned by the studied SMEs, due to the costs. For that reason, the application has been considered, but still in development because of the number of factors to be assessed and due to the priority given to the BIM adoption.

In the case of the technology application for lean adoption, the technology aspect is not seen as a problem because, according to the experiences from the implementation efforts of the studied SMEs, it does not take many technological resources in terms of hardware and software to apply lean tools other than having IT connection to the web and computers to run programming software. Although software prototypes are developed, for example, Visilean (Dave et al., 2011), the application of lean tools does not require fancy software to run, but the immersion of the philosophy, which is solved by training and education in this area (Pons and Rubio, 2021).

Saieg et al. (2018) found that the integration of BIM, lean and sustainability has as main barriers and challenges the high cost of the BIM hardware and software to support the application. The respondents from the case studies have mentioned that their organisations have purchased licences to implement BIM and possess the capacity to carry on with the process. However, they acknowledge the issues for SMEs due to the high initial costs and the uncertain return on investment.

The problems with the Chilean construction industry have become evident by the responses provided by the interviewees, who have highlighted the issues of low efficiency, errors and omissions, time, and cost overruns. In this era of new methods and technologies emerging, the problems are still persistent because, as per the three studied SMEs, there is a lack of efficiency in the exchange of information (TD1). This is because there is still overreliance on the 2D data systems based on CAD, which is the critical issue that has slowed down the efficiency (TD2) in how the data is used in the BIM process, which is consistent with the literature as shown by Lee and Borrmann (2020).

The next issue, data security (TD3), has been brought to attention by respondents from the three studied SMEs. According to their views, the sharing of data of models brings many people together, contributing information to a centralised model. Therefore, protocols and standard processes are needed to determine obligations and for design and validation purposes (Singh et al., 2011).

SME2 has maintained their models in-house but is considering upgrading to a secure server provider for future projects to ensure data security. According to their experience, it is also one of the aspects to consider when developing the strategy and policy.

The final set of factors mentioned by the respondents, constructability (TS5), design errors (TS6) and less paperwork (TS7), are factors that were mentioned a couple of times and reflect the need from the technical perspective to purchase software that can immediately deal with these issues. Especially TS5 and TS6, which have been identified in the responses as aspects that are decreasing efficiency and productivity, leading to poor performance and waste (Mokhatab et al., 2014; Ko and Chung, 2014).

Finally (TS7) was also mentioned to achieve maturity because, as per SME2, less paperwork will be required by using efficient systems, and the promotion of software usage will be the norm.

5.5 Discussion of findings in the management category

In this category, after the cross-analysis process, fifteen factors were found across the three studied SMEs. As shown in table 5.1, the frequency of responses again varies.
After evaluation, the factors from table 5.1 can be classified into a management subcategory. The subcategory, along with each factor, is shown below in table 5.5.

Table 5.5 Management factors subcategories.

Category	Subcategory	Code	Factors
Management (M)	Direction (D)	MD1	Leadership
		MD2	Motivation
		MD3	Vision
		MD4	Top-down approach
		MD5	Bottom-up approach
		MD6	Commitment to change from top management
		MD7	Flexibility
		MD8	Management support
		MD9	Subcontractors commitment
	Transition (T)	MT1	Planning
		MT2	Resistance to change
		MT3	Risk Management
		MT4	Adaptability
		MT5	Align (Organisation objectives)
		MT6	Management of information

In the management category, two subcategories can be identified based on the factors found in the case studies, namely leadership and transition.

The leadership factor (MD1) is mentioned as the most important factor according to the respondents because implementing change requires a vision (MD3) and commitment to change (MD6) from top management. This is reflected in the decisions of the studied SMEs to invest in improving their systems to support the change process and add value to their organisation and the projects that will be carried out under the new method of working (Saieg et al., 2018). In terms of the use of BLS practices, Saieg et al. (2018) suggest that they rely on leadership in the application of proactive solutions, innovative methods and tools that will enhance the sustainability outcomes and the management of information (MT6). In addition, leadership has been regarded as one of the main drivers of innovation in the construction industry (Ozorhon et al., 2010). Similarly, the literature also shows that leadership plays an important role in shaping project spirit and as motivation (MD2) for the team to commit to the objectives set by the organisation (Aronson et al., 2013).

A very good example of leadership is the one mentioned by Ozorhon et al. (2014), who found that the application of leadership in a case study was essential to implement innovation through effective knowledge sharing by the client to the project team. In this case study, the client took the initiative, brought the contractor early in the process and pushed it to innovate. The client shared knowledge about modern methods of construction, offered to cover half the cost of the lean construction consultancy, and played an important part in finding partnerships with the supply chain that shared its vision, allowing the client to fulfil its goals. This partnership with the supply chain shows that commitment from subcontractors (MD9) is also possible, and it is expected that they also take part in the transformation process the construction industry in Chile is facing.

This example is a similar situation as explained in the results chapter where SME3 shares the experience of leadership from the top management to deal with the application of lean in one of the projects. The integration of the contractor at the early stages is one of the items discussed in the previous section and highlights the responses from the SMEs in this area. This demonstration of leadership is consistent with Mention (2011), who also argues that managers should encourage and put mechanisms to share knowledge in groups and encourage innovation.

The respondents also mentioned the top-down approach (MD4) and bottom-up approaches (MD5) as important factors. According to Kurdve et al. (2014), implementing efficient actions that are sustainable in time is the foundation of the top-down management approach, whilst the feedback back to the management is provided by the bottom-up approach.

In this sense, the government requirement is a top-down movement that has made the construction organisations take action to adapt their practices to comply with such requirements. For that reason, resistance to change (MT2) has been found in the organisations which have had to become adaptable (MT4) and flexible (MD7) to align their goals (MT5) to the new construction requirements. As discussed in the findings, the responders encourage the use of both a top-down approach from the organisation to promote change and lead the implementation efforts, which is consistent with findings from the literature (Smith and Tardif, 2009; Succar, 2009). The bottom-up approach provides feedback from the lower levels and deals with resistance to change (Arayici et al., 2011). In this sense, Arayici et al. (2011) encourage the application of bottom-up approaches to deal with resistance to change, but management support (MD8) is still required (Vass and Gustavsson, 2017).

In the case of the sustainability requirement, Alwan et al. (2017) argue that the government's top-down approach puts pressure on construction organisations by taxing waste derived from the construction process and expecting to reduce waste inefficiencies. However, the same author argues that this measure does not accomplish the desired effect because the contractors remain inefficient and put this cost to the client, leading to more expensive construction and not positively impacting the environment.

In the lean case, there are different ways to implement it in organisations, including top-down and bottom-up approaches (Zanotti et al., 2017). The top-down approach is described as goals set by top management, while the bottom-up approach is person-focused (Höök and Stehn, 2008). Arbulu and Zabelle (2006) suggest that the top-down approach is often forced on organisations and mandated by leadership with no stakeholder engagement strategies, leading to poor application and lack of trust in the system, leading to an unsustainable way of working (Berroir et al., 2015). Implementing BLS practices comes with associated risks (MT3) (Cherrafi et al., 2021; Ghaffarianhoseini et al., 2017; Pierce and Pons, 2013) that organisations need to overcome by planning (MT1) and by looking into the future for potential risks that may arise which can only be done by having a deep understanding of the organisation, industry, technology, and culture (Lou et al., 2020).

5.6 Discussion of findings in the economic category

In this category, after the cross-analysis process, fourteen factors were found across the three studied SMEs. After evaluation, the factors from table 5.1 can be classified in an economic subcategory. The subcategory, along with each factor, is shown below in table 5.6.

Table 5.6 Economic factors subcategories.

Category	Subcategory	Code	Factors
Economic (E)	Cost (C)	EC1	Cost control
		EC2	Cost reduction
		EC3	Implementation cost
	Financial strategy (FS)	EFS1	Financial support
		EFS2	Incentives
		EFS3	Subsidies
		EFS4	Return on investment (ROI)
		EFS5	Market demand for BLS deliverables
	Returns (R)	ER1	Increased competitive advantage
		ER2	Increased value
		ER3	Productivity improvement
		ER4	Quality improvement
		ER5	Resource optimisation
		ER6	Increased economic performance

In the economic category, three groups are identified from the case studies' factors: cost, financial strategy, and returns.

Implementation cost (EC3) is one of the most repeated factors, along with market demand for BLS deliverables (EFS5).

The literature supports the high cost of BIM implementation, including the acquisition of technology and training as a major barrier to its adoption (Giel et al., 2010; Azhar et al., 2011; Crotty, 2012). Despite this high cost, the application of BIM is driven by clients and the market requirements, which in the Chilean case, is the government. As Hore et al. (2011) suggest, for the adoption of BIM when it is mandated, there must be government support in terms of subsidies (EFS3) and incentives (EFS2) to facilitate the implementation, which may be out of reach for SMEs due to its cost (Koudier et al., 2007).

In the Chilean case, financial support (EFS1) is one of the aims of the Chilean strategy to increase the number of specialised people in the area to commit the industry to improve its standards (CChC, 2020). The number of higher education institutions and private institutes has increased their teaching in BIM subjects (Planbim, 2021). However, the respondents think that this financial support is not enough because training is only a part of the whole BIM scheme, and more guidance from a managerial point of view should be given to promote this transition. SME2 has mentioned that they had to carry out a full assessment before piloting their first BIM project, including a risk assessment of their financial capability and staff competences, so for that reason, they suggest that financial support is key in the adoption, especially in the acquisition of technology. The same situation happens with the application of sustainability considerations. In this case, the high cost of these kinds of solutions is also an issue that organisations must tackle, and without support, it is even more difficult to commit to the established goals (Ekins and Zenghelis, 2021). The application and focus on building sustainable projects bring benefits, including energy efficiency, improved indoor environment quality, better use of resources (ER5), better quality (ER4) in the long run, productivity (ER3) and the organisations' ability to increase their economic performance (ER6), competitive advantage (ER1) and value (ER2) due to their ability to offer attractive solutions to investors and developers (Lapinski et al., 2006). Although these benefits may sound attractive and have been identified by the respondents in the case studies as drivers to implement sustainability practices, the reality is that readiness to fulfil those goals needs extra requirements. These requirements include a higher level of complex design analysis, which will require more skilful and specialised people, extra interdisciplinary collaboration and different materials selection that also may require specialised people to execute the job (Riley et al., 2004).

In this scenario, the problem for SMEs is that they must see a return on investment (ROI) (EFS4) if they are going to commit resources to those tasks because sustainability application in SMEs is only considered if it can have a positive financial impact on the business. Otherwise, it is seen as a costly and unnecessary activity (Upstill-Goddard et al., 2016). This is evident in the studied SMEs that are planning to promote sustainability but moving forward from ideas to actions that have been postponed due to the financial commitments the BIM process is taking.

Although the financial measures are an important factor to assess previous BLS implementation, the focus on the long-run impact should be the focus of attention. For example, in the case of lean application, a study by Pearce et al. (2018) shows that in a case study, the implementation of lean was pushed down from the top management, and the focus was only on reporting financial measures, which resulted in the implementation process to fail because other aspects such as knowledge and other resources were missing. In this sense, Alkhoraif et al. (2018) suggest that lean implementation is a philosophy and a long-term strategy focusing on the efficient use of the resources available, reducing waste and controlling and reducing costs (EC1 and EC2, respectively). As reported in the case studies, this efficient management of costs is seen as a way to direct the savings made from the lean application to the implementation of other initiatives such as lean and sustainability.

5.7 BLS organisational framework to assess maturity

The factors discussed in the previous sections resulted from a cross-analysis process of the three case studies, which were discussed and theoretically validated as shown in the above subchapters. The result is the proposed conceptual BLS framework to assess maturity as shown in figure 5.1.

BLS framework			
	Subcategory	Code	Factors
Process (P)	Business transformation (BT)	PBT1	Business process reengineering
		PBT2	Gradual change
		PBT3	Focus on long run
		PBT4	Change strategy plan
		PBT5	Continuous improvement
		PBT6	Government initiative
	Strategy (S)	PS1	Implementation strategy

		PS2	Strategic planning
		PS3	Alignment
		PS4	Resource allocation
	Culture (C)	PC1	Culture change
		PC2	Client experience in BLS
		PC3	Early contractor involvement
	Information (I)	PI1	Communication
		PI2	Collaboration
		PI3	Clear BLS policy
		PI4	Controlling and monitoring
Human and attitudinal (H)	Expertise (EX)	HEX1	Competencies of top staff
		HEX2	Skills
		HEX3	Champion
		HEX4	Understanding of the BLS concepts
		HEX5	Qualified staff
	Education (ED)	HED1	Education
		HED2	Knowledge
		HED3	Development
		HED4	Training
	Attitudes (A)	HA1	Attitudes and behaviours
		HA2	Awareness
		HA3	Motivation
		HA4	Roles
	Engagement (EG)	HEG1	People management
		HEG2	People support
		HEG3	Stakeholder engagement
		HEG4	Teamwork
Technology (T)	Infrastructure (I)	TI1	Appropriate hardware
		TI2	Capacity to implement tools
		TI3	Infrastructure
	Software (S)	TS1	Appropriate software
		TS2	Interoperability
		TS3	Tech support
		TS4	Compatibility
		TS5	Constructability
		TS6	Design errors
		TS7	Less paperwork
	Data (D)	TD1	Appropriate exchange of information
		TD2	Efficiency
		TD3	Data security
	Protocols (P)	TP1	Policy
		TP2	Standards

Management (M)	Direction (D)	MD1	Leadership
		MD2	Motivation
		MD3	Vision
		MD4	Top down approach
		MD5	Bottom up approach
		MD6	Commitment to change from top management
		MD7	Flexibility
		MD8	Management support
		MD9	Subcontractors commitment
	Transition (T)	MT1	Planning
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		MT4	Adaptability
		MT5	Align (Organisation objectives)
		MT6	Management of information
Economic (E)	Cost (C)	EC1	Cost control
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		EC3	Implementation cost
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		EFS3	Subsidies
		EFS4	Return on investment (ROI)
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	Returns (R)	ER1	Increased competitive advantage
		ER2	Increased value
		ER3	Productivity improvement
		ER4	Quality improvement
		ER5	Resource optimisation
		ER6	Increased economic performance

Figure 5.1 BLS conceptual framework

In terms of the framework's practicalities, chapter 1 discusses that the government goal for organisations in the Chilean construction industry is to move away from traditional practices to embrace a new way of working in which BLS practices are set to become the norm. As explained in chapter 2, the Chilean construction industry is comprised mainly of SMEs, and the workers' skills are increasing following the application of BLS, as shown in the responses provided by the respondents. In that sense, the framework does include a human and attitudinal category which targets the identification of people's skills and the opportunity to identify gaps that can lead to more professionals with a

BLS-oriented mindset and skills. It is worth mentioning that the other aspects, such as the heat island effect and the concrete nature of the country due to seismic activity, are inherent characteristics of the country that the BLS alone would not solve. The opportunity of the BLS framework is to allow SMEs to adopt these practices before assessing categories and factors that would establish the organisation's ability to implement these changes and, from there, promote opportunities for change. The construction of concrete structures in the country is not something that will change, especially due to the seismic nature of the country. However, the efficiency and sustainability provided by BLS practices and that the BLS framework addresses would impact the quality of construction and the methods that are chosen to perform tasks, allowing the possibility of reaching the global construction targets of efficiency, productivity, and sustainability.

A starting point for SMEs is to assess their realities in terms of promoting these practices where the proposed BLS framework aims to provide organisations attempting to adopt BLS, the key areas of focus. In this sense, the framework shows the factors that SMEs organisations should assess to establish maturity in the BLS area at the organisational level and thus, establish an organisational adoption of BLS practices. The framework includes the process, human, technological, managerial, and economic perspectives, in which subcategories are identified to classify the factors found in the case studies. These factors describe the considerations that SMEs should have to embed BLS in their practices from an organisational point of view. Thus, according to their current implementation status, they identify the level of maturity in the described areas and act when required.

To determine the level of maturity toward BLS adoption, SMEs should assess their current capability and compare it with the factors in each category. This can be done by experienced members of the organisation in the upper levels, by an internal team set up for such purposes or by having external consultancy from people with an understanding of the BLS requirements and the organisation’s goals and objectives. This knowledge of capability and maturity can be done by carrying out observations, interviews, report checking etc. Top management can engage people from the organisation to lead the process, or as a point of connection between the organisation and external consultants to make sure that the process aligns with the organisational objectives, and constant feedback is suggested to connect the engagement of the other levels. When the assessment of the categories is done, the gap can be established, and areas of improvement can be targeted and prioritised according to the needs of the SME. The results from the case studies show that the SMEs involved in this study are yet to become BLS oriented organisations, their maturities are still in transition, and the overall government strategy is yet to be reached. The question remains of how to meet the targets if organisations show slow transitions to the construction industry goals, especially considering that SMEs are the vast majority in the country.

5.8 Summary

This chapter discusses the findings from the previous chapter along with the support of the literature to justify and make sense of the responses provided by the participants in this study.

The state of uptake regarding BLS application and implementation is assessed, and the factors found by the respondents are analysed and discussed.

According to the realities of the studied SMEs, there is still a long way for organisations to embed BLS in their operations, and the maturities in the subject are still low and in transition to becoming proficient in their use. The BLS framework developed with the categories studied and the identified factors is a way to help SMEs to assess the aspects that need to be considered to promote their use and reach maturity.

Chapter 6 Framework validation

The development of the theoretical framework has been discussed in chapter 5, which served as the basis for the data collection process and analysis. The BLS framework consists of factors that enable organisations to assess maturity and achieve the capability levels that will allow them to move towards a BLS organisation. The theoretical framework was developed and presented into a conceptual framework shown in section 5.7 by cross analysing the data from the case studies and linking it with the literature review discussed in the previous chapter. The BLS framework as presented is still theoretical in nature, and it is limited to the findings from the case studies. For that reason, it is necessary to validate it to obtain a broader view of its use and make it general so that other SMEs can use it. This chapter presents the validation process of the BLS framework factors found in the case studies. The data collected from the validation process is used to refine the framework further, and the final version is later presented at the end of this chapter.

6.1 Focus group overview

This research employs a focus group technique to validate the framework as discussed in the methodology chapter. The selection of the appropriate participants was based on their experience in the BLS area and SME organisation. The diffusion of the focus group was with the help of key contacts in the construction industry and academia who played an important part to engage participants.

This part of the research employed a quantitative approach in the focus group, namely a questionnaire to evaluate the BLS framework factors and assess the current state of maturity. This is done to establish the reliability and to determine the position of the participants' SMEs in the factors that would enable them to move towards reaching maturity in the BLS area. The reason for using a questionnaire format was due to the time constraints that the focus group had and to structure and facilitate the discussion among the participants. This questionnaire can be found in annexe 2. The questionnaire was handed out in advance to the start of the focus group so the participants could familiarise themselves with it and allow enough time to provide the answers and later facilitate the discussion. At this point, the participants were already informed of the objectives of the research and the purpose of the evaluation. This was done in the first contact and after the respondents had committed to participate in the process. The questionnaire responses are analysed by employing the relative importance index (RII), which is derived from the average index but considering the Likert scale effect of the responses. The questionnaire employed a five-point Likert scale type, with one being the lowest score and five the highest with a middle option. The questionnaire details can be found in annexe 2, and below is table 6.1 showing the scoring options provided.

Table 6.1 Scoring options for the factors and maturity questionnaire

Rating scale:	Interpretation
1	No importance whatsoever
2	Little importance
3	Neutral
4	Important
5	Very important

The focus group also engaged in a discussion of the topics, which are qualitative in nature, to find explanations of the responses provided in the questionnaire and to make suggestions for the framework. The participants engaged in discussions and consensus on the factors was found, agreeing that some were unimportant and needed to be discarded. This part is presented later in the chapter. The qualitative responses were analysed using content analysis and checked with the questionnaire responses (See annexe 2).

6.1.1 Participants' background

The background of the focus group respondents is presented in table 6.3. All the participants come from contractor SMEs which is the requirement for this study because the framework is targeted to that audience.

Table 6.2 Focus group participants' background

Code	Respondent	Background	BIM experience	Lean experience	Sustainability experience
FGR1	Senior Civil Engineer	Engineer	4 years	8 years	2 years
FGR2	Senior Constructor	Engineer	3 years	6 years	2 years
FGR3	Senior Architect	Architect	5 years	2 years	3 years
FGR4	Director	Engineer	3 years	9 years	2 years
FGR5	Director	Architect	3 years	9 years	2 years
FGR6	Assistant Construction	Engineer	3 years	11 years	3 years
FGR7	Senior Manager	Engineer	4 years	15 years	2 years
FGR8	Senior Manager	Architect	5 years	12 years	2 years

The selection of the focus group participants was based on their experience in the construction industry in Chile in the BLS areas and are in plans to transition or expecting to transition to adopting BLS in the near future. This selection is because their experience in the transition can help assess the identified maturity factors needed to promote the use of the BLS framework to other SMEs. The participant's experience is important because it reflects their knowledge in the area, increasing their input and reliability in the BLS framework that has been developed. Finally, given that the framework is proposed to be applicable at the strategic organisational level, the respondents must come from the top and middle management levels.

Table 6.3 shows that the participants have the required experience in the BLS areas. The participants' experience in sustainability is less than the lean and BIM aspects, showing that they are still new in the area and are managing the transition toward the requirements. The BIM experience is the second-best, and most of the respondents have vast experience applying the lean philosophy.

6.2 Focus group results and discussion

This section discusses the results to validate the BLS framework from the focus groups. The results present graphs showing the RII to compare the importance of the factors and the current level of maturity. This graphical representation shows the gaps (if any) between the factors and the state of maturity. The results presented show the BLS framework's process, human and attitudinal, management, technology, and economic proposed categories.

6.2.1 Process factors focus group results

Figure 6.1 shows the summary of the findings in the process category. For more details, the full results can be found in annexe 3.

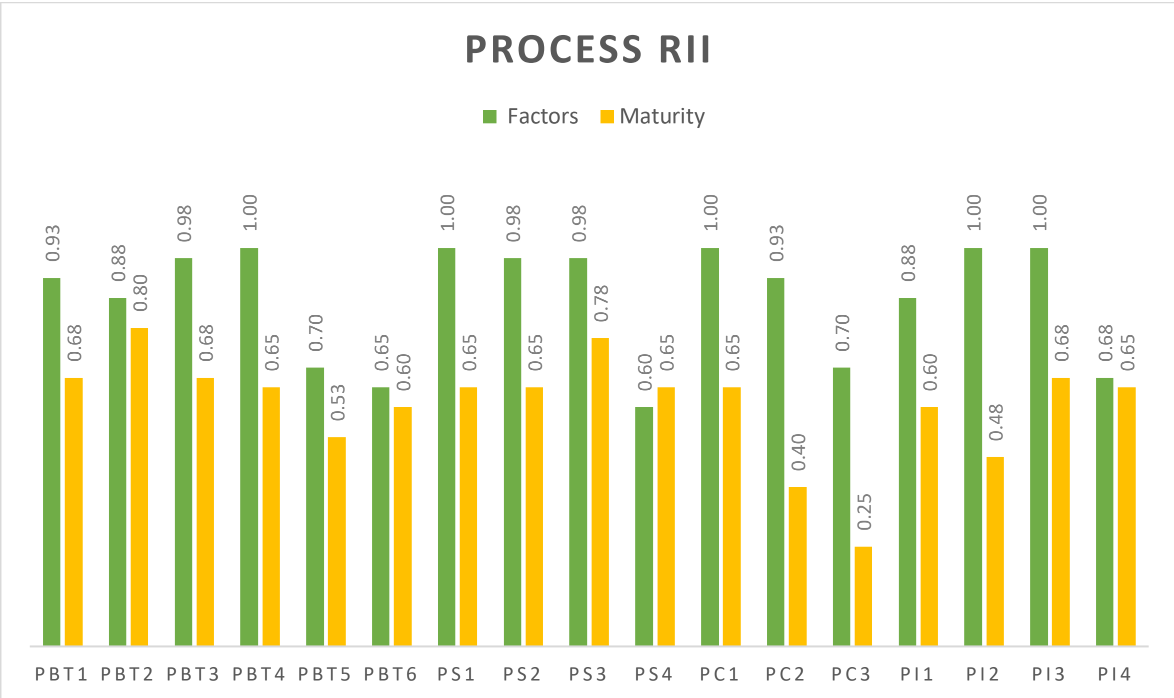

Figure 6.1 Focus group results in the process category

From figure 6.1, all the elements in the process category score above 0.6 RII in the assessment of the factors category, while the lowest score in the maturity levels is 0.25

RII, and the highest is PBT2: Gradual change with 0.8 RII. The results show a gap between the current maturity levels and the factors' importance levels to reach full maturity. PBT4 records the highest score in the factors category: Change strategy plan; PS1: Implementation strategy; PC1: Culture change; PI2: Collaboration and PI3: Clear BLS policy, all of them with 1.0 RII, which means that all the respondents are in concordance with the level of importance of these factors for the BLS framework.
In terms of maturity, the RII shows that the levels are still low, and the PBT2: Gradual change is the highest scored option with a 0.8 RII, indicating that the respondents are experiencing that process and that it has been approached in their SMEs as an incremental transition towards the transformation process.

PBT1: Business process reengineering, scores 0.93 RII in the factors category. In this sense, three respondents gave a score of 4, and five respondents scored this factor as 5, confirming the importance of establishing a restructure of the organisation to commit to applying BLS practices. The respondents scored a 0.68 RII in the maturity category, with a neutral response repeating five times while the score of 4 repeated three times, indicating a strong indication of maturity.
In addition, based on the focus group discussion, the participants strongly suggested that the incorporation of BIM processes should overtake the current use of CAD and that this change should be part of the process restructure of the organisations. Moving away from CAD has been agreed upon as a challenge, and one of the issues found when delivering BIM projects due to the reliance on CAD drawings. This situation has been commented on and agreed upon due to the levels of skills and competences from people within the organisation and due to some lack of understanding of the deliverables required, including stakeholders. In addition, SMEs reengineering to adopt a BIM driven organisation has been acknowledged to sustain the implementation of the continuous improvement of the lean philosophy and to drive the adoption of sustainability by the application of BIM. The lean process is about a change of philosophy and should not be as difficult as the BIM process, so a major business reengineering is not seen as a significant barrier to adopting lean.

PBT2 and PBT 3 were brought up in the same discussion because they were seen as supplementary items. PBT2: gradual change had a diverse set of responses in the factors category, including one neutral option, three scores of 4 (important), and four scores of 5 (Very important) with a 0.88 RII. On the other hand, PBT3: Focus on the long run was scored as 5, on seven occasions and 4 in one opportunity, with a 0.98 RII.

According to FGR3, implementing these practices and the transformation of SMEs towards government requirements brings several challenges and unknown risks that are of concern if not managed properly. People are one of the risks that can be managed, and that transition needs to be taken gradually. The change should not happen overnight, but it is a process that requires time to be accepted and acknowledged. In their implementation efforts, this participant mentioned that when deciding on what software to acquire for the BIM part, they encountered many options and features that were great on paper. However, after analysing the skills needed to best use that specific software, they found that they lacked in terms of people capacity. They thought that no matter what the software could do, without the right people for the job, the software would not do any good but only cause problems. Capacity needs to be built to implement BIM, lean and sustainability. This situation is a similar example provided by FGR1, who adds to the discussion that when the first time they heard about the Last Planner System, they wanted to implement it right away, which they did, but the results were not coming because they did not communicate it properly and did not implement it gradually. For that reason, people in their organisation thought they were going to get immediate results by applying a tool that was having good results somewhere else. In this sense, the same respondent also added that the focus needs to be on the long run and expecting immediate results is not the way to measure the application. The success is dependable on how well the system is put in place. Obtaining good results is a reflection of that because it is more than acquiring a piece of software to run a couple of energy checks to claim sustainability points. It is also more than applying lean tools in a couple of projects to claim that the organisation is doing lean. This gradual and long-term process to be successful needs a process that takes time.

PBT4: Change strategy plan scores a RII of 1.0, which means that all the respondents agree that this factor is essential to reaching maturity in the BLS areas. The respondents agree that having a strategic plan to implement change is essential to support the PBT1 factor: business process reengineering because of the risks that the transformation may bring. By having a clear plan of action or framework of action as per FGR3, those risks can be identified, minimised, and managed accordingly. FGR1 adds that a general strategy, like the one provided by the government, although helpful to provide general implementation guidelines, should be considered for just what it is, a general approach. Organisations, especially SMEs, should create a plan that suits their needs and their needs only, according to their reality and resources, which need to be assessed before creating the change strategy.

These arguments support the PBT5 and PBT6 factors because it is necessary to elaborate the change strategy plan based on the government requirements. The idea of focusing on continuous improvement is something that SMEs should acquire to keep their business sustainable and attract more projects, which is why these SMEs are moving away from traditional practices. PBT5: continuous improvement and PBT6: government initiative scored 0.7 RII and 0.65 RII, respectively.

The PS1 factor implementation strategy scored a perfect 1.0 RII, meaning that all the respondents strongly agree that this factor is one of the key BLS aspects to reaching maturity in the area. In this sense, FGR4 shares that the alignment of BLS into an implementation strategy should be done considering a clear definition of what the organisation wants to accomplish, setting specific, realistic goals, and ways to use BLS in different stages depending on the reality of the SME. This respondent also shares that the exchange of information process must be mapped out so responsibilities are clear and everyone knows with whom they need to interact.

PS2: Strategic planning and PS3: Alignment both score a 0.98 RII. The distribution of the responses in both items shows that everyone but one scored the item as very important and one as important. On the other hand, PS4: Resource allocation scored a 0.6 RII, and the most frequent response was a neutral option, and only one scored as important. According to the discussion held during this part, the alignment of BLS implementation to business needs and the reality of the SME is considered a key aspect. In this sense, FGR5 adds that the application of BLS is important. The acquisition of technology to accomplish BLS goals is helpful, but technologies are only tools that allow the SME to deliver projects with the specifications set by the client, so in the end, the BLS application depends on what they want to achieve, but also on what the business can support and offer. FGR5 also agrees that the future requirements will make SMEs build better and more efficiently, so they need to be ready to align what they are offering to the future industry demands. FGR2 also supports this comment and identifies that in terms of technology and tools, the application of BLS is led by the BIM application, which is more urgent. The lean and sustainability features have been viewed as the positive impact of the successful BIM application. However, they need to be planned and aligned to the organisation's needs and objectives. In the current scenario, they should be the increase in productivity, increased quality, increased efficiency, less wasteful processes, and fewer environmental impacts.

PS4: Resource allocation scored 0.6 RII, and the distribution of responses shows this aspect is considered medium importance.

PC1: Culture change scored a 1.0 RII, meaning that every respondent gave it the maximum importance score, while PC2: Client experience in BLS scored 0.93 RII and PC3: early contractor involvement scored 0.70 RII.

FGR1 briefly mentions that PC3 is seen as a positive way to reduce the inefficiency levels the industry is known for and supports the idea that bringing the contractor early in the process, seen from the contractual point of view, should be considered and reflected in the contract. This is because it is necessary to build trust and communication from both parties for this agreement to work. In this sense, FGR6 adds that bringing the contractor early in the process would guarantee waste reduction and sustainability, consistent with applying lean methods. This links to the PI3: Clear BLS policy scores 1.0 RII. The participant describes that a more integrated way to project delivery should be suggested and acquired broadly in the industry rather than the traditional lump sum method, which is still the current scenario. The lump-sum method does not promote collaboration, and it encourages individual goals and interests, which is the total opposite of where the industry is moving towards. FGR8 adds to this discussion that moving away from this traditional project delivery and adopting more integrated methods should improve the current flow of information to a simpler communication (PI1 score of 0.88 RII) and collaboration (PI2, score of 1.0 RII) between the different project parties.

In this sense, it is also mentioned that the client's experience in BLS is a key enabler for organisational adoption and acceptance of the practices because it is believed that an experienced client would promote these practices, incurring less unexpected changes with knowledge of the goals. FGR6 argues that this is a complete cultural change not only in the construction industry but also at the SMEs' organisational level.
Finally, PI4 controlling and monitoring 0.68 RII. There were no major comments on this factor.

6.2.2 Human and attitudinal factors focus group results

Figure 6.2 shows the summary of the findings in the human and attitudinal category. For more details, the full results can be found in annex 3.

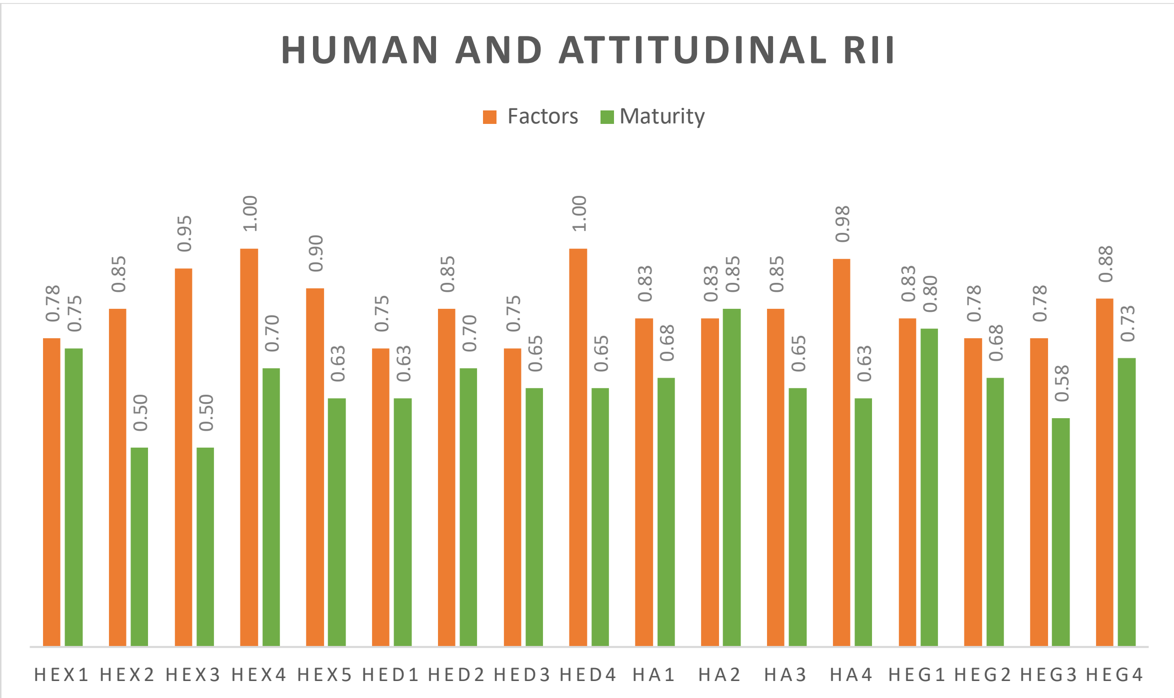

Figure 6.2 Focus group results in the human and attitudinal category

From figure 6.2 above, all the factors discussed are above 0.75 RII, while the current maturity levels are below in every factor except HA2, Awareness.

During the focus group, the discussion in this category was quick, and the respondents agreed that these are all important factors.

For example, a comment was made by FGR7 in terms of the HEX3: champion, 0.95 RII, who adds that a champion role in leading attitudinal and behavioural change (HA1; 0.83 RII) is highly necessary to promote the use of BLS practices and the focus should be on finding someone with very good technical abilities, but most importantly with excellent interpersonal and soft skills to promote the implementation by engaging people (HEG1; 0.83 RII) and stakeholders (HEG3; 0.78 RII), showing leadership attributes and by having people motivated (HA3; 0.85 RII).

FGR3 adds that this person in charge of championing the process will help increase awareness (HA2; 0.83 RII) of the forthcoming changes, and the designation of roles (HA4; 0.98 RII) that people will have in the process should also be determined by this person. In this sense, FGR1 shares that there is a champion role in their SME, and the person fulfilling the role is more technical-focused. Although FGR1 agrees with FGR7 and FGR3 on the soft skills attributes, FGR1 thinks that sometimes more technical people are needed in the role, and it depends on the organisation’s goals and the clients’ requirements. FGR1 shares that in their SME, the focus is on adding more information and analysis to their models, so the people in charge of the process are more focused on that aspect. The key is to find someone who leads the implementation process and possesses technical and soft management skills who can help organisations in their transition.

In terms of HEX1 Competencies of top staff, 0.78 RII; HEX2: Skills, 0.85 RII; HEX4: Understanding of the BLS concepts, 1.0 RII and HEX: Qualified staff, 0.9 RII, the respondents think that all of these are relevant and relate to the HED4 factor: Training, 1.0 RII. This item has been agreed upon as one of the most important aspects to promote BLS practices in the construction industry in Chile. FGR5 shares that providing people with the right tools to perform a job is required for any implementation to be successful in the long run, promoting continuous improvement as long it is sustained and promoted by the organisation’s leadership. In applying BLS practices, the respondents share that

experience in the construction industry is important, but it is more important to have delivered projects under the BLS methodology. For that reason, FGR5 acknowledges that in their personal experience, the use of BIM is just starting, so the organisation, to be competent, needs to run full BIM projects before calling itself a BIM oriented organisation. The same situation can be said about lean, in which the experience is vast, and sustainability, in which the experiences are slightly less. FGR5 argues that people need to increase and develop (HED3, 075 RII) their capabilities and abilities in the BLS methods to guarantee that consistency. Proper training is required to increase the understanding levels, education (HED1, 0.75 RII) and knowledge (HED2, 0.85 RII).
Finally, in the engagement category factors HEG1: People management, 0.83 RII; HEG2: People support, 0.78 RII and HEG4: Teamwork, 0.88 RII, no extra comments were made.

6.2.3 Technology factors focus group results

Figure 6.3 shows the summary of the findings in the technology category. For more details, the full results can be found in annexe 3.

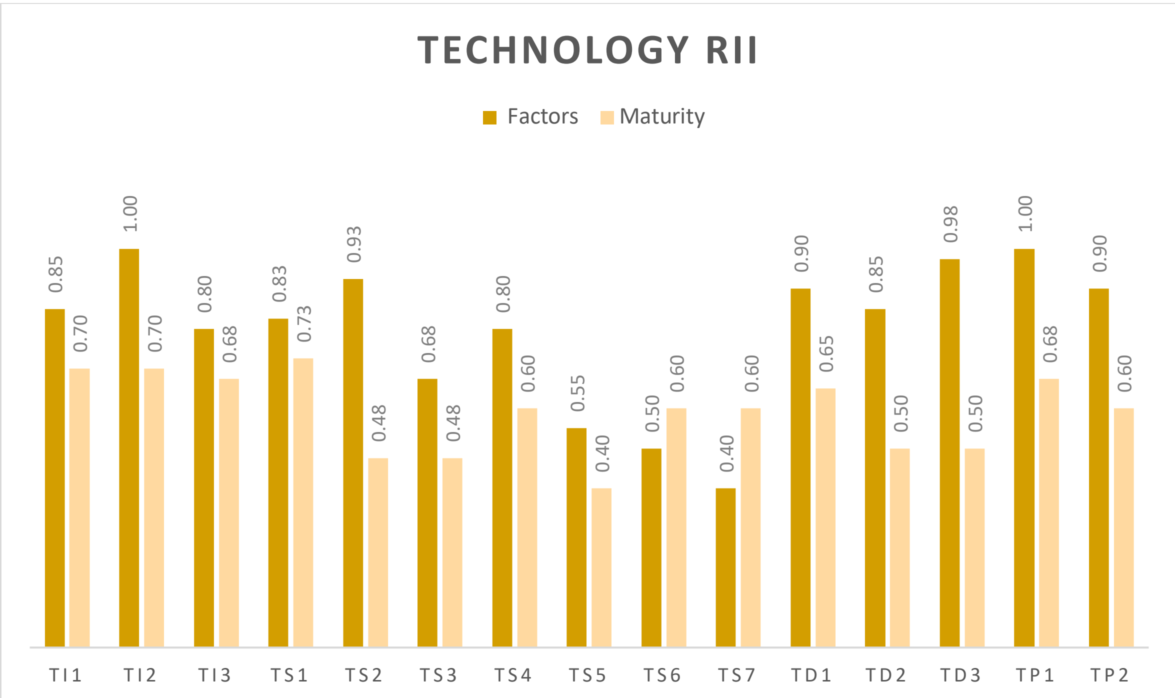

Figure 6.3 Focus group results in the technology category

From figure 6.3 above, all the factors discussed score above the 0.5 RII while the current maturity levels are below in all the factors except the TS6 factor: Design errors and TS7 factor: less paperwork. During the focus group, the discussion in this category was again quick, and the respondents agreed that these are all important factors to promote BLS maturity.

In the infrastructure category, TI1: Appropriate hardware, 0.85 RII; TI2: Capacity to implement tools, 1.0 RII; and TI3: Infrastructure, 0.80 RII are all important, scoring above the 0.8 RII. In this part, the capacity to implement tools from the organisation scored the highest RII since FGR1 argues that technology is a driver for innovation, and SMEs need an analysis of their capacity to implement technology that would enable them to achieve BLS targets. There should be an analysis of existing equipment and project the purchase of new technologies to support the implementation, especially the BIM part. In the FGR1 case, new equipment was purchased because the existing ones did not meet the minimum software requirements in terms of RAM and graphic card. So appropriate hardware (TI1, 0.85 RII) is required for such purposes. For that reason, it has been discussed that a policy (TP1, 1.0 RII) must include this expenditure part to support the transition because the systems put in place need upgrading or renewing every certain period. In this sense, FGR2 agrees that a good policy should be incremental because the change towards BLS, as discussed previously, needs to be gradual, and that needs to be clearly shown. Hence, everyone understands the steps that are required and include aspects such as hardware and software (TS1, 0.83 RII), but also it should be clearly stated the need for training mentioned in the previous discussion and everything related to the technology changes that are required to promote BLS.

The rest of the factors in the software subcategory TS2: Interoperability, 0.93 RII, TS3: Tech support, 0.68 RII; TS4: Compatibility, 0.80 RII; TS5: Constructability, 0.55 RII; TS6: Design errors, 0.50 RII and TS7: Less paperwork, 0.40 RII, are mentioned as important but the factors TS5, TS6, TS7 were considered not as important as the others to establish organisational maturity towards BLS. The explanation came from the discussion where FGR4 shares that achieving maturity in constructability depends on the effective use of technologies that will directly impact other aspects such as efficiency in the designs that will lead construction SMEs to build better. Therefore, improving constructability will depend on how well the organisation applies BLS technologies, which comes by achieving maturity in the other factors discussed. Constructability is a consequence of applying effective BLS. The same situation happens with reducing design errors, the efficiency in digitalisation and the use of less paperwork.

The TS2: Interoperability, 0.93 RII and TS4: Compatibility, 0.80 RII factors have been agreed to be important because the exchange of information (TD1, 0.9 RII) needs to be efficient (TD2, 0.85 RII), and it is dependable on how well the technologies are being applied by companies in the construction industry in Chile because according to FGR3, most of the ones working with their SME, are still relying on the use of CAD but moving to the use of a popular BIM software of the same provider, so interoperability should not be an issue. All the participants have agreed with this statement. Finally, TD3: Data security, 0.98 RII and TP2: Standards, 0.90 RII were agreed as important, and no more comments were made on these factors.

6.2.4 Management factors focus group results

Figure 6.4 shows the summary of the findings in the management category. For more details, the full results can be found in annexe 3.

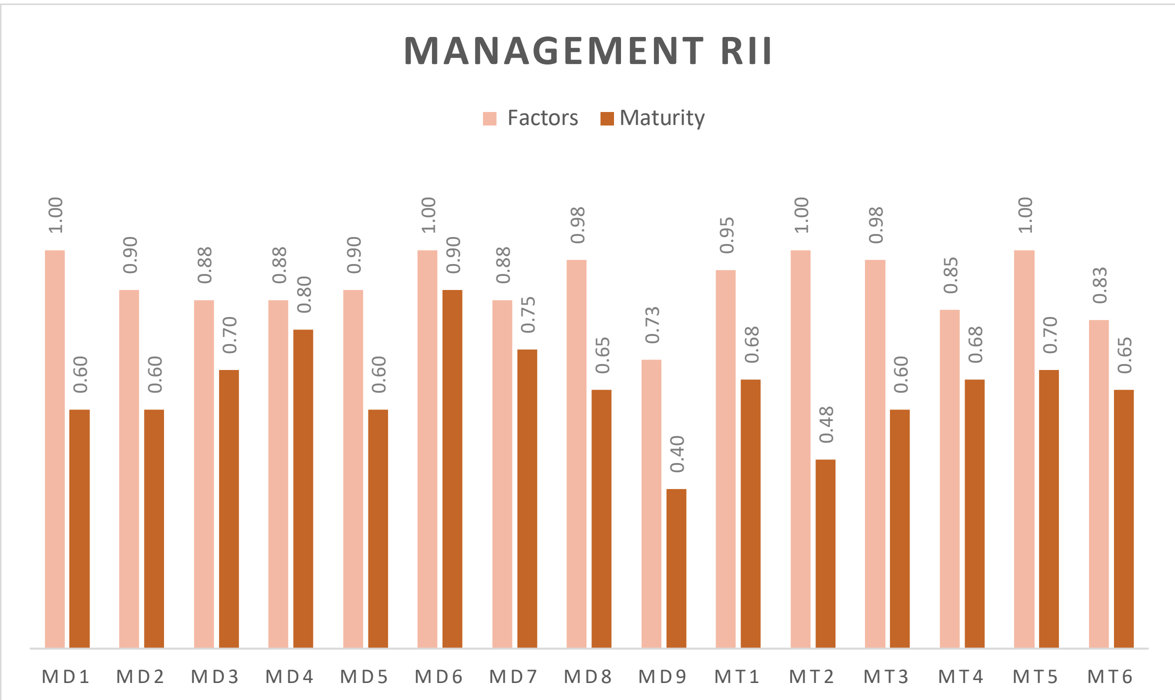

Figure 6.4 Focus group results in the management category

From figure 6.4 above, all the factors discussed score above the 0.7 RII, while the current maturity levels are below the proposed factors.

The highest scores come from MD1: Leadership and MD6: Commitment to change from top management, scoring 1.0 RII.

In this sense, implementation of BLS practices has been argued by FGR4 and FGR5 as a process in which leadership plays a vital role since the ones in charge of leading the implementation must be able to translate the mission and vision (MD3, 0.88 RII) from the organisation towards the adoption of BLS practices. The respondent also shares that leadership is about engaging people and motivating (MD2, 0.9 RII) them to embark upon the transformation process, so motivation is an aspect that depends on how well leadership is established.

FGR5 argues that this long strategic vision should be emphasised over the short-term project vision that is currently the practice. According to the respondent, this vision needs to come from the top management (MD4, 0.88 RII). It needs to clearly establish the elements of the transformation, such as goals, purpose, and stages and where the SME is moving by applying BLS. The top-down approach is mentioned because the leadership, strategy, and decisions to promote BLS practices must come from the top-level and align them to support business needs, plus people at the top are the ones who know how the business is running, the resources available, and what it needs to keep running, FGR5 adds. The respondents scored the top-down approach highly favourable, but they also considered a bottom-up approach (MD5, 0.9 RII) to promote the transformation process. FGR1 suggests that the bottom-up approach is also a factor to consider because the best way, according to their experience, to promote full integration is to receive feedback from the lower levels to the top on how the practices operate since they are the ones that will be using it on a regular basis, so the top levels can take more informed decisions when needed.

The commitment from the top to change (MD6, 1.0 RII) and management support (MD8, 0.98 RII) are connected, as discussed by the respondents. Commitment to change is related to the vision of where the decision-makers want to position their SME in the future, and the management support is because it is expected that the process takes some time to reach maturity. Therefore, the commitment to keep moving the business forward and not revert to well-known old practices will require commitment, especially as FGR7 adds, when the economic impacts of the process may take some time to see results.

Finally, in this subcategory, subcontractor commitment (MD9, 0.73 RII) and Flexibility (MD7, 0.88 RII), the respondents suggested that the organisations must be flexible to adapt to new requirements and the commitment from the entire construction industry, including subcontractors, is required to meet the requirements established by the government.

In the transition subcategory MT2: Resistance to change, 1.0 RII and MT5: Align (Organisation objectives), 1.0 RII were considered very important by all the respondents, closely followed by MT3: Risk Management, 0.98 RII and MT1: Planning, 0.95 RII. Finally, MT4: Adaptability, 0.85 RII and MT6: Management of information, 0.83 RII were the last set of factors in this subcategory scoring above the 0.8 RII.

There were no major comments in the transition category. FGR4 shared that resistance is overcome by having clear goals and objectives, clear communication, and assigning responsibilities to people, especially those identified as "resistants" or those that were not motivated by the changes, to make them feel part of the process. FGR1 shares that a risk management plan is required to assess the potential risk associated with implementing and adopting new processes. In addition, this transition should not bring any extra risks to existing projects if everything is planned and closely monitored and controlled. In this sense, the same respondent adds that other than technical risks associated with the adoption of technologies to comply with the BLS plan, the human and attitudinal aspects were the most important risk that could be identified. This is because of the new skills that need to be adopted that could detriment the organisation's deliverables. FGR1 shares that when adopting and promoting BIM, errors, omissions, and clashes still occurred even by using BIM software due to the novelty of the tools for staff members, causing, on some occasions, a lack of trust in the system.

6.2.5. Economic factors focus group results

Figure 6.5 shows the summary of the findings in the economic category. For more details, the full results can be found in annexe 3.

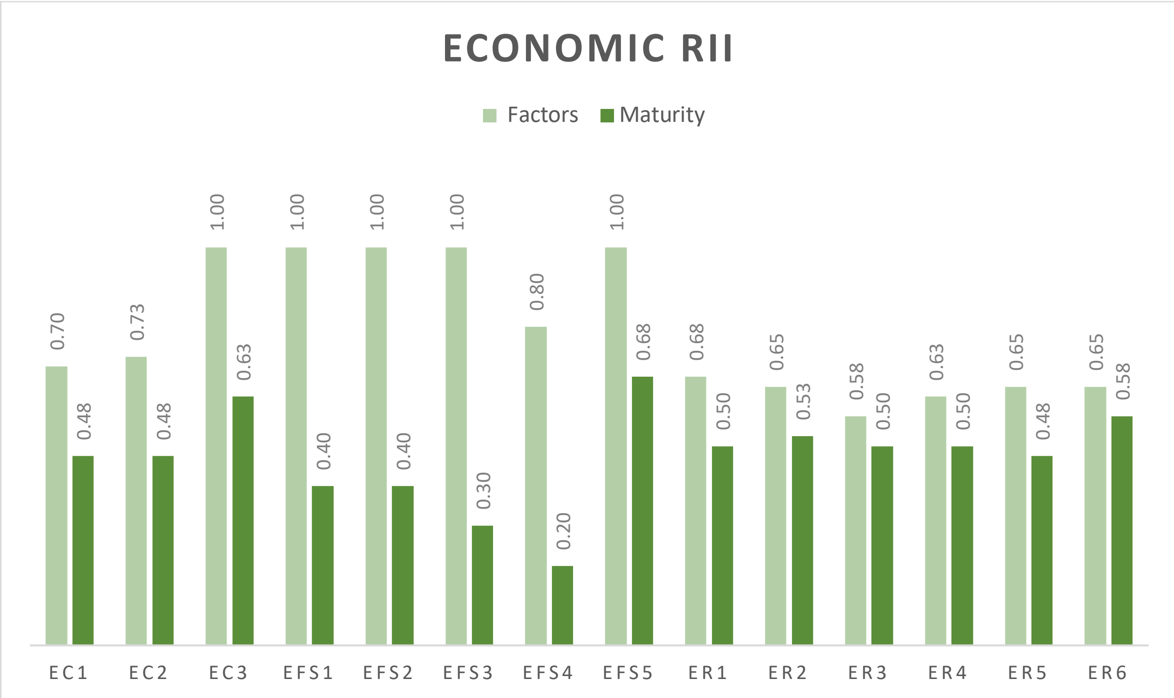

Figure 6.5 Focus group results in the economic category

From figure 6.5 above, all the factors discussed score above 0.5 RII, while the current maturity levels are below the proposed factors.

The most important factors in this category scoring all a 1.0 RII are EC3: Implementation cost; EFS1: Financial support; EFS2: Incentives; EFS3: Subsidies and EFS5: Market demand for BLS deliverables. The other factors are EFS4: Return on investment (ROI), 0.80 RII; EC2: Cost reduction, 0.73 RII and EC1: Cost control, 0.70 RII.

FGR3 argues that the demand for BLS requirements is increasing, especially those focused on BIM and sustainability. This has also been a driver for organisations to change their strategy to tackle how the market is moving and what it is currently demanding and will demand in the future. The respondents agree that the market is still young in the BIM and sustainability area, and it is more experienced in applying lean methods. They all agree that a step in the right direction would be to prepare their organisations to deal with these requirements since they foresee that more clients will ask to provide the use of BLS practices to some extent once they become more aware and mature in their use. The government strategy has helped raise awareness among the industry players, and for that reason, SMEs need to be prepared to deliver. During the discussion, the respondents made clear that most of their clients were aware of the use of BIM and lean; however, the sustainability awareness was low compared with the other two.

Implementation cost was also a topic that was mentioned as an important barrier to adopting BLS. In this sense, the respondents shared that there is no option but to adopt the changes to keep participating in the market that is demanding other requirements, and to some extent, FGR8 shares that in their SME, they had to control costs in other areas to direct resources to the BLS strategy. The respondents discussed that training and the cost of software, and the acquisition of new hardware in some cases, were the most expensive areas that needed addressing. In this sense, the respondents value government support regarding subsidies (EFS3) to provide training. However, it is believed that more incentives (EFS2) are needed for organisations to commit to the changes fully. In this sense, it is argued that the internal incentives from the organisation such as payment for training courses or prizes to the members of staff that excel in the acquisition of knowledge can also boost the morale and encourage people to learn, but whatever the incentive is, it is important to make sure that people are willing and motivated to adopt new practices. Therefore, financial support (EFS1) is essential to implement BLS, considering that ROI is not immediate, as mentioned in earlier sections.

The next set of factors, ER1: Increased competitive advantage; ER2: Increased value; ER3: Productivity improvement; ER4: Quality improvement; ER5: Resource optimisation, ER6: Increased economic performance scored over 0.58 RII but less than 0.7 RII, and the range of responses were diverse. The discussion and the consensus are that these factors are not important when considering evaluating SMEs' maturity and should be seen as benefits and a consequence of the efforts to promote the BLS adoption at the organisational level. This reflects that the organisation's preparedness to adopt BLS is more important than obtaining immediate results. Although it is important to obtain short-term results, the respondents commented that how well the organisation is prepared to deliver those results should matter most. If it is sorted and well defined, good results are more likely to be obtained.

6.3 Focus group summary

The focus group's main points are summarised as follows:

1. The factors derived from the case studies and the literature review scored high average values and high RII values, which means that they are significant and are validated by the focus group participants, with some exceptions explained in the next paragraph.
2. Some factors were not considered important and were not relevant to assessing organisation's maturity to adopt BLS. These include TS5: Constructability; TS6: Design errors and TS7: Less paperwork in the technology category and the ER1: Increased competitive advantage; ER2: Increased value; ER3: Productivity improvement; ER4: Quality improvement; ER5: Resource optimisation, ER6: Increased economic performance factors in the economic category. These factors were considered benefits from implementing BLS but still were scored, so they are suggested to be discarded since they do not represent organisational maturity.
3. In implementing BLS, the respondents think that the main driver is the BIM adoption that will enable lean and sustainability more easily. The preparation of the organisations to implement BIM is found to be similar at the organisational level to promote sustainability and lean. The difference is in the methods and tools to apply lean and sustainability, but the organisational strategy in terms of leadership and preparedness to promote change, as identified in the study, should give SMEs enough information to comply with the BLS industry requirements and objectives.
4. The focus group shows that the BLS factors' maturity levels are still low, and the transition to adopting these practices is still a work in progress. The individual efforts to adopt BLS from the SMEs are valuable, but to achieve

the goals of the global construction industry in which SMEs are vital. Individual efforts are not enough if they are not sustained, which is shown in this study. Isolated efforts to apply BLS do not mean that those organisations comply with the application.

6.4 Final BLS framework

Based on the focus group results and the validation of the factors, the final framework is presented below in figure 6.6. The corrections were made and show a variation compared to the proposed BLS factor presented in chapter 5. As explained in the previous section, the main changes suggested are removing the factors that were not considered important in assessing maturity.

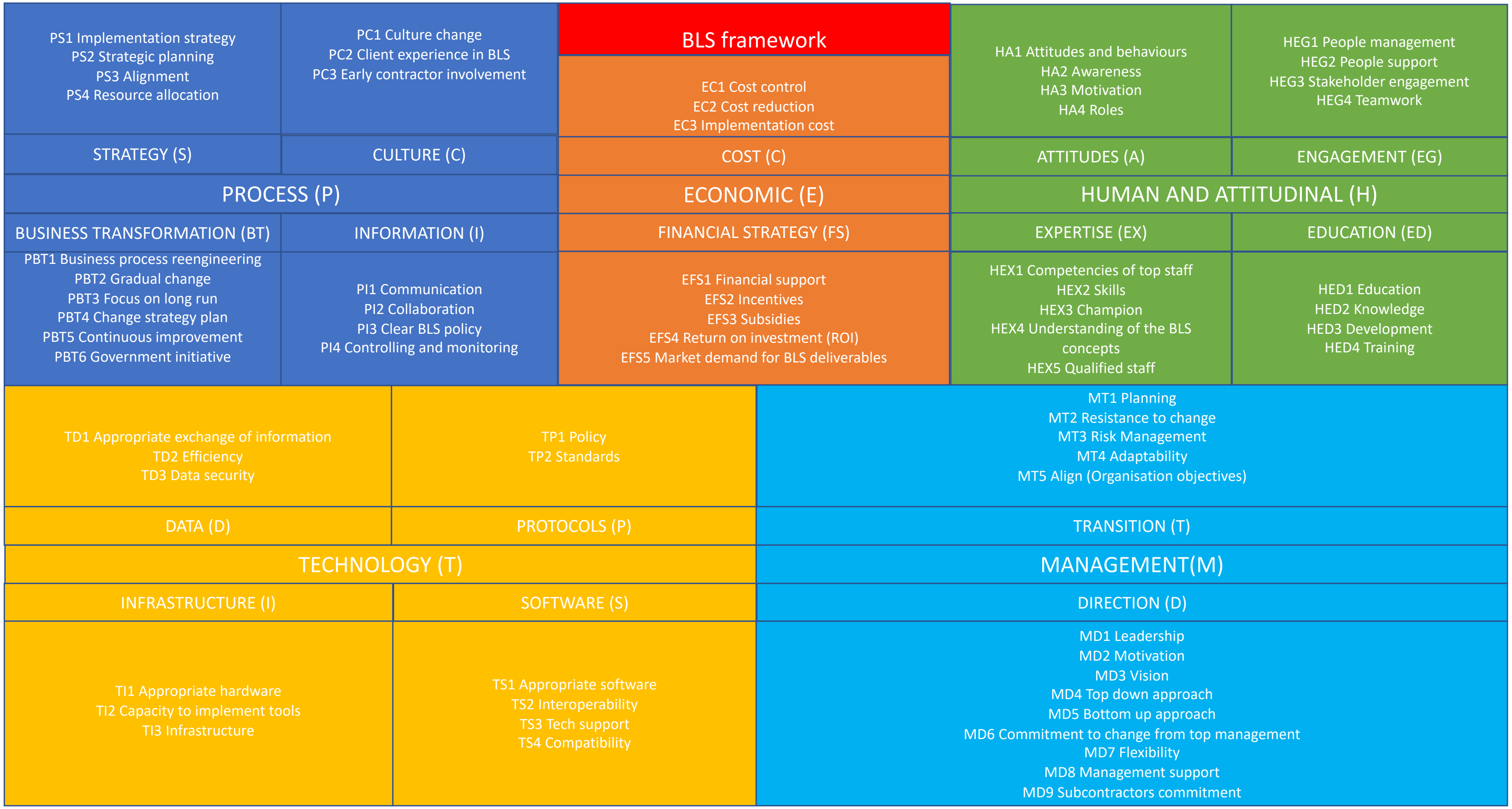

Figure 6.6 Final BLS framewor

6.5 Summary

This chapter discusses the validation of the BLS framework by engaging a focus group technique that analyses and discusses the findings from the previous chapters to present the final version of the BLS framework, which accomplished the main objective of this research. The discussion led to modifying the initial framework presented in chapter 5 to the one presented in this chapter. The factors that were not considered important and were not relevant to assessing organisation’s maturity to adopt BLS included TS5: Constructability; TS6: Design errors, and TS7: Less paperwork in the technology category, and the ER1: Increased competitive advantage; ER2: Increased value; ER3: Productivity improvement; ER4: Quality improvement; ER5: Resource optimisation, ER6: Increased economic performance factors in the economic category.

The final BLS framework consists of five main categories: Processes, human and attitudinal, technology, management, and economic factors and a total of 69 factors are distributed in these categories.

The next chapter presents the conclusions and recommendations of this study, along with suggestions for future research.

Chapter 7 Conclusions and recommendations for future work

In this final chapter, the conclusions of the study are presented along with recommendations and suggestions for future research to enhance knowledge in the area and encourage future researchers to improve and apply this study to different contexts. The research objectives are reviewed, and the process of accomplishing those objectives is presented as well, along with the limitations and weaknesses of the adopted method.

7.1 Research overview

This study is developed by first carrying out a literature review to determine knowledge of the current issues that the Chilean construction industry faces to develop the research problem, aims and objectives. As explained in the introduction chapter, the Chilean construction industry faces many challenges, and it has established a report whose goals are to reduce the inefficiencies levels it is known for. BIM, lean, and sustainability have been identified as a solution to increase productivity levels and comply with the global construction industry requirements of a more digitalised, sustainable, and efficient industry. The gap found is that no current maturity frameworks promote the use of BIM, lean and sustainability in conjunction applied to the organisational levels in SMEs. This problem led to the development of the research aim and objectives applied to contractors' SMEs in Chile to narrow down the scope of this study. The development of the objectives is derived from this initial literature review and are presented as follows:

1. Critically review the concept of BIM, lean, and sustainability in the existing literature, focusing on their concepts, synergies and linkage, requirements usage and success factors.
2. Critically review existing maturity frameworks to understand their concepts, usage, and components.
3. Explore the BLS implementation efforts in SMEs in Chile.
4. Identify the maturity factors to enable BLS implementation.

5. Develop a conceptual framework derived from the results derived from objective 4.
6. Validate and refine the conceptual framework from objective 5 to establish the organisational maturity BLS framework.

After that process, a second stage of the literature review was undertaken to detail and further justify the topic's selection. It also assisted in developing the theoretical BLS framework. The context of the literature review was first set in the specific Chilean case to understand and learn the topics from that perspective. Later, the review moved to a wider approach to learn from the broader available literature on the topics to answer specific objective one and the literature review on maturity models and readiness assessment to propose the theoretical framework and answer the specific objective two. The purpose of reviewing maturity and readiness assessment models was to explore existing attempts from researchers and to be able to identify the areas that the BLS framework could develop. The process led to identifying factors by clearly understanding the areas that needed exploring. This step helped identify five categories and clarified the employed research methodology.

A literature review was again undertaken to determine and justify the most suitable way to develop this study in the research methodology. A qualitative approach is established given the nature of the study, which involves using case studies as a data collection strategy. The research methodology in full can be seen in figure 1.1 in chapter 1. The unit of analysis for the case studies was top and middle managers due to the aim of the BLS framework to be developed and implemented at the organisational level. In this research, three different SMEs took part in the study, identified as SME1, SME2, and SME3. Three different members for each SME were identified, so the total number of people who participated was nine. This process was done to provide answers to specific objectives three and four, where the current implementation efforts regarding BLS were explored, and the factors that enable maturity towards BLS at the organisational level were determined. This process was done by using a semi-structured interview technique. The data analysis was done by transcribing the recorded ones and taking notes on the ones that were not. Content analysis was performed to find patterns that were put into the tables presented in chapter 5. Once that process was finished, a literature review was carried out to justify the answers provided by the respondents and to make sense of their responses with support of the existing literature, which allowed the researcher to propose the BLS conceptual framework shown at the end of chapter 5. The number of identified factors was 78, put into different categories, pending validation. Validation of these findings was by carrying out a focus group technique in which the participants gave their views on the framework and provided scores on the factors found in the case studies. In this opportunity, the respondents provided the level of importance to the factors ranging from 1, lowest importance to 5, highest importance level, and provided answers to the current level of maturity regarding these aspects. The answers were analysed using the relative importance index (RII). In the discussion, there was agreement that some of the factors were not important to determine maturity, so in the end, the recommendation was to discard them. Finally, the final version of the BLS framework is presented, consisting of 68 factors.

7.2 Conclusions of main findings

The aim of this study is to develop an organisational maturity framework to assess BIM, lean, and sustainability (BLS) implementation in construction SMEs in Chile. To achieve this aim, six specific objectives were determined, which are concluded as follows:

Objective 1: Critically review the concept of BIM, lean, and sustainability in the existing literature, focusing on their concepts, synergies, and linkage.

This objective was discussed in chapter 2 of the literature review. The Chilean government has suggested BIM, lean, and the focus on sustainability as approaches to improve the efficiency of the construction industry. The government has set a report including these initiatives as suggestions for organisations to comply with the established requirements. However, there are no frameworks, guidelines, or approaches on how to apply them in conjunction. In addition, the literature suggests that these three approaches are synergistic and can be integrated to promote improvements. However, there are no frameworks promoting integration. The literature search also suggests that the application of these initiatives fails because they are not well immersed in the organisation and have been used mainly in projects, bringing benefits but not sustained through time. For that reason, the proposal of establishing maturity at the organisational level because it is thought that once they are integrated at this level and once maturity is reached, the full benefits can be reached. Studies in the literature show that SMEs are neglected in this aspect, and the focus is usually on big companies with resources to carry out implementation efforts. For that reason, the proposal of studying SMEs is also suggested.

Objective 2: Critically review existing maturity frameworks to understand their concepts, usage, and components.

In chapter 2, different maturity frameworks were presented to understand their usage and to take inspiration to build the BLS framework. Twenty-three models were reviewed, focusing on different aspects, not necessarily BLS focused, to learn from a successful application. Common features could be established from this process, which allowed the development of the components that needed to be explored. In this part, the theoretical composition of the BLS framework was derived from analysing literature on existing maturity frameworks to have a foundation on what to consider when populating the BLS framework. The data from the case studies served as the basis of the elements considered in the BLS framework. Therefore, the literature review on existent maturity models was done to develop the aspects that needed exploring applied to SMEs in Chile, and the factors were derived from the results of the case studies.
This part is done to assess the gap organisations may have in implementing BLS in terms of maturity. The idea is that organisations can assess their gaps towards BLS-oriented objectives and put their efforts into improving the gaps found, promoting continuous improvement, and understanding the implementation requirements needed, which for this research are the factors found in the case studies.

Objective 3: Explore the BLS implementation efforts in SMEs in Chile
This objective was explored in chapter 4, where the current level of BLS implementation was assessed for each SME. SME1 has applied lean in their projects with different levels

of success, but mostly with positive results, and they have recently appointed a BIM specialist to carry out the BIM implementation process. SME2 has delivered a project with BIM protocols, and the use of lean is extensive, with different levels of success in their projects. The organisation is fully committed to the sustainability theme and has developed a plan to follow the strategy set out by the Chilean government. Finally, SME3 is transitioning towards the adoption of BIM. In the case of lean, they have applied it in the past in a couple of projects, but it is not mandatory. Sustainability is a priority, and they are developing plans to deliver more projects with these characteristics.

SME2 is the most advanced in terms of BIM application since they have piloted one project, while SME1 is in the process of implementing BIM, and SME3 is starting to transition towards its adoption but at very early stages. In the case of lean, the three SMEs have applied lean tools in their projects with different levels of success and with no consistency in their application. Finally, the sustainability requirement is something that the SMEs value, but only initial and very early days plans are in consideration.

Objective 4: Identify the maturity factors to enable BLS implementation.

This objective was accomplished by obtaining from the case studies the factors identified by the respondents of each SME. The discussion of these results is found in chapter 5. Table 7.1, shown below provides the summary of the factors and their respective categories.

Table 7.1 Summary of the factors and their respective categories.

Category	Factors	SME1	SME2	SME3
Process	Alignment to strategy	✓✓	✓✓	✓
	Business process reengineering	✓✓✓	✓✓✓	✓✓✓
	Change strategy plan	✓✓	✓✓	✓
	Clear BLS policy	✓✓	✓✓	✓✓
	Client experience in BLS	–	✓✓	–
	Collaboration	✓✓	✓✓	✓✓
	Communication	✓✓✓	✓✓	✓✓

	Continuous improvement	–	✓	✓
	Controlling and monitoring	✓	✓	–
	Culture change	✓✓	✓✓	✓
	Early contractor involvement	✓	✓	✓
	Focus on long run	✓✓	✓✓	✓✓✓
	Government initiative	✓	✓✓	✓✓
	Gradual change	✓	✓	–
	Implementation strategy	✓	✓✓	✓
	Optimise resource allocation	✓	✓	✓
	Strategic planning	✓	–	✓
Human and attitudinal	Attitudes and behaviours	✓✓	✓✓	✓✓✓
	Awareness	✓	✓	✓
	Champion	✓	–	✓✓
	Competencies of top staff	✓	✓✓	✓✓
	Development	✓	–	–
	Education	✓	✓✓	✓✓
	Knowledge	✓	✓✓	–
	Motivation	–	✓✓	✓
	People management	–	–	✓✓
	Qualified staff	✓✓✓	✓✓✓	✓✓✓
	Roles	✓✓	✓	✓✓
	Skills	✓✓	✓	✓
	People support	✓	✓	–
	Stakeholder engagement	✓✓	✓✓✓	✓

	Teamwork	✓✓	✓✓	–
	Training	✓✓	✓	✓
	Understanding of the BLS concepts	✓✓	✓✓	✓✓✓
Technology	Appropriate exchange of information	✓✓	✓	✓✓
	Appropriate hardware	✓✓✓	✓✓✓	✓✓✓
	Appropriate software	✓✓	✓✓✓	✓✓
	Capacity to implement tools	✓✓	✓✓	✓✓
	Compatibility	–	✓✓	✓
	Constructability	✓	✓	✓
	Data security	✓✓	✓✓	✓✓
	Design errors	✓	✓✓	✓✓
	Efficiency	✓	✓✓	✓
	Infrastructure	✓	✓	✓
	Interoperability	✓	✓	✓
	Less paperwork	–	✓	✓
	Policy	✓	✓✓	✓✓
	Tech support	✓✓	✓✓	✓✓✓
	Standards	✓✓	✓	✓
Management	Adaptability	✓	–	✓✓
	Align (Organisation objectives)	✓	✓✓	✓✓
	Management of information	✓✓	✓	✓✓
	Bottom up approach	✓	✓✓	✓✓
	Commitment to change from top management	✓	✓✓	✓✓

	Flexibility	✓	✓	✓✓
	Leadership	✓✓✓	✓✓✓	✓✓✓
	Management support	✓	✓	✓
	Motivation	✓✓	✓✓	✓✓
	Planning	✓	✓	✓
	Resistance to change	✓✓✓	✓✓✓	✓✓
	Risk Management	✓✓	✓✓	✓
	Subcontractors commitment	✓	✓	✓✓
	Top down approach	✓✓	✓✓	✓✓
	Vision	✓	✓	✓
Economic	Increased competitive advantage	✓✓	✓✓✓	✓
	Cost control	✓	✓✓	✓
	Cost reduction	✓✓	✓	✓
	Financial support	✓✓	✓✓	✓✓
	Implementation cost	✓✓✓	✓✓	✓✓✓
	Incentives	✓✓	✓✓	✓✓
	Increased economic performance	✓	✓✓	✓
	Increased value	✓✓	✓	✓
	Market demand for BLS deliverables	✓✓✓	✓✓✓	✓✓✓
	Productivity improvement	✓✓	✓✓	✓✓
	Quality improvement	✓✓	✓✓✓	✓✓
	Resource optimisation	✓✓	✓✓	✓✓

	Return on investment (ROI)	✓✓	✓✓	✓✓ ✓
	Subsidies	✓✓	✓✓	✓✓

Objective 5: Develop a conceptual framework derived from the results from objective 4.

This objective is accomplished by cross analysing the contents of objectives 3 and 4. The factor found were discussed in chapter 5 to understand their implications and to further justify them with the current literature. After cross analysing the data from the interviews, patterns were found, which are reflected in table 7.1 above. The conceptual framework with the data from the case studies is presented in figure 7.1 below.

BLS framework			
	Subcategory	Code	Factors
Process (P)	Business transformation (BT)	PBT1	Business process reengineering
		PBT2	Gradual change
		PBT3	Focus on long run
		PBT4	Change strategy plan
		PBT5	Continuous improvement
		PBT6	Government initiative
	Strategy (S)	PS1	Implementation strategy
		PS2	Strategic planning
		PS3	Alignment
		PS4	Resource allocation
	Culture (C)	PC1	Culture change
		PC2	Client experience in BLS
		PC3	Early contractor involvement
	Information (I)	PI1	Communication
		PI2	Collaboration
		PI3	Clear BLS policy
		PI4	Controlling and monitoring
Human and	Expertise (EX)	HEX1	Competencies of top staff
		HEX2	Skills
		HEX3	Champion
		HEX4	Understanding of the BLS concepts

		HEX5	Qualified staff
	Education (ED)	HED1	Education
		HED2	Knowledge
		HED3	Development
		HED4	Training
	Attitudes (A)	HA1	Attitudes and behaviours
		HA2	Awareness
		HA3	Motivation
		HA4	Roles
	Engagement (EG)	HEG1	People management
		HEG2	People support
		HEG3	Stakeholder engagement
		HEG4	Teamwork
Technology (T)	Infrastructure (I)	TI1	Appropriate hardware
		TI2	Capacity to implement tools
		TI3	Infrastructure
	Software (S)	TS1	Appropriate software
		TS2	Interoperability
		TS3	Tech support
		TS4	Compatibility
		TS5	Constructability
		TS6	Design errors
		TS7	Less paperwork
	Data (D)	TD1	Appropriate exchange of information
		TD2	Efficiency
		TD3	Data security
	Protocols (P)	TP1	Policy
		TP2	Standards
Management (M)	Direction (D)	MD1	Leadership
		MD2	Motivation
		MD3	Vision
		MD4	Top down approach
		MD5	Bottom up approach
		MD6	Commitment to change from top management
		MD7	Flexibility
		MD8	Management support
		MD9	Subcontractors commitment
	Transition (T)	MT1	Planning
		MT2	Resistance to change
		MT3	Risk Management
		MT4	Adaptability
		MT5	Align (Organisation objectives)

		MT6	Management of information
Economic (E)	Cost (C)	EC1	Cost control
		EC2	Cost reduction
		EC3	Implementation cost
	Financial strategy (FS)	EFS1	Financial support
		EFS2	Incentives
		EFS3	Subsidies
		EFS4	Return on investment (ROI)
		EFS5	Market demand for BLS deliverables
	Returns (R)	ER1	Increased competitive advantage
		ER2	Increased value
		ER3	Productivity improvement
		ER4	Quality improvement
		ER5	Resource optimisation
		ER6	Increased economic performance

Figure 7.1 BLS framework version 1

Objective 6: Validate and refine the conceptual framework from objective 5 to establish the organisational maturity BLS framework.

Chapter 6 discusses the results of the framework validation resulting from the focus group, which had 8 participants. The factors were validated and considered important on average. Suggestions were made to remove some of the factors found in the case studies because they were found to be not relevant to assessing maturity towards BLS implementation. These factors include TS5: Constructability; TS6: Design errors, and TS7: Less paperwork in the technology category, and the ER1: Increased competitive advantage; ER2: Increased value; ER3: Productivity improvement; ER4: Quality improvement; ER5: Resource optimisation, ER6: Increased economic performance factors in the economic category. Therefore, after this focus group, the final BLS is presented in figure 7.2.

The BLS framework presented is an organisational framework thought to be used by SMEs to assess their implementation efforts and become a BLS oriented organisation. The framework comprises five main categories and sixteen subcategories where the factors are organised accordingly. The factors are aspects that SMEs should consider to become a BLS mature organisation, increase their capability by comparing their current status and determine the gap so informed decisions and actions can be taken to reduce it. These actions include interviews, observations, etc., and other methods that the organisation deem necessary to obtain information.

7.3 Limitations

In developing this research, the following limitations were encountered.

- Lack of literature focusing on the Chilean context. The information is limited to current industry reports and some papers published by Chilean authors regarding isolated topics about the subject under study. This research contributes to that aspect by enhancing the literature focused on the Chilean industry.
- Although the literature, as presented in the methodology chapter, suggests that 3 cases studies are a good number, this research has that limitation. More SMEs

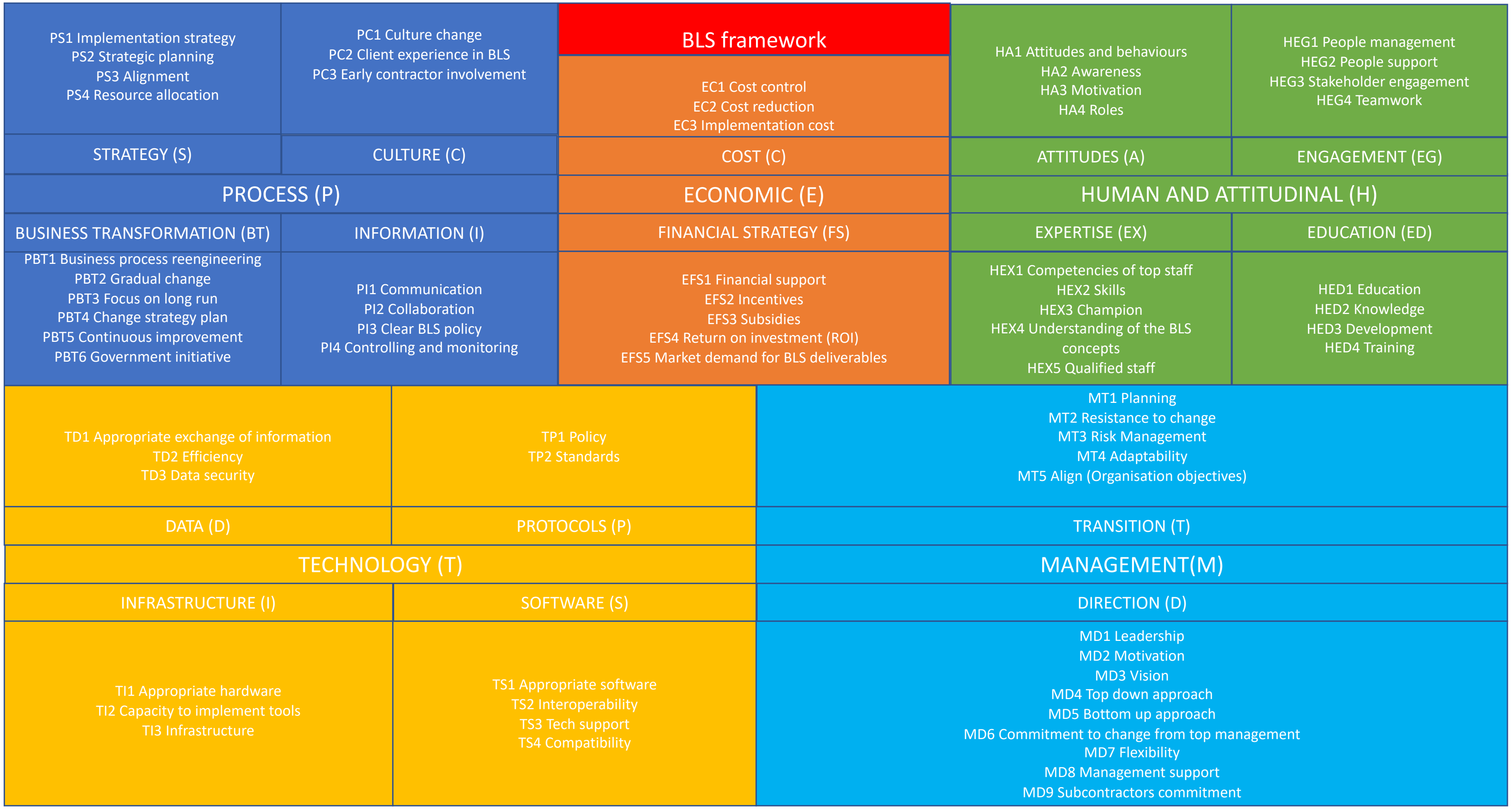

Figure 7.2 Final BLS framework

- would have been ideal, but time constraints and the scope of this research focused on BIM, lean, and sustainability was also an issue because the selected SMEs had to fulfil that requirement. Although a number higher than 3 SMEs were identified, the ones selected were the ones that in the end, were willing to participate in this study.
- The factors were identified by people who are knowledgeable in the areas and are showing interest in developing and moving their organisation practices towards these topics, so the factors found and shown in chapter 5 reflect their current experiences. This shows that the industry lacks experts in the area, and it isn't easy to find people experiencing a full BLS journey. Therefore, the results and application to other SMEs may not be as general as intended, and the assessment of factors may vary from organisation to organisation. However, the factors found and presented in this research are applicable to other SMEs and promote a very good initial idea to assess maturity.
- Time and financial constraints were found, and the negative effect of the COVID-19 situation has also impacted this research and was one of the impediments to finding more people due to lockdown and mobility restrictions.
- Lack of awareness and knowledge of the topics was also a negative factor that impacted the number of SMEs that could participate in this research.
- As mentioned before, the focus group method found difficulties finding suitable respondents due to the lack of experts. The coordination of available dates that could suit everyone was also an issue that limited the focus group to 8 respondents.
- In the focus group, the time spent on the topics was not the same for each category. For example, in the process category, more time was spent in the discussion while the time spent in the other categories was less in comparison, so the researcher had to rely on the scores when no qualitative data was given. Although it was attempted to allocate the same amount of time to each category, the discussion inevitably led to something different. In addition, a couple of respondents were more dominant than the others and, on a few occasions, led the discussion, while the others were more passive.

7.4 Contributions to knowledge

The novelty of this study is the development of the BLS organisational framework to allow SMEs to assess their maturity towards BLS adoption and thus, comply with the industry's requirements. In addition, this study enhances the knowledge of the required factors to reach maturity in the BIM, lean and sustainability integration areas. The literature says that these aspects are synergistic and work better when integrated but with no current frameworks on how to do so at this level. For that reason, the BLS is proposed to fill that gap. The context, however, is limited to the Chilean sector but with exciting prospects that someone could pick up on this study to apply it in their own context and other organisations.

In addition, this study presents the issues necessary to assess when developing a BLS adoption strategy from the contractor's perspective. In this sense, SMEs in this category, policymakers, and the government can use this framework and the issues covered to identify areas that need further development and included in the government strategy in Chile and would allow them to understand the key areas that need addressing when proposing changes. Current maturity can also be established in SMEs to give a clear picture of how the industry is moving towards achieving objectives and requirements. Roadmaps can be established to form a clear path on how to accomplish the industry's targets.

7.5 Recommendations for future research

Recommendations for future work are provided to improve the BLS framework and validate it worldwide in the broader construction industries. A global framework would be an exciting proposition. This research's scope can be broadened to include other construction industry stakeholders, including design consultants and owners. In addition, this study was developed by involving three case studies and a focus group including eight respondents. Therefore, to refine and generalise the results, a wider audience can be included by administering a survey to obtain more views on the subject by using the factors found in this research as a baseline.

A further exploration area would be to use the factors to quantify their use and their importance in achieving BLS targets so that more research areas can be derived from this approach.

BIM, lean and sustainability integration is a new area that needs more research to expand its use in theory and practice. This research was proposed at the strategic organisational level, so further research may be focused on other areas such as how BLS work when applied in projects and how its application can be quantified to measure the construction industry targets of increasing effectiveness, productivity, and the reduction of environmental impacts.

In addition, the BLS framework is expected to be handed to SMEs aiming to promote BLS practices in their organisations. The next step is to use government contacts to help deliver this framework to as many SMEs as possible. Given that the Chilean construction industry aims to improve efficiency and sustainability by promoting BLS practices, the logical step would be diffusion which can be done by engaging official government institutions and through academic publications. Before the submission of this thesis, two papers have been published related to this subject (See annexe 4). The BLS framework shown in this research is derived from the experiences of a selected organisation sample, and the idea is to collect more information to feed the framework further by using surveys to increase the target population. This exciting scenario could help the BLS framework identified in this study become an official framework for organisations led by the government.

References

Abdelhamid, T.S. (2004). The self-destruction and renewal of lean construction theory: a prediction from Boyd's theory. 12th Annual Conference of the International Group for Lean Construction, Helsingør, Denmark (2004).

Abidin, N.Z., Pasquire, C.L. (2007). Revolutionize value management: A mode towards sustainability. Int. J. Proj. Manag. 25, 275–282.

Achanga, P., Shehab, E., Roy, R., Nelder, G. (2006). Critical success factors for lean implementation within SMEs. J. Manuf. Technol. Manage. 2006; 17:460–71

Agbesi, K., Fugar, F.D., Adjei-Kumi, T. (2018), "Modelling the adoption of sustainable procurement in construction organisations", Built Environment Project and Asset Management, Vol. 8 No. 5, pp. 461-476.

Aghili, N., Hosseini, S.E., Mohammed, A.H.B., Abidin, N.Z. (2019). Management criteria for green building in Malaysia; relative important index. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 41:21, 2601-2615

Ahmad, T., Aibinu, A., Thaheem, M.J. (2017). The effects of high-rise residential construction on sustainability of housing systems. Procedia Engineering, 180 (2017), pp. 1695-1704

Ahmed, M.D., Sundaram, D. (2012). Sustainability modelling and reporting: from roadmap to implementation. Decis. Support Syst., 53 (3) (2012), pp. 611-624

Ahuja, R., Sawhney, A., Arif, M. (2017). Driving lean and green project outcomes using BIM: a qualitative comparative analysis. Int. J. Sustain. Built Environ., 6 (2017), pp. 69-80

Ahuja, R., Sawhney, A., Arif, M. (2018). Developing organizational capabilities to deliver lean and green project outcomes using BIM. Eng. Constr. Archit. Manag. 2018, 25, 1255–1276.

Ahuja, V., Yang, J., Shankar, R. (2010). IT-enhanced communication protocols for building project management. Engineering, Construction and Architectural Management, 17(2), 159–179.

Aibinu, A.A., Odeyinka, H.A. (2006). Construction delays and their causative factors in Nigeria. J. Constr. Eng.Manage. 132 (7), 667–677.

Akunyumu, S., Fugar, F.D.K., Adinyira, E., Danku, J.C. (2021). "A review of models for assessing readiness of construction organisations to innovate", Construction Innovation, Vol. 21 No. 2, pp. 279-299.

Al Hattab, M. (2021). The dynamic evolution of synergies between BIM and sustainability: a text mining and network theory approach. J. Build. Eng., 37 (2021), p. 102159.

Al-Balushi, S., Sohal, A.S., Singh, P.J., Al Hajri, A., Al Farsi, Y.M., Al Abri, R. (2014). “Readiness factors for lean implementation in healthcare settings – a literature review”, Journal of Health Organization and Management, Vol. 28 No. 2, pp. 135-153.

Alarcón, L., Diethelmand, S., Rojo, O. (2002). Collaborative implementation of lean planning systems in Chilean construction companies. Proceedings IGLC-10, Aug. 2002, Gramado, Brazil

Albliwi, S.A., Antony, J., Arshed, N. (2014). “Critical literature review on maturity models for business process excellence”, Proceedings of the IEEE International Conference on Industrial Engineering and Engineering Management, Hong Kong, December, pp. 79-83.

Ali, A.J., Islam, A., Howe, L.P. (2013). A study of sustainability of continuous improvement in the manufacturing industries in Malaysia: organizational self-assessment as a mediator. Manag. Environ. Qual. Int. J., 24 (3) (2013), pp. 408-426

Alkhoraif, A., Hamad, R., McLaughlin, P. (2018). “Lean Implementation in Small and Medium Enterprises: Literature Review.” Operations Research Perspectives 6: 100089.

Alkhoraif, A., Rashid, H., McLaughlin, P. (2019). Lean implementation in small and medium enterprises: literature review”. Operations Research Perspectives, 6 (2019), p. 100089.

Allen, R., Becerik, B., Pollalis, S., Schwegler, B. (2005). “Promise and barriers to technology enabled and open project team collaboration.” J. Prof. Issues Eng. Educ. Pract., 10.1061/(ASCE)1052-3928 (2005)131:4(301), 301–311.

Almanei, M., Salonitis, K., Xu, Y. (2017). Lean implementation frameworks: The challenges for SMEs. Procedia CIRP, 63 (2017), pp. 750-755.

Alshawi, M., Arif, M. (Eds.). (2012). Cases on E-Readiness and Information Systems Management in Organizations: Tools for Maximizing Strategic Alignment. IGI Global.

Alves, J.R.X., Alves, J.M. (2015). Production management model integrating the principles of lean manufacturing and sustainability supported by the cultural transformation of a company Int. J. Prod. Res., 53 (17) (2015), pp. 5320-5333.

Alwan, Z., Jones, P., Holgate, P. (2017). Strategic sustainable development in the UK construction industry, through the framework for strategic sustainable development, using Building Information Modelling. Journal of Cleaner Production, 140, 349–358.

Antony, J., Krishan, N., Cullen, D., Kumar, M. (2012). Lean Six Sigma for higher education institutions (HEIs): challenges, barriers, success factors, tools/techniques. Int. J. Product. Perform. Manag., 61 (8) (2012), pp. 940-948.

Antony, J., Vinodh, S., Gijo, E.V. (2016). Lean Six Sigma for Small and Medium Sized Enterprises: A Practical Guide. CRC Press (2016)

Araújo, A.G., Carneiro, A.M.P., Palha, R.P. (2020). Sustainable construction management: a systematic review of the literature with meta-analysis. J. Clean. Prod., 256 (2020), pp. 1-10

Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C., O'Reilly, K. (2011). Technology adoption in the BIM implementation for lean architectural practice. Autom. Constr. 2011, 20, 189–195.

Arbulu, R., Zabelle, T. (2006). Implementing Lean in Construction: How to Succeed. Proceedings of IGLC, Santiago, Chile, pp 553-565.

Arditi, D., Elhassan, A., Toklu, Y. C. (2002). "Constructability analysis in the design firm." J. Constr. Eng. Manage., 128(2), 117–126.

Aronson, Z. H., Shenhar, A. J., Patanakul, P. (2013). "Managing the intangible aspects of a project: Quantitative and qualitative evidence on the affect of vision, artifacts, and leader values on project spirit and success in technology driven projects." Proj. Manage. J., 44(1), 35–58.

Arrotéia, A.V., Freitas, R.C., Melhado, S.B. (2021). Barriers to BIM adoption: A case study in Brazil. *Front. Built Environ.* 2021, *7*, 16.

Ateş, N.Y., Tarakci, M., Porck, J.P., van Knippenberg, D., Groenen, P.J. (2020). The dark side of visionary leadership in strategy implementation: strategic alignment, strategic consensus, and commitment. J. Manag., 46 (5) (2020), pp. 637-665.

Azhar, S., Carlton, W., Olsen, D., Ahmad, I. (2011). Building information modelling for sustainable design and LEED rating analysis. Autom. Constr., 20 (2) (2011), pp. 217-224

Aziz, R.F., Hafez, S.M. (2013). Applying lean thinking in construction and performance improvement. Alexandria Eng. J., 52 (4) (2013), pp. 679-695

Babalola, O., Ibem, E.O., Ezema, I.C. (2019). Implementation of lean practices in the construction industry: a systematic review. Build. Environ., 148 (2019), pp. 34-43.

Bachiochi, P.D., Weiner, S.P. (2002) `Qualitative data collection and analysis', in S. G. Rogelberg (ed.) Handbook of Research Methods in Industrial and Organizational Psychology: Blackwell Handbooks of Research Methods in Psychology, pp. 161-83. Malden, MA: Blackwell Publishers.

Ballard, G. (2000). Lean Project Delivery System. Lean Construction Institute, Ketchum (2000).

Ballard, G., Howell, G. (2003). Competing construction management paradigms. Construction Research Congress: Wind of Change: Integration and Innovation, pp. 1–8.

Banawi, A., Bilec, M.M. (2014). A framework to improve construction processes: Integrating lean, green and six sigma. Int. J. Constr. Manag. 14, 45–55.

Banihashemi, S., Hosseini, M.R. Golizadeh, H., Sankaran, S. (2017). Critical success factors (CSFs) for integration of sustainability into construction project management practices in developing countries. Int. J. Proj. Manag., 35 (2017), pp. 1103-1119.

Barros, N.J., Alves, T. (2007). Strategic Issues in Lean Construction implementation. In: Proc. 15th Ann. Conf. of the Int'l Group for Lean Construction. Michigan, USA, July 18-20.

Becker, J., Knackstedt, R., Pöppelbuß, J. (2009). "Developing maturity models for IT management – a procedure model and its application", Business & Information Systems Engineering, Vol. 1 No. 3, pp. 213-222.

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

Berg, B. L. (1998). Qualitative research methods for the social sciences, Boston: Pearson.

Bernard, H. R. (2000). Social research methods quantitative and qualitative approaches. Califonia: Sage publication

Berroir, F., Harbouche, L., Boton, C. (2015). Top down vs. Bottom up approaches regarding the implementation of lean construction through a French case study. In: Proc. 23rd Ann. Conf. of the Int'l. Group for Lean Construction. Perth, Australia, July 29-31, pp. 73-82

Blaikie, N. (2003). Analysing Quantitative Data. London: Sage Publications 2003.

Briones, C., Soto, C. (2017). La enseñanza de BIM en Chile, el desafío de un cambio de enfoque centrado en la metodología por sobre la tecnología. [BIM education in Chile, the challenge of a shift of focus centred on methodology over technology]. SIGraDi 2017, XXI Congreso de la Sociedad Ibero-americana de Gráfica Digital 22 – 24 Noviembre, 2017 – Concepción, Chile

Bryde, D., Broquetas, M., Volm, J.M. (2013). The project benefits of Building Information Modeling (BIM). Int. J. Proj. Manag., 31 (2013), pp. 971-980.

Bryman, A., Bell, E. (2011). Business Research Methods, *Oxford University Press.*

BSI (2014). PAS 1192-3:2014. Specification for information management for the operational phase of assets using building information modelling UK: British Standard Institution.

Burke, S., Gaughran, W. (2007). Developing a framework for sustainability management in engineering SMEs. Rob. Comp. Integr. Manuf., 23 (2007), pp. 696-703

Burnard, P. (1995). Interpreting text: an alternative to some current forms of textual analysis in qualitative research. Social Sciences in Health, 1 (1995), pp. 236-245

Cambra-Fierro, J., Ruiz-Benítez, R. (2011). Sustainable business practices in Spain: A two-case study. Eur. Bus. Rev. 2011, 23, 401–412.

Cao, Y., Zhang, L., McCabe, B., Shahi, A. (2019). The benefits of and barriers to BIM adoption in Canada. In Proceedings of the ISARC International Symposium on Automation and Robotics in Construction 2019, Banff, AB, Canada, 21–24 May 2019; pp. 152–158.

Carley, K. (1990). Content analysis. The encyclopedia of language and linguistics. Edinburgh: Pergamon Press.

Carmeli, A., Halevi, M.Y. (2009). How top management team behavioral integration and behavioral complexity enable organizational ambidexterity: the moderating role of contextual ambidexterity Leader. Q., 20 (2) (2009), pp. 207-218.

Catanzaro, M. (1988). Using qualitative analytical techniques. N.F. Woods, M. Catanzaro (Eds.), Nursing: research theory and practice, The CV Mosby Company, St.Louis (1988), pp. 437-456.

CChC (2020). Estudio de productividad: Impulsar la productividad de la industria de la Construcción en Chile a estándares mundiales. [Productivity study: Boosting the productivity of the Chilean construction industry to worldwide standards]. Matrix consulting.

Chan, D.W., Olawumi, T.O., Ho, A.M. (2019). Perceived benefits of and barriers to Building Information Modelling (BIM) implementation in construction: The case of Hong Kong. *J. Build. Eng.* 2019, *25*, 100764.

Charef, R., Alaka, H., Emmitt, S. (2018). Beyond the third dimension of BIM: a systematic review of literature and assessment of professional views. Journal of Building Engineering, 19 (2018), pp. 242-257

Charef, R., Emmitt, S., Alaka, H., Fouchal, F. (2019). Building information modelling adoption in the European Union: An overview. *J. Build. Eng.* 2019, *25*, 100777.

Chen, L., Luo, H. (2014). A BIM-based construction quality management model and its applications. Autom. Constr. 46, 64–73.

Cherrafi, A., Elfezazi, S., Govindan, K., Garza-Reyes, J.A., Benhida, K., Mokhlis, A. (2017). A framework for the integration of Green and Lean Six Sigma for superior sustainability performance, International Journal of Production Research, 55:15, 4481-4515

Cherrafi, A., Garza-Reyes, J. A., Belhadi, A., Kamble, S. S., Elbaz, J. (2021). "A Readiness Self-Assessment Model for Implementing Green Lean Initiatives." Journal of Cleaner Production 309: 127401

Chileshe, N., Dzisi, E. (2012). "Benefits and barriers of construction health and safety management (HSM): perceptions of practitioners within design organisations", Journal of Engineering, Design and Technology, Vol. 10 No. 2.

Chofreh, A., Goni, F. (2017). Review of Frameworks for Sustainability Implementation. Sustain. Dev. 2017, 25, 180–188.

Choi, S. W., Oh, B. K., Park, J. S., Park, H. S. (2016). Sustainable design model to reduce environmental impact of building construction with composite structures. Journal of Cleaner Production, 137(2016), 823–832.

Chong, H., Lee, C., Wang, X. (2017). A mixed review of the adoption of Building Information Modelling (BIM) for sustainability. J. Cleaner Prod., 142 (2017), pp. 4114-4126

Chowdhury, P., Shumon, R. (2020). Minimizing the Gap between Expectation and Ability: Strategies for SMEs to Implement Social Sustainability Practices. Sustainability 2020, 12, 6408.

Cohen, L., Manion, L., Morrison, K. (2000). Research Methods in Education. 5th edn. London: Routledge Falmer 2000.

Construye 2025. (2019). Hoja de Ruta RCD. Consulta Pública. [Roadmap RDC. Public Enquiry] Available at: http://construye2025.cl/rcd/hoja-de-ruta/

CORFO & PMG. (2016). Hoja de ruta de Programa Nacional de Productividad y Construcción Sustentable. [National Productivity and Sustainable Construction programme roadmap]. Santiago de Chile, Chile. Retrieved from https://construye2025.cl

Creswell J. W. (2009). Research Design: Qualitative, Quantitative and Mixed Method Approaches (3rd ed.), London: SAGE Publications.

Creswell, J. W. (1994). Research design: Qualitative & quantitative approaches. Thousand Oakes, CA: Sage.

Creswell, J., Plano Clark, V. (2007). Designing and Conducting Mixed Methods Research. Thousand Oaks, CA: Sage

Crosby, P. B. (1979). Quality is free: The art of making quality certain. New York: New American Library.

Crotty, R. (2012). The Impact of Building Information Modelling Transforming Construction. (1st ed.), Taylor and Francis, London, UK (2012)

Crowe, T.J., Fong, P.M., Zayas-Castro, J.L. (2002). “Quantative risk level estimation of business process reengineering efforts”, Business Process Management Journal, Vol. 8 No. 5, pp. 490-511.

Dainty, A., Leiringer, R., Fernie, S., Harty, C. (2017). “BIM and the small construction firm: a critical perspective”, Building Research and Information, Vol. 45 No. 6, pp. 696-709.

Dave, B., Boddy, S., Koskela, L. (2011). Visilean: designing a production management system with lean and BIM. Proceedings of the 19th Annual Conference of the International Group for Lean Construction 2011, IGLC 2011, Lima (2011), pp. 477-487

Dave, B., Koskela, L., Kiviniemi, A., Tzortzopoulos, P., Owen, R. (2013). Implementing Lean in construction: Lean construction and BIM. CIRIA, London, UK; 2013.

De Carvalho, J.V., Rocha, Á., de Vasconcelos, J.B. (2016). "Maturity models for hospital information systems management: are they mature?", in Chen, Y.-W., Tanaka, S., Howlett, R.J. and Jain, L.C. (Eds), Innovation in Medicine and Healthcare, 2015, Springer International Publishing, New York, NY, pp. 541-552.

de Leeuw, S., van den Berg, J. P. (2011). Improving operational performance by influencing shopfloor behavior via performance management practices, Journal of Operations Management 29(3): 224–235

De Solminihac, H., Thenoux, G. (2017). Procesos y técnicas de construcción [Construction processes and techniques]. Ediciones UC. Retrieved April 10, 2020, from www.jstor.org/stable/j.ctt17t77f3

Demirkesen, S., Bayhan, H.G. (2020). A Lean Implementation Success Model for the Construction Industry, Engineering Management Journal, 32:3, 219-239

Demirkesen, S., Ozorhon, B. (2017). Impact of integration management on construction project management performance. International Journal of Project Management. 35(8), pp. 1639–1654.

DeSanctis, I., Ordieres Mere, J. B., Bevilacqua, M., Ciarapica, F. E. (2018). "The Moderating Effects of Corporate and National Factors on Lean Projects Barriers: A Cross-National Study." Production Planning and Control 29(12): 972–991.

Dhingra, R., Kress, R., Upreti, G. (2014). Does lean mean green? J. Clean. Prod., 85 (2014), pp. 1-7.

Doan, D.T., GhaffarianHoseini, A., Naismith, N., Ghaffarianhoseini, A., Zhang, T., Tookey, J. (2020). Examining critical perspectives on building information modelling (BIM) adoption in New Zealand. *Smart Sustain. Built Environ.* 2020. ahead-of-print.

Duarte, S. Cruz-Machado, V. (2013). Modelling lean and green: a review from business models. International Journal of Lean Six Sigma, 4 (3) (2013), pp. 228-250.

Duarte, S., Cruz-Machado, V. (2019). Green and lean supply-chain transformation: a roadmap. Prod. Plann. Contr., 30 (14) (2019), pp. 1170-1183.

Durdyev, S., Mbachu, J. (2017). “Key constraints to labour productivity in residential building projects: evidence from Cambodia”, International Journal of Construction Management, Vol. 18 No. 5, pp. 1-9.

Easterby-Smith, M., Thorpe, R., Lowe, A. (2002). Management Research: An Introduction. London, UK: Sage Publications.

Eastman, C., Teicholz, P., Sacks, R., Liston, K. (2011). BIM Handbook: a Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors, BIM Handbook. John Wiley & Sons, Inc.

Edmondson, A.C., McManus, S.E. (2007). Methodological fit in management field research. Academy of Management Review, 32(4), pp.1155–1179.

EFQM. (2008). European Foundation for Quality Management. Retrieved March 23, 2022, from http://www.efqm.org/

Egan, J. (1998). Rethinking construction. HMSO, London.

Ekins, P., Zenghelis, D. (2021). The costs and benefits of environmental sustainability. Sustainability Science, 16(3), 949–965.

Elkington, J. (1994). Towards the suitable corporation: win–win–win business strategies for sustainable development. California Management Review 36:90–100.

Elkington, J. (2004). Enter the triple bottom line. In Henriques A, Richardson J (eds.). The Triple Bottom Line: Does It All Add Up? Earthscan: London; 1–16.

Elmualim, A., Gilder, J., (2014). BIM: Innovation in design management, influence, and challenges of implementation. Architectural Engineering and Design Management. 10(3–4), pp. 183–199.

Elo, S., Kääriäinen, M., Kanste, O., Pölkki, T., Utriainen, K., Kyngäs, H. (2014). Qualitative content analysis: a focus on trustworthiness. SAGE Open, 4 (2014)

Enache-Pommer, E., Horman, M.J., Messner, J.I., Riley, D. (2010). A unified process approach to healthcare project delivery: Synergies between greening strategies, lean principles and BIM, in: Construction Research Congress 2010: Innovation for Reshaping

Construction Practice - Proceedings of the 2010 Construction Research Congress. pp. 1376–1385.

Erdogan, B., Anumba, C. J., Bouchlaghem, D., Nielsen, Y. (2008). “Collaboration environments for construction: Implementation case studies.” J. Manage. Eng., 10.1061/(ASCE)0742-597X (2008)24:4 (234), 234–244.

Erdogan, B., Anumba, C., Bouchlaghem, D., Nielsen, Y. (2014). Collaboration environments for construction: Management of organizational changes. Journal of Management in Engineering, 30(3).

Faules, D. (1982). The use of multi-methods in the organizational setting, Western Journal of Speech Communication, 46:2, 150-161

Fellows, R.F., Liu, A.M. (2015). Research Methods for Construction, 4th ed., John Wiley & Sons, Oxford.

Forstner, E., Kamprath, N., Röglinger, M. (2014). “Capability development with process maturity models – decision framework and economic analysis”, Journal of Decision Systems, Vol. 23 No. 2, pp. 127-150.

Francis, A., Thomas, A. (2020). Exploring the relationship between lean construction and environmental sustainability: A review of existing literature to decipher broader dimensions. Journal of Cleaner Production. Volume 252, 10 April 2020, 119913

Fuenzalida, G. (2010). Instituto de capacitación para el obrero de la construcción y su entorno familiar y comunitario. [Training institute for the construction worker and their community and family environment]. Santiago, Universidad de Chile, Facultad de Arquitectura y Urbanismo, Escuela de Arquitectura, 2010. p7.

Gable, G. (1994). Integrating case study and survey research methods: an example in information systems. Eur J. Inf. Syst. 3, 112–126.

Gallotta, B., Garza-Reyes, J.A., Anosike, A., Lim, M., Roberts, I. (2016). A conceptual framework for the implementation of sustainability business pro-cesses. In Proceedings of the 27th Production and Operations Management Society (POMS): Orlando, FL; 1–11

Gambatese, J.A., Hallowell, M. (2011). Enabling and measuring innovation in the construction industry, Construction Management and Economics, 29:6, 553-567.

Gan, V.J.L., Deng, M., Tse, K.T., Chan, C.M., Lo, I.M.C., Cheng, J.C.P. (2018). Holistic BIM framework for sustainable low carbon design of high-rise buildings. J. Clean. Prod., 195

(2018), pp. 1091-1104.

Gao, S., Low, S.P. (2014). Lean Construction Management. (first ed), Springer, Berlin (2014).

Garavan, T.N. (1997). Training, development, education, and learning: different or the same? Journal of European Industrial Training 21, 39–50

Gerring, J., McDermott, R. (2007). "An experimental template for case study research", American Journal of Political Science, Vol. 51 No. 3, pp. 688-701

Ghaffarianhoseini, A., Tookey, J., Ghaffarianhoseini, A., Naismith, N., Azhar, S., Efimova, O., Raahemifar, K. (2017). Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges. Renewable and Sustainable Energy Reviews, 75 (2017), pp. 1046-1053

Gibbs, G. (2007). Analyzing qualitative data. London: Sage Publications

Giel, B., Issa, R.R.A., Olbina, S. (2010). Return on Investment Analysis of Building Information Modelling in Construction. Nottingham University Press, Nottingham (2010)

Glavic, P., Lukman, R. (2007). Review of sustainability terms and their definitions. Journal of Cleaner Production, 15 (2007), pp. 1875-1885

Glover, W.J., Farris, J.B., Van Aken, E.M. (2015). The relationship between continuous improvement and rapid improvement sustainability. Int. J. Prod. Res., 53 (13) (2015), pp. 4068-4086

Goh, C.S., Chong, H.Y., Jack, L., Faris, A.F.M. (2020). Revisiting triple bottom line within the context of sustainable construction: a systematic review. J. Clean. Prod., 252 (2020), p. 119884.

Gonzalez-Caceres, A., Bobadilla, A., Karlshøj, J. (2019). Implementing post-occupancy evaluation in social housing complemented with BIM: A case study in Chile. Build. Environ., 158 (2019), pp. 260-280

Gonzalez, V., Alarcon, L.F., Mundaca, F. (2008). Investigating the relationship between planning reliability and project performance, Production Planning & Control, 19:5, 461-474

Goodyer J, Murti Y, Grigg NP, Shekar A. (2011). Lean: insights into SMEs ability to sustain improvement. Cambridge, United Kingdom: University of Cambridge; 2011.

Govindan, K., Azevedo, S.G., Carvalho, H., Cruz-Machado, V. (2015). Lean, green, and resilient practices influence on supply chain performance: interpretive structural modeling approach Int. J. Environ. Sci. Technol., 12 (2015), pp. 15-34.

Grudens-Schuck, N., Allen, B.L., Larson, K. (2004). Focus Group Fundamentals, Methodology Brief. IOWA State University, University Extension (2004), pp. 1-6.

Gu, N., London, K. (2010). Understanding and facilitating BIM adoption in the AEC industry. Automation in Construction 19 (2010), 988–999.

Gudergan, G., Buschmeyer, A., Kretching, D., Feige, B. (2015). “Evaluating the readiness to transform towards a product-service system provider by a capability maturity modelling approach”, Procedia Cirp, Vol. 30, pp. 384-389.

Hahn, T., Pinkse, J., Preuss, L., Figge, F. (2015). Tensions in corporate sustainability: towards an integrative framework. J. Bus. Ethics, 127 (2) (2015), pp. 297-316

Häkkinen, T., Belloni, K. (2011) Barriers and drivers for sustainable building, Building Research & Information, 39:3, 239-255.

Halabi, A., Kenett, R. S., Sacerdote, L. (2017). Modeling the relationship between reliability assessment and risk predictors using Bayesian networks and a multiple logistic regression model. Quality Engineering, 30(4), 663–675.

Harrison J. R., Lin Z., Carroll G. R., Carley K. M. (2007). Simulation modeling in organizational and management research. Academy of Management Review, 32 (4): 1229–1245.

He, Q., Wang, G., Luo, L., Shi, Q., Xie, J., Meng, X. (2017). Mapping the managerial areas of Building Information Modeling (BIM) using scientometric analysis. Int. J. Proj. Manag., 35 (2017), pp. 670-685

Heaton, J., Parlikad, A., Owens, D., Pawsey, N. (2019). BIM as an enabler for digital transformation. International Conference on Smart Infrastructure and Construction 2019, ICSIC 2019: Driving Data-Informed Decision-Making, 49-54

Hernandez, M. (2021, November 12). COP26: Chile presentó en cumbre de Glasgow su plan de construccion sustentable [Chile presented in COP 26 in Glasgow their sustainable construction plan]. Available at: https://portal.nexnews.cl/showN?valor=hxjvh. Accessed: 1 December 2021.

Holt, G. (2014). "Asking questions, analysing answers: relative importance revisited", Construction Innovation, Vol. 14 No. 1, pp. 2-16

Höök, M., Stehn, L. (2008). Lean principles in industrialized housing production: the need for a cultural change. Lean Construction Journal, 2, pp.20-33.

Hore, A., Montague, R., Thomas, K., Cullen, F. (2011). Advancing the use of BIM through a government funded construction industry competency centre in Ireland. CIB W78 2011: 28th International Conference, Paris, 26–28 October 2011 (2011).

Horta, I., Camanho, A., Da Costa, J., (2010). Performance Assessment of Construction Companies Integrating Key Performance Indicators and Data Envelopment Analysis. Journal of Construction Engineering and Management. 136(5), pp. 581–594.

Hutchinson, A., Finnemore, M. (1999). Standardized process improvement for construction enterprises. Total Quality Management, 10, 576-583.

Idrus, A. B., Newman J. B. (2002). Construction related factors influencing choice of concrete floor systems, Construction Management and Economics, 20, 13-19

Ilhan, B., Yaman, H. (2016). Green building assessment tool (GBAT) for integrated BIM-based design decisions. Autom. Constr. 70, 26–37.

INE (2018). Instituto Nacional de Estadisticas. Censo 2017. [National Statistics Institute. Census 2017]. Gobierno de Chile

ISO (2010). Building Information Modeling — Information Delivery Manual — Part 1: Methodology and Format (2010)

Jamieson, S. (2004). Likert scales: how to (ab)use them. Medical Education, 38(12), 1217-1218.

Jankowicz, A. (2000). Business research project for students. London: Chapman &Hall.

Jick, T.D. (1979). Mixing qualitative and quantitative methods: Triangulation in action. Administrative Science Quarterly, 24, 602-611.

Johnson, M.P., Schaltegger, S. (2016). Two decades of sustainability management tools for SMEs: How far have we come? J. Small Bus. Manag. 2016, 54, 481–505.

Juan, Y. K., Lai, W. Y., Shih, S. G. (2017). Building information modeling acceptance and readiness assessment in Taiwanese architectural firms, Journal of Civil Engineering and Management 23(3): 356–367.

Kalcheva, E., Taki, A., Hadi, Y. (2016). Sustainable high-rises in a sustainable development-the case of Salford Quays. Procedia - Social and Behavioral Sciences, 216, 960-973.

Kaplan, B., Duchon, D. (1988). Combining Qualitative and Quantitative Methods in Information Systems Research: A Case Study. MIS Quarterly, 12(4), 571–586.

Kaplan, R.S., Norton, D.P. (1992). "The balanced scorecard: measures that drive performance", Harvard Business Review, Vol. 70 No. 1, pp. 71-9.

Khalfan, M.M.A., Anumba, C.J., Carrillo, P.M. (2001). Development of a readiness assessment model for concurrent engineering in construction. Benchmarking An Int. J. 8, 223–239.

Khalife, S., Hamzeh, F. (2019). A Framework for understanding the dynamic nature of value in design and construction. 27th Annual Conference of the International Group for Lean Construction (2019), pp. 617-628. Dublin, Ireland.

Khanzode, A., Fischer, M.A., Reed, D., Ballard, G. (2006). A Guide to Applying the Principles of Virtual Design & Construction (VDC) to the Lean Project Delivery Process. CIFE, Stanford Univ. Palo Alto, Calif.

Khosrowshahi, F., Arayici, F. (2012). Roadmap for implementation of BIM in the UK construction Industry. *Engineering* Construction and Architectural Management, 19 (6) (2012), pp. 610-635

Kibert, C. J. (1994). Establishing Principles and a Model for Sustainable Construction. Proceedings of First International Conference of CIB TG 16 on Sustainable Construction. November 6–9, Tampa, Florida. pp.3–12

Kiviniemi, A., Wilkins, C. (2008). Engineering centric BIM. Journal of American Society of Heating, Refrigerating and Air-Conditioning Engineers, December ed., 44-48.

Ko, C.H., Chung, N.F. (2014). Lean design process. Journal of Construction Engineering and Management 2014;140(6):04014011

Koskela, L. (1992). Application of the new production philosophy to construction, CIFE Technical Report #72, Stanford Univ., Stanford, CA.

Koskela, L. (2000). An Exploration towards a Production Theory and its Application to Construction. Espoo, VTT Technical Research Centre of Finland, VTT Publications (2000), p.408

Koskela, L., Owen, B., Dave, B. (2010). Lean Construction, Building Information Modelling and Sustainability. Eracobuild Workshop on BIM and Lean. April 15-16, 2010, Malmö, Sweden

Koskenvesa, A., Koskela, L. (2012). Ten years of last planner in Finland–where are we? [Paper presentation]. 20th Annual Conference of the International Group for Lean Construction, San Diego.

Kothari, C.R. (2004). Research methodology: methods and techniques. 3rd ed. New Delhi (India): New Age International Pvt. Ltd.

Kouider, T., Paterson, G., Thomson, C. (2007). BIM as a viable collaborative working tool: a case study. Proceedings of the 12th International Conference on Computer Aided Architectural Design Research in Asia CAADRIA 2007 Conference, Nanjing, China (2007)

Krippendorff, K. (1980). Content Analysis: an introduction to its methodology. Newbury Park and London: Sage.

Kucukvar, M., Tatari, O. (2013). Towards a triple bottom-line sustainability assessment of the US construction industry. Int. J. Life Cycle Assess., 18 (2013), pp. 958-972

Kurdve, M., Zackrisson, M., Wiktorsson, M., Harlin, U. (2014). Lean and Green integration into production system models e experiences from Swedish industry. Journal of Cleaner Production, Volume 85, 15 December 2014, Pages 180-190

Lagos, R., Kupper, M., Lindenberg, J., Bonelli, P., Saragoni, R., Gueldelman, T., Massone, L., Boroschek, R., Yanez, F. (2012). "Seismic Performance of High-Rise Concrete Buildings in Chile", International Journal of High-Rise Buildings, Vol. 1, No. 3, pp. 181-194.

Lapinski, A.R., Horman, M.J., Riley, D.R. (2006). Lean processes for sustainable project delivery J. Constr. Eng. Manag., 132 (10) (2006), pp. 1083-1091.

Laurenti, R., Sinha, R., Singh, J., Frostell, B. (2016). Towards addressing unintended environmental consequences: a planning framework. Sustainable Development 24:1–17

Lee, R.M. (2004). Recording technologies and the interview in sociology, 1920–2000. Sociology 38(5): 869–889.

Lee, T.Y., Wong, W.K., Yeung, K.W. (2011), "Developing a readiness self-assessment model (RSM) for Six Sigma for China enterprises", International Journal of Quality & Reliability Management, Vol. 28 No. 2, pp. 169-194

Lee. G., Borrmann, A. (2020). BIM policy and management, Construction Management and Economics, 38:5, 413-419.

Liao, L., Teo, E.A.L. (2019). Managing critical drivers for building information modelling implementation in the Singapore construction industry: an organizational change perspective, International Journal of Construction Management, 19:3, 240-256

Liker, J. (2004). The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer. New York: McGraw-Hill.

Lloyd-Jones, G. (2003). "Design and control issues in qualitative case study research", International Journal of Qualitative Methods, Vol. 2 No. 2, pp. 33-42.

Lockamy III, A., McCormack, K. (2004). The development of a supply chain management process maturity model using the concepts of business process orientation. Supply Chain Management: An International Journal, 9(4), 272-278.

Long, T., Johnson, M. (2000). Rigour, reliability, and validity in qualitative research. Clinical Effectiveness in Nursing, 4 (2000), pp. 30-37.

Loorbach, D., van Bake, J. C., Whiteman, G., Rotmans, J. (2010). “Business strategies for transitions towards sustainable systems,”. *Bus. Strateg. Environ.*, vol. 19, no. 2, pp. 133–146, 2010.

López-Pérez, M.E., Melero-Polo, I., Vázquez-Carrasco, R., Cambra-Fierro, J. (2018). Sustainability and business outcomes in the context of SMEs: Comparing family firms vs. nonfamily firms. Sustainability 2018, 10, 4080.

Lou, E.C.W., Goulding, J.S. (2010). “*The pervasiveness of e-readiness in global built environment arena*”, Journal of Systems and Information Technology, Vol. 12 No. 3, pp. 180-195.

Lou, E.C.W., Lee, A., Goulding, J. (2020). E-readiness in construction (ERiC): self-assessment framework for UK small and medium enterprise building services providers, Architectural Engineering and Design Management, 16:1, 3-22.

Loyola, M. (2019). Encuesta Nacional BIM 2019: Informe de Resultados. [National BIM survey 2019: Report of results]. Santiago: Universidad de Chile. Available at: www.bim.uchilefau.cl.

Loyola, M., López, F. (2018). An evaluation of the macro-scale adoption of Building Information Modeling in Chile: 2013-2016. Revista de la construcción, 17(1), 158-171.

Lu, Y., Wu, Z., Chang, R., Li, Y. (2017). Building Information Modeling (BIM) for green buildings: A critical review and future directions. Automation in Construction, 83 (2017), pp. 134-148

Luo, H., Ambrosius, B., Russo, R.M., Mocanu, V., Wang, K., Bevis, M., Fernandes, R. (2020). A recent increase in megathrust locking in the southernmost rupture area of the giant 1960 Chile earthquake, Earth and Planetary Science Letters, Volume 537, 2020, 116200.

Mack, N., Woodsong, C., MacQueen, K. M., Guest, G., Namey, E. (2005). Qualitative research methods: A data collector's field guide. North Carolina, USA: USAID, Family Health International.

Mahalingam, A., Yadav, A.K., Varaprasad, J. (2015). Investigating the role of lean practices in enabling BIM adoption: evidence from two Indian cases J. Constr. Eng. Manag., 05015006 (2015).

Makabate, C.T., Musonda, I., Okoro, C.S., Chileshe, N. (2021), "Scientometric analysis of BIM adoption by SMEs in the architecture, construction and engineering sector", Engineering, Construction and Architectural Management, Vol. ahead-of-print No. ahead-of-print.

Malmbrandt, M., Åhlström, P. (2013). An instrument for assessing lean service adoption. International, Journal of Operations & Production Management, 33, 113 -1165.

Mc Lafferty, I. (2004). Focus group interviews as a data collecting strategy. Journal of Advanced Nursing, 48 (2) (2004), pp. 187-194

McGraw Hill Construction (2007). McGraw Hill Smart Market Report on Interoperability

Mellado, F., Lou, E.C.W. (2020). Building information modelling, lean and sustainability: An integration framework to promote performance improvements in the construction industry. Sustainable Cities and Society. Volume 61, October 2020, 102355.

Mention, A. L. (2011). “Co-operation and co-opetition as open innovation practices in the service sector: Which influence on innovation novelty?” Technovation, 31(1), 44–53

Merton, R. (1987). The focused group interview and focus groups: Continuities and discontinuities. Public Opinion Quarterly, 51, 550–566.

Mihindu, S., Arayici, Y. (2008). “Digital construction through BIM systems will drive the re-engineering of construction business practices”, 2008 international conference visualisation, IEEE, pp. 29-34

Miles, M., Huberman, A.M. (1994). Qualitative Data Analysis. Thousand Oaks, CA: Sage Publications.

Minichiello, V., Kottler, J.A. (2010). Qualitative Journeys: Student and Mentor Experiences with Research. SAGE, Thousand Oaks, Calif (2010). London

Mohajerani, A., Bakaric, J., Jeffrey-Bailey, T. (2017). The urban heat island effect, its causes, and mitigation, with reference to the thermal properties of asphalt concrete. J. Environ. Manag., 197 (2017), pp. 522-538.

Mokhatab, S., Mak, J.Y., Valappil, J.V., Wood, D.A. (2014). Chapter 11-LNG Project Management, Handbook of Liquefied Natural Gas, Gulf Professional Publishing, 2014, pp 465-498.

Mollasalehi, S., Aboumoemen, A.A., Rathnayake, A., Underwood, J. (2018). Development of an Integrated BIM and Lean Maturity Model, in: 26th Annual Conference of the International Group for Lean Construction (IGLC), Chennai, India. pp. 1217–1228.

MOP. (2013). Ministerio de Obras Públicas: Estrategia Nacional de Construcción Sustentable. [Ministry of Public Works: National Sustainable Construction Strategy]. Santiago, Chile, 2013.

Nascimento, D.L., Sotelino, E.D., Lara, T.P.S., Caiado, R.G.G., Ivson, P. (2017). Constructability in industrial plants construction: a BIM-Lean approach using the Digital Obeya Room framework. J. Civ. Eng. Manag. 23, 1100–1108.

Nesensohn, C., Bryde, D., Ochieng, E., Fearon, D. (2014). 'Maturity and maturity models in lean construction', Australasian Journal of Construction Economics and Building, 14 (1) 45-59.

Neuman, W. L. (2006). Social Research Methods: Qualitative and Quantitative Approaches (6th ed.), London: Pearson Education, Inc.

Newman, I., Benz, C. R. (1998). Qualitative–quantitative research methodology: Exploring the interactive continuum, Carbondale, IL: Southern Illinois University Press.

Ng, R., Low, J.S.C., Song, B. (2015). Integrating and implementing Lean and Green practices based on proposition of Carbon-Value Efficiency metric. J. Clean. Prod. 95, 242–255.

Nguyen, T., Chileshe, N., (2015). Revisiting the construction project failure factors in Vietnam. Built Environment Project and Asset Management. 5(4), pp. 398–416.

NIBS (2007). U.S National Building Information Modeling Standard: Version 1-Part 1, Overview, Principle and Methodologies. U.S: National Institute of Building Science

Nightingale, D. J., Mize, J. H. (2002). Development of a Lean Enterprise Transformation Maturity Model. Information Knowledge Systems Management, 3(1), 15.

NIST. (2008). Baldrige National Quality Program - Criteria for Performance Excellence: National Institute of Standards and Technology, US.

Niven, P. (2006). Balanced scorecard step-by-step: maximizing performance and maintaining results. Chichester: Wiley. 327 p.

Nuñez, D., Ferrada, X., Neyem, A., Serpell, A., Sepúlveda, M. (2018). A user-centered mobile cloud computing platform for improving knowledge management in small-to-medium enterprises in the Chilean construction industry. Applied Sciences, 8 (4) (2018), p. 516.

Ochieng, N.T, Wilson, K., Derrick, C.J., Mukherjee, N. (2018). The use of focus group discussion methodology: Insights from two decades of application in conservation. Methods Ecol Evol. 2018; 9: 20– 32.

Okoroh, M.I., Gombera, P.P., Ilozor, B.D. (2002). "Managing FM (support services): business risks in the healthcare sector", Facilities, Vol. 20 No. 1, pp. 41-51

Olatunji, A. O. (2011). Modelling the costs of corporate implementation of building information modelling. Journal of Financial Management of Property and Construction 16(3), 211-231

Olawumi, T.O., Chan, D.W., Wong, J.K., Chan, A.P. (2018). Barriers to the integration of BIM and sustainability practices in construction projects: a Delphi survey of international experts. J. Build. Eng., 20 (2018), pp. 60-71.

Omotayo, T.S., Boateng, P., Osobajo, O., Oke, A., Obi, L.I. (2019). "Systems thinking and CMM for continuous improvement in the construction industry", International Journal of Productivity and Performance Management, Vol. 69 No. 2, pp. 271-296.

Othman, A.A.E., Hassan, T.M., Pasquire, C.L. (2005), “Analysis of factors that drive brief development in construction”, Engineering, Construction and Architectural Management, Vol. 12 No. 1, pp. 69-87

Ozorhon, B., Abbott, C., Aouad, G. (2014). Integration and leadership as enablers of innovation in construction: case study. J. Manag. Eng., 30 (2) (2014), pp. 256-263

Ozorhon, B., Abbott, C., Aouad, G., Powell, J. (2010). Innovation in construction: A project life-cycle approach, Univ. of Salford, Salford, U.K.

Ozorhon, B., Karahan, U. (2017). Critical Success Factors of Building Information Modeling Implementation. J. Manage. Eng., 2017, 33(3): 04016054.

Panagiotakopoulos, P.D., Espinosa, A., Walker, J. (2016). Sustainability management: insights from the viable system model. Journal of Cleaner Production 113: 792–806.

Patel, H., Pettitt, M., Wilson, J. R. (2012). “Factors of collaborative working: A framework for a collaboration model.” Appl. Ergonomics, 43(1), 1–26.

Paulk, M. C., Weber, C. V., Garcia, S. M., Chrissis, M. B., Bush, M. (1993). Key Practices of the Capability Maturity Model - Version 1.1 (Technical Report): Software Engineering Institute, Carnegie Mellon University.

Peansupap, V., Walker, D.H.T. (2006). "Information communication technology (ICT) implementation constraints: A construction industry perspective", Engineering, Construction and Architectural Management, Vol. 13 No. 4, pp. 364-379

Pearce, A., Pons, D. (2013). Implementing lean practices: managing the transformation risks. J Ind Eng. 2013:79029.

Pearce, A., Pons, D., Neitzert, T. (2018). Implementing lean—Outcomes from SME case studies. Oper. Res. Perspect., 5 (2018), pp. 94-104.

Peng, W., Pheng, L. (2010). Lean production, value chain and sustainability in precast concrete factory–a case study in Singapore. Lean Construction (2010), pp. 92-109

Pheng, L., Gao, S., Lin, J. (2015). "Converging early contractor involvement (ECI) and lean construction practices for productivity enhancement: Some preliminary findings from Singapore", International Journal of Productivity and Performance Management, Vol. 64 No. 6, pp. 831-852.

Picchi, F., Granja, A. (2004). Construction sites: using lean principles to seek broader implementations. In: Proceedings of International Group of Lean Construction, 12th Annual Conference, Copenhagen, Denmark, August 3-5, p. 6

Planbim (2019). BIM STANDARD FOR PUBLIC PROJECTS. Information Exchange between Appointing and Appointed Parties. Comité de Transformación Digital CORFO. Retrieved from: https://planbim.cl/?lang=en

Planbim (2021). Enseñanza de BIM en Chile: avances 2016-2020. [BIM teaching in Chile: Progress 2016-2020]. (Enero,2021). Planbim. Available at: https://planbim.cl/ensenanza-de-bim-en-chile/

Pons J.F., Rubio I. (2021). Lean construction las 10 claves del éxito para su implantación [Lean construction: 10 success keys for its implementation]. Consejo General de la Arquitectura Técnica de España.

CORFO (2016). Hoja de Ruta Programa Estratégico Nacional Productividad y Construcción Sustentable 2025, Informe Final, Fase 3; Technical Report; CORFO. [Production Development Corporation (CORFO). National strategy of productivity and sustainable construction 2025, final report, phase 3; technical report, CORFO]. Santiago, Chile, 2016.

Qureshi, T. M., Warraich, A. S., Hijazi, S. T. (2009). Significance of project management performance assessment (PMPA) model, International Journal of Project Management 27(4): 378–388.

Radnor, Z., Walley, P., Stephens, A., Bucci, G. (2006). “Evaluation of the lean approach to business management and its use in the public sector”, full report, Scottish Executive, Edinburgh.

Renken, J. (2004). Developing an IS/ICT management capability maturity framework. Proceedings of the 2004 annual research conference of the South African institute of computer scientists and information technologists on IT research in developing countries. Stellenbosch, Western Cape, South Africa: South African Institute for Computer Scientists and Information Technologists.

Revilla, M. A., Saris, W. E., Krosnick, J. A. (2014). Choosing the Number of Categories in Agree–Disagree Scales. Sociological Methods & Research, 43(1), 73–97.

Ribeiro, F.L., Fernandes, M.T. (2010). “Exploring agile methods in construction small and medium enterprises: a case study”, Journal of Enterprise Information Management, Vol. 23 No. 2, pp. 161-180.

Riley, D., Magent, C., Horman, M. (2004). “Sustainable metrics: A design process model for high performance buildings,” CIB World Building Congress, May 2–7, Toronto, CIB, The Netherlands.

Ritchie, J., Lewis, J. (2003). Qualitative Research Practice: A Guide for Social Science Students and Researchers. Sage Publications, London.

Robson, C. (2002). Real world research: a resource for social scientists & practitioner researchers (2nd ed.) Oxford: Blackwell

Röglinger, M., Pöppelbuß, J., Becker, J. (2012). “Maturity models in business process management”, Business Process Management Journal, Vol. 18 No. 2, pp. 328-346

Rojas, E. (2016). Housing Policies and Urban Development: Lessons from the Latin American Experience. Land and the City. 2016, Lincoln Institute of Land Policy, Cambridge, MA (1960–2010), pp. 301-356.

Rubio-Bellido, C., Pérez-Fargallo, A., Pulido-Arcas, J. (2018). Energy Optimization and Prediction in Office Buildings: A Case Study of Office Building Design in Chile. Springer, Cham (2018)

Ruikar, K., Anumba, C.J., Carrillo, P.M. (2006). VERDICT-An e-readiness assessment application for construction companies, Automation in construction 15, 98-111.

Rutakumwa, R., Mugisha, J. O., Bernays, S., Kabunga, E., Tumwekwase, G., Mbonye, M., Seeley, J. (2020). Conducting in-depth interviews with and without voice recorders: a comparative analysis. Qualitative Research, 20(5), 565–581.

Sacks, R., Barak, R. (2010). Teaching building information modeling as an integral part of freshman year. Journal of Civil Engineering Education 136(1), 30-38

Sacks, R., Koskela, L., Dave, B.A., Owen, R. (2010). Interaction of Lean and Building Information Modeling in Construction. ASCE J. Comput. Civ. Eng. 136, 968–980.

Saieg, P., Sotelino, E.D., Nascimento, D., Gusmao Caiado, R.G. (2018). Interactions of Building Information Modeling, Lean and Sustainability on the Architectural, Engineering and Construction industry: A systematic review. J. Clean. Prod. 174, 788–806.

Saleh, Y., Alshawi, M. (2005). "An alternative model for measuring the success of IS projects: the GPIS model", Journal of Enterprise Information Management, Vol. 18 No. 1, pp. 47-63.

Salvatierra, J.L., Alarcón, L.F., López, A., Velásquez, X. (2015). Lean Diagnosis for Chilean Construction Industry: Towards More Sustainable Practices. In: Proc. 23rd Ann. Conf. of the Int'l. Group for Lean Construction. Perth, Australia, July 29-31, pp. 642-651

Salvatierra, J.M. (2021, May 18). Lean Construction en Chile: La gestión de proyectos está cambiando [Lean Construction in Chile: Project management is changing]. Available at: https://digital.elmercurio.com/2021/05/18/B/PO3VEM8J/light?gt=003501 Accessed: 1 December 2021.

Sambrook, S. (2004). A "critical" time for HRD? Journal of European Industrial Training 28, 611–624.

Sánchez, A.M., Pérez, M.P. (2001). "*Lean indicators and manufacturing strategies*", *International Journal of Operations & Production Management*, Vol. 21 No. 11, pp. 1433-51.

Santos, R., Costa, A.A., Grilo, A. (2017). "Bibliometric analysis and review of building information modeling literature published between 2005 and 2015", Automation in Construction, Vol. 80, pp. 118-136

Sarhan, S., Fox, A. (2013). Barriers to Implementing Lean Construction in the UK Construction Industry. Built Hum. Environ. Rev. 6, 1–17.

Sarshar, M., Haigh, R., Finnemore, M., Aouad, G., Barrett, P., Baldry, D. (2000). SPICE: a business process diagnostics tool for construction projects. Engineering Construction & Architectural Management, 7(3), 241-250.

Saunders, M., R., Lewis, P., Thornhill, A. (2008). Research Method for Business Students. 4th Edition. Prentice Hall, London, UK.

SEI. (2008). Capability Maturity Model Integration - Software Engineering Institute / Carnegie Melon.

Sepasgozar, S.M.E., Hui, F.K.P., Shirowzhan, S., Foroozanfar, M., Yang, L., Aye, L. (2021). “Lean practices using building information modeling (BIM) and digital twinning for sustainable”, Construction, Vol. 13, p. 161.

Serpell, A., Kort, J., Vera, S. (2013). Awareness, actions, drivers and barriers of sustainable construction in Chile, Technological and Economic Development of Economy, 19:2, 272-288

Serpell, A., Solminihac, H., Figari, C. (2002). Quality in construction: The situation of the Chilean construction industry. Total Quality Management. 13. 579-587.

Serpell, A., Ferrada, X. (2020). The performance of the Chilean construction industry. Programs, initiatives, achievements, and challenges. Improving the Performance of Construction Industries for Developing Countries. 1st Edition. 2020. Routledge. Pages 24

Sfakianaki, E. (2018). Critical success factors for sustainable construction: A literature review. Management of Environmental Quality an International Journal, 30 (1) (2018), pp. 176-196

Shang, G., Pheng, L. (2014). "Barriers to lean implementation in the construction industry in China", Journal of Technology Management in China, Vol. 9 No. 2, pp. 155-173

Shelbourn, M. A., Bouchlaghem, N. M., Anumba, C. J., Carrillo, P. (2007). “Planning and implementation of effective collaboration in construction projects.” Constr. Innov. J., 7(4), 357–377.

Siegel, R., Antony, J., Garza-Reyes, J.A., Cherrafi, A., Lameijer, B. (2019). Integrated green lean approach and sustainability for SMEs: from literature review to a conceptual framework. J. Clean. Prod., 240 (2019), Article 118205.

Siembieda, W., Johnson, L., Franco, G. (2012). Rebuild Fast but Rebuild Better: Chile’s Initial Recovery following the 27 February 2010 Earthquake and Tsunami. Earthquake Spectra, 28(1_suppl1), 621–641.

Silverman, D. (2004). Doing Qualitative Research, 2nd Edition, Sage Publications, Thousand Oaks, CA.

Singh V., Gu N., Wang X. (2011). A theoretical framework of a BIM-based multi-disciplinary collaboration platform. Autom. Constr., 20 (2) (2011), pp. 134-144

Singh, R.K., Garg, S.K., Deshmukh, S.G. (2008). Strategy development by SMEs for competitiveness: a review. Benchmarking: An International Journal 2008;15(5):525–47.

Sinkovics, N. (2018). Pattern matching in qualitative analysis. The sage handbook of qualitative business and management research methods, 468-485.

Smith, D.K., Tardiff, M. (2009). Building information modeling: a strategic implementation guide for architects, engineers, constructors and real estate asset managers. New Jersey: John Wiley & Sons, Inc

Smits, W., van Buiten, M., Hartmann, T. (2017). Yield-to-BIM: impacts of BIM maturity on project performance, Building Research & Information, 45:3, 336-346.

Soh, C., Markus, M.L. (1995). How IT creates business value: a process theory synthesis. In: Proceedings of the 16th Annual International Conference on Information Systems, Amsterdam, The Netherlands, December, pp. 29–41.

Song, J., Migliaccio, G., Wang, G., Lu, H. (2017). Exploring the influence of system quality, information quality, and external service on BIM user satisfaction. J. Manag. Eng. 2017, 33, 04017036.

Song, L., Mohamed, Y., AbouRizk, S. (2009). "Early contractor involvement in design and its impact on construction schedule performance", Journal of Management in Engineering, Vol. 25 No. 1, pp. 12-20.

Succar, B. (2009). Building information modelling framework: a research and delivery foundation for industry stakeholders. Autom. Constr., 18 (2009), pp. 357-375

Succar, B. (2010). Building Information Modelling maturity matrix. In J. Underwood, & U. Isikdag, *Handbook of research on Building Information Modelling and construction informatics: concepts and technologies* (pp. 65-103). Hershey, PA: IGI Publishing.

Succar, B. (2014). Building Information Modelling: Conceptual Constructs and Performance Improvement Tools. Ph.D. Thesis, Faculty of Engineering and Built Environment, School of Architecture and Built Environment, University of Newcastle, Callaghan, NSW,Australia, 2014.

Sutrisna, M. (2009). Research methodology in doctoral research: understanding the meaning of conducting qualitative research. Working paper presented in ARCOM doctoral workshop, Liverpool John Moores University

Switzerland Global Enterprise (2020, October). Swiss Cleantech in the construction sector in Chile. Available at: https://www.s-ge.com/sites/default/files/publication/free/s-ge-20204-c5-chile-cleantech-construction.pdf

Tauriainen, M., Marttinen, P., Dave, B., Koskela, L. (2016). The effects of BIM and lean construction on design management practices. Procedia Eng. 164, 567–574.

Toledo, M., Olivares, K., González, V. (2016). Exploration of a Lean-BIM Planning Framework: A Last Planner System and BIM-Based Case Study. Proc. 24th Ann. Conf. Int. Gr. Lean Constr. Boston, MA, USA 3–12.

Tsvetkova, D., Bengtsson, E., Durst, S. (2020). Maintaining Sustainable Practices in SMEs: Insight from Sweden. Sustainability 2020, 12, 10242.

Ugalde, D., Lopez-Garcia, D. (2017). Behaviour of reinforced concrete shear wall buildings subjected to large earthquakes. Procedia Eng, 199 (2017), pp. 3582-3587

Uhlaner, L.M., Berent-Braun, M.M., Jeurissen, R.J.M., de Wit, G. (2012). Beyond size: Predicting engagement in environmental management practices of Dutch SMEs. J. Bus. Ethics 2012, 109, 411–429.

Upstill-Goddard, J., Glass, J., Dainty, A., Nicholson, I. (2016). Implementing sustainability in small and medium-sized construction firms: the role of absorptive capacity. Eng. Constr. Architect. Manag., 23 (4) (2016), pp. 407-427

Urban, W. (2015). The Lean Management Maturity Self-assessment Tool Based on Organizational Culture Diagnosis. Procedia - Social and Behavioral Sciences. Volume 213, 2015, Pages 728-733

Vass, S., Gustavsson, T.K. (2017). Challenges when implementing BIM for industry change, Construction Management and Economics, 35:10, 597-610

Vidalakis, C., Abanda, F.H., Oti, A.H. (2020), "BIM adoption and implementation: focusing on SMEs", Construction Innovation, Vol. 20 No. 1, pp. 128-147.

Volk, R., Stengel, J., Schultmann, F. (2014). Building information modeling (BIM) for existing buildings—literature review and future needs. Autom. Constr., 38 (2014), pp. 109-127

Vukomanovic, M., Radujkovic, M., Nahod, M.M. (2014). EFQM excellence model as the TQM model of the construction industry of south-eastern Europe, Journal of Civil Engineering and Management, 20:1, 70-81.

Wilkinson, S. (1998). Focus group methodology: A review. International Journal of Social Research Methodology, 1(3), 181–203.

WCDE (World Commission on Environment and Development) (1987). Our Common Future Oxford University Press, Oxford (1987)

Weisberg, H.F. (2008). The Methodological Strengths and Weaknesses of Survey Research; The SAGE Handbook of Public Opinion Research; SAGE: Thousand Oaks, CA, USA.

Womack, J. P., Jones, D. T., Roos, D. (1990). The machine that changed the world, Rawson associates. New York, 323 PP.

Wong, W.P., Wong, K.Y. (2014). Synergizing an ecosphere of lean for sustainable operations J. Clean. Prod., 85 (2014), pp. 51-66 (2014).

Yin, R.K. (2003). Case Study Research: Design and Methods, 3rd ed., Sage, London.

Yin, R.K. (2009). Case Study Research: Design and Methods, 4th ed., e-book, Sage, CA

Yin, R.K. (2013). *Case study research: Design and methods*, Sage publications

Yılmaz, M., Bakış, A. (2015). Sustainability in Construction Sector. Procedia - Social and Behavioral Sciences. 195 (2015). 2253-2262.

Yuan, H., Yang, Y., Xue, X. (2019). Promoting owners' BIM adoption behaviors to achieve sustainable project management. Sustainability, 11 (14) (2019), p. 3905

Zanotti, N.L., Maranhão, F.L., Aly, V.L.C. (2017). “Bottom-up strategy for lean construction on site implementation”, 25th Annual Conference of the International Group for Lean Construction, Heraklion, July, pp. 325-331

Zeng, S.X., Tian, P., Tam, C.M. (2005). “Quality assurance in design organisations: a case study in China”, Managerial Auditing Journal, Vol. 20 No. 7, pp. 679-690.

Zhou, Y., Yang, Y., Yang, J.B. (2019). Barriers to BIM implementation strategies in China. *Eng. Constr. Archit. Manag.* 2019, *26*, 554–574.

Annexes.

Annexe 1: Interview questions

<u>SME background:</u>

What kind of business does your organisation perform?

What is the organisation main sector?

What is the number of employees in your organisation?

What are your organisation experience years?

<u>Current BLS implementation</u>

Is your company currently using any BIM software? If yes, which one?

Is your company currently using any lean software? If yes, which one?

Is your company currently using any software to perform sustainability tasks? If yes, which one?

What is the reason behind purchasing software?

What is the current state of BIM, lean, and sustainability use/application in your organisation? To what extent BLS have been applied to your SME?

What is the purpose of your organisation with BLS implementation?

What are the challenges in implementing BLS?

How is the organisation in terms of staff? Does your SME have the staff to implement BLS practices?

<u>Process:</u>

What are the requirements to change the current organisation way of working towards a BLS oriented organisation?

In the application of BLS practices, does the organisation have/needs to change their processes? If yes, how?

Is there a target to implement BLS practices?

In terms of the application of BIM, what is the aim of its use? Clash detection, quantity take off, etc?

What are the transformation challenges for your SME when implementing/applying BLS practices? What is the response to them?

What are the BLS implementation requirements you think are needed to successfully transform your organisation's way of working towards a BLS oriented SME?

Has your organisation developed an implementation plan? What are the considerations in developing that plan and has it been put in practice?

Are there monitoring procedures when implementing BLS?

How having resources impact the implementation of BLS?

Human and attitudinal:

Does your SME have the skills capacity in your staff to transition to a BLS oriented organisation?

What type of skills are required from people to support the implementation?

What are the roles and responsibilities related to the implementation?

Do you think that having clear roles and responsibilities is important in the implementation?

What are the aspects required to develop skills in your organisation members?

Is there a strategy in your SME aiming to increase your staff skills?

Technological aspects:

How has the implementation transformed your SME in terms of acquisition of new technology (Software, hardware, infrastructure)?

What are the software requirements of your SME in terms of BLS adoption? Did your SME have to upgrade?

Are there any technical difficulties in implementing technology for BLS adoption?

In BIM terms, did your SME assess software requirements in terms of interoperability, compatibility etc?

What aspects are important when selecting the appropriate software for your organisation?

What aspects are important when managing the use of software for your organisation?

Management:

What are the requirements to support the BLS implementation in terms of strategy?

How does your organisation deal with stakeholders who are not ready for a BLS transition? is your organisation aware of the steps to take to respond to this issue?

Do your clients support the idea of moving towards BLS practices?

What are the skills/competences that are required from the management to support the implementation of BLS?

What aspects are the ones that are relevant when managing risks derived from implementing BLS?

How important is the support of top management to commit to a BLS oriented organisation? How does it translate from vision to actions?

Economic aspects:

What are the economic benefits of the BLS implementation?

What are the economic considerations associated with the implementation of BLS?

Are you aware of the financial support schemes that are available for SMEs? Do you think that financial support available is enough?

What does your SME expect from the government initiative of promoting the use of BLS in terms of economic returns?

Is the economic aspect the most important to your SME when considering the application/implementation of BLS practices?

END OF QUESTIONS

Annexe 2: Focus Group questionnaire

Section 1: Details

Please provide the following details:

Respondent:
Background:
BIM experience:
Lean Experience:
Sustainability experience:
Organisation type:
Number of employees:

Section 2: BLS Framework scores.

Please rate the presented factors according to the level of importance as shown:
1: No importance whatsoever; 2: Little importance; 3: Neutral; 4: Important: 5: Very important

For the maturity assessment please refer to the table provided

BLS organisational maturity framework				Importance					Maturity				
Category	Subcategory	Code	Factors	1	2	3	4	5	1	2	3	4	5
Process (P)	Business transformation (BT)	PBT1	Business process reengineering										
		PBT2	Gradual change										
		PBT3	Focus on long run										
		PBT4	Change strategy plan										
		PBT5	Continuous improvement										
		PBT6	Government initiative										
	Strategy (S)	PS1	Implementation strategy										
		PS2	Strategic planning										
		PS3	Alignment										
		PS4	Resource allocation										
	Culture (C)	PC1	Culture change										
		PC2	Client experience in BLS										
		PC3	Early contractor involvement										
	Information (I)	PI1	Communication										
		PI2	Collaboration										
		PI3	Clear BLS policy										
		PI4	Controlling and monitoring										
Human and attitudinal (H)	Expertise (EX)	HEX1	Competencies of top staff										
		HEX2	Skills										
		HEX3	Champion										
		HEX4	Understanding of the BLS concepts										
		HEX5	Qualified staff										
	Education (ED)	HED 1	Education										
		HED 2	Knowledge										
		HED 3	Development										
		HED 4	Training										
	Attitudes (A)	HA1	Attitudes and behaviours										
		HA2	Awareness										
		HA3	Motivation										
		HA4	Roles										
	Engagement (EG)	HEG 1	People management										
		HEG 2	People support										

		HEG 3	Stakeholder engagement										
		HEG 4	Teamwork										
Technology (T)	Infrastructure (I)	TI1	Appropriate hardware										
		TI2	Capacity to implement tools										
		TI3	Infrastructure										
	Software (S)	TS1	Appropriate software										
		TS2	Interoperability										
		TS3	Tech support										
		TS4	Compatibility										
		TS5	Constructability										
		TS6	Design errors										
		TS7	Less paperwork										
	Data (D)	TD1	Appropriate exchange of information										
		TD2	Efficiency										
		TD3	Data security										
	Protocols (P)	TP1	Policy										
		TP2	Standards										
Management (M)	Direction (D)	MD1	Leadership										
		MD2	Motivation										
		MD3	Vision										
		MD4	Top down approach										
		MD5	Bottom up approach										
		MD6	Commitment to change from top management										
		MD7	Flexibility										
		MD8	Management support										
		MD9	Subcontractors commitment										
	Transition (T)	MT1	Planning										
		MT2	Resistance to change										
		MT3	Risk Management										
		MT4	Adaptability										
		MT5	Align (Organisation objectives)										
		MT6	Management of information										
Economic (E)	Cost (C)	EC1	Cost control										
		EC2	Cost reduction										
		EC3	Implementation cost										
	Financial strategy (FS)	EFS1	Financial support										
		EFS2	Incentives										

		EFS3	Subsidies										
		EFS4	Return on investment (ROI)										
		EFS5	Market demand for BLS deliverables										
	Returns (R)	ER1	Increased competitive advantage										
		ER2	Increased value										
		ER3	Productivity improvement										
		ER4	Quality improvement										
		ER5	Resource optimisation										
		ER6	Increased economic performance										

End of questions

Annexe 3: Distribution of responses focus group

BLS organisational maturity framework				Factors importance								Current maturity								Factors		Maturity	
Category	Subcategory	Code	Factors	R1	R2	R3	R4	R5	R6	R7	R8	R1	R2	R3	R4	R5	R6	R7	R8	Avg	RII	Avg	RII
Process (P)	Business transformation (BT)	PBT1	Business process reengineering	4	4	5	5	4	5	5	5	3	4	3	3	3	4	3	4	4.63	0.93	3.38	0.68
		PBT2	Gradual change	4	3	5	4	4	5	5	5	4	4	4	4	4	4	4	4	4.38	0.88	4.00	0.80
		PBT3	Focus on long run	5	5	5	4	5	5	5	5	3	4	3	3	4	3	3	4	4.88	0.98	3.38	0.68
		PBT4	Change strategy plan	5	5	5	5	5	5	5	5	3	4	3	3	3	4	3	3	5.00	1.00	3.25	0.65
		PBT5	Continuous improvement	3	3	4	4	3	4	4	3	2	3	3	2	2	4	2	3	3.50	0.70	2.63	0.53
		PBT6	Government initiative	3	4	3	4	3	3	3	3	3	4	2	2	2	4	3	4	3.25	0.65	3.00	0.60
	Strategy (S)	PS1	Implementation strategy	5	5	5	5	5	5	5	5	3	4	3	3	3	4	3	3	5.00	1.00	3.25	0.65
		PS2	Strategic planning	5	5	4	5	5	5	5	5	3	4	3	3	3	4	2	4	4.88	0.98	3.25	0.65
		PS3	Alignment	5	5	5	5	5	5	5	4	4	5	3	3	3	5	3	5	4.88	0.98	3.88	0.78
		PS4	Resource allocation	2	3	3	3	4	3	3	3	3	4	3	3	2	4	3	4	3.00	0.60	3.25	0.65
	Culture (C)	PC1	Culture change	5	5	5	5	5	5	5	5	3	4	3	3	2	4	3	4	5.00	1.00	3.25	0.65
		PC2	Client experience in BLS	4	4	5	5	5	4	5	5	2	2	1	1	2	3	2	3	4.63	0.93	2.00	0.40
		PC3	Early contractor involvement	3	4	3	4	3	4	3	4	1	2	1	1	1	2	1	1	3.50	0.70	1.25	0.25

	Information (I)	PI1	Communication	5	5	5	4	4	4	4	4	3	3	3	3	3	2	3	4	4.38	0.88	3.00	0.60
		PI2	Collaboration	5	5	5	5	5	5	5	5	2	3	2	2	2	3	2	3	5.00	1.00	2.38	0.48
		PI3	Clear BLS policy	5	5	5	5	5	5	5	5	3	4	3	3	3	4	3	4	5.00	1.00	3.38	0.68
		PI4	Controlling and monitoring	2	3	3	3	3	4	4	5	3	3	3	3	3	4	3	4	3.38	0.68	3.25	0.65
Human and attitudinal (H)	Expertise (EX)	HEX1	Competencies of top staff	4	4	3	4	4	4	4	4	4	4	3	4	4	4	3	4	3.88	0.78	3.75	0.75
		HEX2	Skills	4	5	4	4	4	4	5	4	2	3	2	2	2	3	2	4	4.25	0.85	2.50	0.50
		HEX3	Champion	5	4	5	5	4	5	5	5	1	5	1	1	1	5	1	5	4.75	0.95	2.50	0.50
		HEX4	Understanding of the BLS concepts	5	5	5	5	5	5	5	5	3	4	3	4	4	3	3	4	5.00	1.00	3.50	0.70
		HEX5	Qualified staff	5	5	4	4	4	5	4	5	4	4	3	3	2	3	2	4	4.50	0.90	3.13	0.63
	Education (ED)	HED1	Education	5	3	3	3	4	4	4	4	3	3	3	3	3	3	3	4	3.75	0.75	3.13	0.63
		HED2	Knowledge	4	4	5	3	4	4	5	5	3	4	3	4	4	3	3	4	4.25	0.85	3.50	0.70
		HED3	Development	4	3	4	3	4	3	5	4	3	4	3	3	3	3	3	4	3.75	0.75	3.25	0.65
		HED4	Training	5	5	5	5	5	5	5	5	2	5	2	3	2	4	3	5	5.00	1.00	3.25	0.65
	Attitudes (A)	HA1	Attitudes and behaviours	3	4	4	4	5	4	4	5	3	4	3	3	3	4	3	4	4.13	0.83	3.38	0.68
		HA2	Awareness	4	4	4	4	4	4	5	4	4	5	4	4	4	4	4	5	4.13	0.83	4.25	0.85
		HA3	Motivation	3	5	4	4	5	4	5	4	3	4	3	3	3	3	3	4	4.25	0.85	3.25	0.65
		HA4	Roles	4	5	5	5	5	5	5	5	3	4	2	3	2	4	3	4	4.88	0.98	3.13	0.63
	Engagement (EG)	HEG1	People management	4	4	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4.13	0.83	4.00	0.80
		HEG2	People support	3	4	4	4	4	4	4	4	3	4	3	3	3	4	3	4	3.88	0.78	3.38	0.68
		HEG3	Stakeholder engagement	3	3	4	4	5	4	4	4	2	3	2	2	3	4	3	4	3.88	0.78	2.88	0.58

		HEG4	Teamwork	4	4	4	4	5	5	5	4	4	4	3	3	3	4	4	4	4.38	0.88	3.63	0.73
Technology (T)	Infrastructure (I)	TI1	Appropriate hardware	5	4	4	4	5	4	4	4	3	5	3	2	2	5	4	4	4.25	0.85	3.50	0.70
		TI2	Capacity to implement tools	5	5	5	5	5	5	5	5	3	5	3	2	2	5	4	4	5.00	1.00	3.50	0.70
		TI3	Infrastructure	5	4	3	4	3	4	5	4	3	4	4	2	3	4	3	4	4.00	0.80	3.38	0.68
	Software (S)	TS1	Appropriate software	4	4	4	4	4	5	4	4	3	5	3	3	2	5	4	4	4.13	0.83	3.63	0.73
		TS2	Interoperability	4	4	5	4	5	5	5	5	2	3	2	2	2	3	2	3	4.63	0.93	2.38	0.48
		TS3	Tech support	3	4	4	3	2	3	4	4	2	3	2	2	2	3	2	3	3.38	0.68	2.38	0.48
		TS4	Compatibility	4	4	5	3	3	3	5	5	3	3	3	3	3	3	3	3	4.00	0.80	3.00	0.60
		TS5	Constructability	2	2	4	3	2	3	3	3	2	2	2	2	2	2	2	2	2.75	0.55	2.00	0.40
		TS6	Design errors	2	3	3	3	2	3	2	2	3	3	3	3	3	3	3	3	2.50	0.50	3.00	0.60
		TS7	Less paperwork	2	2	3	3	1	1	2	2	3	3	3	3	3	3	3	3	2.00	0.40	3.00	0.60
	Data (D)	TD1	Appropriate exchange of information	5	4	4	4	5	4	5	5	3	4	2	3	3	4	3	4	4.50	0.90	3.25	0.65
		TD2	Efficiency	3	5	4	4	4	4	5	5	2	3	2	2	3	3	2	3	4.25	0.85	2.50	0.50
		TD3	Data security	5	5	5	4	5	5	5	5	2	3	2	2	3	3	2	3	4.88	0.98	2.50	0.50
	Protocols (P)	TP1	Policy	5	5	5	5	5	5	5	5	3	4	3	3	3	4	3	4	5.00	1.00	3.38	0.68
		TP2	Standards	4	4	4	5	4	5	5	5	3	3	3	3	3	3	3	3	4.50	0.90	3.00	0.60
Management (M)	Direction (D)	MD1	Leadership	5	5	5	5	5	5	5	5	3	4	2	3	2	4	2	4	5.00	1.00	3.00	0.60
		MD2	Motivation	5	4	4	5	4	5	5	4	2	3	3	3	3	3	3	4	4.50	0.90	3.00	0.60
		MD3	Vision	4	4	3	5	4	5	5	5	3	4	3	3	3	4	4	4	4.38	0.88	3.50	0.70
		MD4	Top down approach	4	4	3	5	4	5	5	5	4	4	4	4	4	4	4	4	4.38	0.88	4.00	0.80
		MD5	Bottom up approach	5	4	3	5	4	5	5	5	3	3	3	3	3	3	3	3	4.50	0.90	3.00	0.60

		MD6	Commitment to change from top management	5	5	5	5	5	5	5	5	4	5	4	4	5	5	4	5	5.00	1.00	4.50	0.90
		MD7	Flexibility	4	4	5	5	3	4	5	5	4	4	4	3	3	4	3	5	4.38	0.88	3.75	0.75
		MD8	Management support	5	4	5	5	5	5	5	5	3	3	4	3	3	4	3	3	4.88	0.98	3.25	0.65
		MD9	Subcontractors commitment	3	3	4	4	2	4	4	5	2	2	2	2	2	2	2	2	3.63	0.73	2.00	0.40
	Transition (T)	MT1	Planning	4	5	5	5	5	4	5	5	3	4	3	3	3	4	3	4	4.75	0.95	3.38	0.68
		MT2	Resistance to change	5	5	5	5	5	5	5	5	2	3	2	2	2	3	2	3	5.00	1.00	2.38	0.48
		MT3	Risk Management	4	5	5	5	5	5	5	5	2	4	2	3	2	4	3	4	4.88	0.98	3.00	0.60
		MT4	Adaptability	3	5	5	5	3	4	4	5	3	4	2	4	3	3	4	4	4.25	0.85	3.38	0.68
		MT5	Align (Organisation objectives)	5	5	5	5	5	5	5	5	3	4	3	4	3	4	3	4	5.00	1.00	3.50	0.70
		MT6	Management of information	4	4	4	5	3	3	5	5	2	4	3	3	3	4	3	4	4.13	0.83	3.25	0.65
Economic (E)	Cost (C)	EC1	Cost control	4	4	3	3	3	3	4	4	2	3	2	2	2	3	2	3	3.50	0.70	2.38	0.48
		EC2	Cost reduction	4	4	4	3	3	3	4	4	2	2	2	2	2	3	3	3	3.63	0.73	2.38	0.48
		EC3	Implementation cost	5	5	5	5	5	5	5	5	3	4	2	3	2	4	3	4	5.00	1.00	3.13	0.63
	Financial strategy (FS)	EFS1	Financial support	5	5	5	5	5	5	5	5	2	2	2	2	2	2	2	2	5.00	1.00	2.00	0.40
		EFS2	Incentives	5	5	5	5	5	5	5	5	2	2	2	2	2	2	2	2	5.00	1.00	2.00	0.40
		EFS3	Subsidies	5	5	5	5	5	5	5	5	1	2	2	1	1	2	1	2	5.00	1.00	1.50	0.30
		EFS4	Return on investment (ROI)	3	5	4	3	4	4	4	5	1	1	1	1	1	1	1	1	4.00	0.80	1.00	0.20
		EFS5	Market demand for BLS deliverables	5	5	5	5	5	5	5	5	3	4	3	3	3	4	3	4	5.00	1.00	3.38	0.68

	Returns (R)	ER1	Increased competitive advantage	2	3	5	3	3	4	3	4	2	3	2	2	2	3	3	3	3.38	0.68	2.50	0.50
		ER2	Increased value	2	2	4	5	3	4	3	3	3	3	2	2	2	3	3	3	3.25	0.65	2.63	0.53
		ER3	Productivity improvement	2	3	4	2	3	3	3	3	2	3	2	2	2	3	3	3	2.88	0.58	2.50	0.50
		ER4	Quality improvement	2	4	4	2	3	3	3	4	3	3	2	2	2	3	2	3	3.13	0.63	2.50	0.50
		ER5	Resource optimisation	2	4	4	4	3	3	3	3	2	3	2	2	2	3	2	3	3.25	0.65	2.38	0.48
		ER6	Increased economic performance	2	4	4	2	4	4	3	3	2	3	3	3	3	3	3	3	3.25	0.65	2.88	0.58

Annexe 4: List of publications

F. Mellado, ECW. Lou (2020). Building Information Modelling, Lean and Sustainability: An integration framework to promote performance improvements in the construction industry. Sustainable Cities and Society. 61, pp.102355-102355.

F. Mellado, PF. Wong, K. Amano, C. Johnson, ECW. Lou (2020). Digitisation of existing buildings to support building assessment schemes: viability of automated sustainability-led design scan-to-BIM process. Architectural Engineering and Design Management. 16(2), pp.84- 99.

F. Mellado, ECW. Lou, CLC. Becerra (2019). Synthesising performance in the construction industry: An analysis of performance indicators to promote project improvement. Engineering, Construction and Architectural Management. 27(2), pp.579-608.

H. Valdes, C. Correa, **F. Mellado** (2018). Proposed model of sustainable construction skills for engineers in Chile. Sustainability, 10 (2018), p. 3093