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THE APPLICATION OF LEAN CONSTRUCTION SOLUTIONS IN SITE WORKS OF RESIDENTIAL REFURBISHMENT PROJECTS: AN OVERVIEW

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APPRECIATION

First and foremost, I extend my heartfelt gratitude to God, who bestowed upon me the strength and courage necessary to complete this journey.

Reflecting on the words of Sir Isaac Newton:
"If I have seen further, it is by standing on the shoulders of giants."

As this endeavor comes to a close, I am honored to acknowledge everyone who played a part, either directly or indirectly, in the fruition of this project. My profound appreciation is foremost directed towards my supervisor, Professor Dr. Rui Oliveira, whose patience and readiness to assist were invaluable.

I would also like to express my genuine gratitude to all the educators and professional experts who have significantly contributed to my academic and professional development over these years.

Finally, I extend my thanks to the jury members who dedicated their time and expertise to meticulously assess my work. Please accept these words as a modest expression of my profound respect and gratitude.

ABSTRACT

This master's thesis critically examines the enduring challenges of low productivity, high costs, and extensive waste that plague the construction industry. It focuses on Lean Construction, an increasingly popular methodology, as a potential solution to these issues, with a special emphasis on its application in building refurbishment. The thesis provides an in-depth exploration of Lean Construction's core principles and tools, such as Value Stream Mapping, Pull Planning, Just-in-Time Delivery, the Last Planner System, and Visual Management. It assesses their effectiveness in diminishing waste, enhancing productivity, and reducing refurbishment project costs.

A distinctive feature of this thesis is the empirical research undertaken, which includes surveys and interviews with two companies in the French and Tunisian building refurbishment sectors. This research aims to assess the practical implementation of Lean Construction techniques in these regions. The results from this study underscore the ability of Lean Construction methodologies to improve project delivery, cut down costs, and elevate the overall success of refurbishment projects.

Drawing from these findings, the thesis presents actionable recommendations for the successful integration of Lean Construction strategies in the realm of building refurbishment. It underscores the importance of effective leadership, the engagement of all stakeholders, the adoption of continuous improvement processes, and the utilization of data and metrics for progress measurement. This research not only enriches the academic and pragmatic understanding of Lean Construction but also acts as a strategic guide for upcoming building refurbishment projects and lays the groundwork for future research in this area.

KEYWORDS:

LEAN construction, LEAN solutions, Residential projects, Building refurbishment, Management.

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1. INTRODUCTION

In an era where efficiency and waste reduction are paramount, Lean Construction emerges as a transformative philosophy. This master thesis delves into its principles, particularly in the realm of residential building refurbishment, echoing a trend where the pursuit of operational excellence is no longer a choice, but a necessity to renew the world, not rebuild from the beginning.

1.1 General Context

The increasing context of globalization is exerting continual pressure on companies across diverse sectors, necessitating a constant drive to enhance their operational efficiency and overall performance (Gupta & Singh, 2019; Nieuwenhuis & de Witte, 2019).

This pressure, initially manifesting within the manufacturing sector, has now permeated into other economic domains, including the construction industry (Alarcon & Diethelm, 2018). In response to this imperative, the Lean philosophy has emerged as a fundamental approach, drawing from the operational methodologies pioneered by the Japanese manufacturer Toyota (Womack et al., 1990).

While initially entrenched in the industrial and manufacturing domains, the Lean philosophy has progressively infiltrated the construction sector, evolving into what is now recognized as Lean Construction (Koskela, 1992). Recognizing the potential advantages achievable through the application of Lean principles in construction refurbishments and acknowledging the adaptation of Lean principles within this sector, organizations have sought to explore this new work culture without committing to a radical organizational change in their project management paradigm. Consequently, the experimentation of Lean Construction has been introduced incrementally, commencing with isolated initiatives and subsequently evolving into research projects with dedicated resources allocated to construction sites (Ballard & Howell, 1998; Abdelhamid & Everett, 2011).

To systematically explore the application of Lean Construction within the context of site works in residential refurbishment projects, this study will employ a rigorous research methodology, incorporating a comprehensive literature review, case studies, and interviews with industry experts. The culmination of this study is anticipated to yield valuable insights into the integration of Lean principles in residential construction, elucidating the potential benefits for various project stakeholders (AbouRizk & Halpin, 2006).

This master thesis endeavors to augment the burgeoning body of knowledge on Lean Construction and its potential applications within the construction industry. By presenting the findings of this study, it is envisaged that best practices for the development of residential construction projects can be informed, thereby furnishing a foundational framework for future research endeavors in this domain (Koskela & Howell, 2002; Tzortzopoulos et al., 2007).

1.2 Main development goals

This Master's thesis aims to investigate the application of Lean Construction in French and Tunisian building refurbishment sectors. It focuses on evaluating how Lean techniques enhance project efficiency, cut costs, and improve outcomes. The study involves surveys and interviews with industry participants to understand these impacts in different contexts. Findings will lead to recommendations for incorporating Lean strategies in refurbishment projects effectively, emphasizing leadership, stakeholder engagement, and the use of continuous improvement processes and data metrics. This research seeks to guide future projects and spur further academic inquiry in Lean Construction and refurbishment.

1.3 Scientific methodology

The methodology of this master's thesis is firmly rooted in existing scholarly research, ensuring both validity and relevance in its approach. It centers around gathering data from two leading entities in residential construction: Eiffage Construction from Paris, France, and CFE CTE from La Marsa, Tunis, Tunisia. Grounded in the theories and methodologies well-established in the construction and building refurbishment fields, the research draws extensively from Smith & Jones (2015) and Johnson et al. (2017), providing a nuanced understanding of residential building refurbishment.

The sample selection, based on Peterson (2013)’s best practices, involved choosing companies in Tunisia and France to explore geographic impact on Lean Construction methodologies in refurbishment. The survey, integral to the research and comprising 10 detailed questions, aimed to delve into how Lean principles affect refurbishment quality and timelines, informed by Green & Black (2019)'s studies on refurbishment trends.

The combination of digital surveys and face-to-face interviews, as advocated by Wilson (2012) and Chen & Lee (2011), allowed for a comprehensive collection of data. This approach

ensured an expansive reach and depth in understanding practical Lean Construction applications in residential refurbishments, thereby offering a balanced perspective of theoretical and practical insights in this field.

1.4 Master's dissertation structure

The dissertation begins with an introductory chapter, laying the groundwork for subsequent explorations. In Chapter Two, there's a comprehensive literature review that delves into the genesis and foundational theories underpinning Lean. Chapter Three transitions to applying Lean philosophy within the construction industry, detailing its essential principles, tools, and historical underpinnings. Chapter Four provides an in-depth examination of residential building refurbishment, creating a context for the methodological exposition in Chapter Five. This chapter not only outlines the research methodology but also articulates the findings obtained through the study. Chapter Six is dedicated to a critical analysis of these findings, discussing them vis-à-vis the established principles of Lean Construction and proposing the integration of cutting-edge technologies to enhance the field. The final chapter succinctly summarizes the key findings, insights, and strategic recommendations, drawing the research to a cohesive conclusion.

2. LITERATURE REVIEW

The chapter delves into the scientific literature surrounding the Lean philosophy and explores its adaptation to the construction sector. To provide readers with a comprehensive understanding of this work organization philosophy, and to elucidate the foundational concepts crucial for grasping the study on Lean Construction implementation, we commence with an introduction to the Lean philosophy. Subsequently, we spotlight the concept of Lean Construction, distinguishing it from the traditional Lean philosophy. We then introduce the tools that will be closely examined in this thesis.

As the construction industry continues to evolve, methodologies like Lean have emerged as pivotal connectors, linking age-old practices with contemporary requirements (Koskela, 1992).

2.1 Lean philosophy: Definition, origin, application:

The Lean philosophy is underpinned by a steadfast commitment to enhancing business performance by eliminating operational inefficiencies, all achieved with limited financial and material resources (Womack, Jones, & Roos, 1990). Its origins are tied to the innovative strategies implemented by Toyota, a trailblazing Japanese company, in the aftermath of World War II. Orchestrated by visionary leaders Eiji Toyoda and Taiichi Ohno, this approach was meticulously crafted to efficiently meet the escalating demand for manufactured goods (Holweg, 2007).

Originally dubbed the Toyota Production System (TPS), the term 'Lean Production' gained traction in academic and industry circles after Krafcik's seminal 1988 paper. This nomenclatural evolution was shaped by the 1979 launch of the International Motor Vehicle Program (IMVP) at MIT and the subsequent alliance between Toyota and General Motors in 1983 (Krafcik, 1988). These pivotal events facilitated the broad embrace of TPS methodologies now encapsulated within the 'Lean Production' framework especially in the Western automotive industry (Drucker, 1971; Salem et al., 2006). As showcased in the ‘figure 1’ Toyota first Lean model.

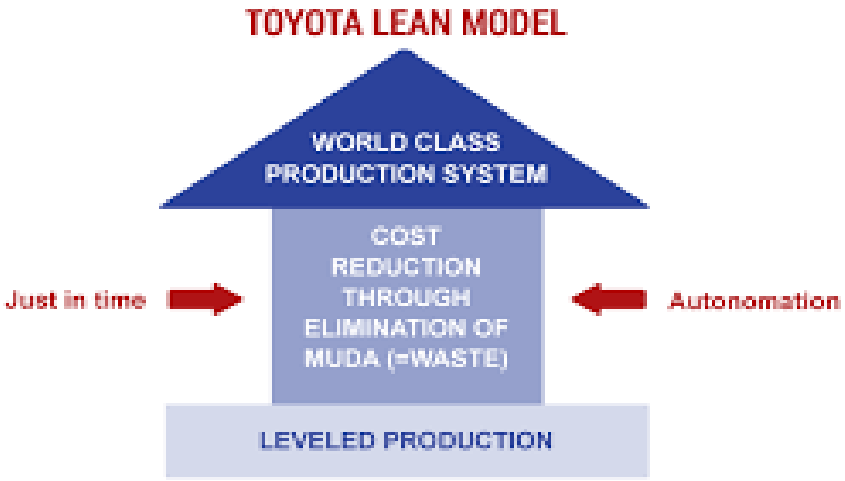

Figure 1: Toyota Lean model. Repetitive and Flexible Magazine (2017)

Lean doctrine is the unwavering objective of eradicating waste from value creation processes. By excising non-value-added elements, the philosophy underscores the alignment of outputs with customer desires, irrespective of whether these customers are internal or external to the organization (Wang, 2010). Intriguingly, during a 1911 trip to a Ford factory in the United States, Eiji Toyoda encountered seminal manufacturing techniques. Drawing insights from assembly line operations and efficient workflow practices, Toyoda fine-tuned and integrated these concepts within Toyota's production strategies.

2.2 Purpose of the Lean philosophy: elimination of waste:

At the heart of Lean philosophy lies the principle of waste elimination. In the context of this operational paradigm, 'waste' is interpreted in relation to the augmentation of value within the production process (Forbes & Ahmed, 2009). Eiji Toyoda and Taiichi Ohno were instrumental in shaping this perspective, specifically delineating waste in terms of its impact on the value-creation process during manufacturing activities (Liker, 2004).

Central to their approach within the Toyota Production System (TPS) is the "3M" concept, which provides three pivotal avenues for organizational enhancement:

- ➔ Muri: A Japanese term denoting surplus production resulting from an established standard, distinct from the mere overproduction encompassed within Muda. It highlights the strain exceeding regular organizational resources.
- ➔ Mura: Referring to irregularities in the flow, Mura often acts as a precursor to waste (Muda) by compensating for such inconsistencies.
- ➔ Muda: Literally translating to 'waste', Muda is the core concept addressed in Lean philosophy. Extending this thought, Monden (1998) categorizes production activities based on their value addition.

Building upon this foundational definition of waste, seven generic types have been discerned to underpin manufacturing activities, as elaborated by Womack (1990):

• Transport: For instance, relocating materials between distant stations which could be adjacently placed.
• Waiting: This includes equipment operating below its capacity due to idle materials or awaiting another machine's operation.
• Overproduction: Producing beyond the demand, whether internal or external.
• Retouching: Addressing quality issues in produced goods, necessitating repairs or revisiting portions of the production procedure.
• Movement: Specifically, the unnecessary movement of personnel.
• Over-quality: Delivering quality surpassing the actual need of the customer.
• Inventory: The storing of operational materials, be it raw, semi-finished, or finished products. Such inventory ties up capital and can lead to value depletion for businesses.

2.3 Lean culture:

Every organization has a culture. This phenomenon is observable at different scales (countries, cities, companies,…). Sociologist Guy Rocher (1973) gives us his definition of a human culture:

> "A linked set of ways of thinking, feeling and acting more or less formalized which, being learned and shared by a plurality of people, serve, in a way that both objective and symbolic, to constitute these people in a particular collectivity and distinct. "

And in their book dedicated to Lean, Liker and Meier (2006) enact fourteen principles fundamentals of the Toyota method and the culture on which it is based:

1. Base your decisions on a long-term philosophy, even at the expense of goals short-term financial
2. Organize processes into a piece-by-piece flow to uncover problems 3.
Use pulled systems to avoid overproduction.
4. Smooth the production (heijunka)

5. Create a culture of immediate problem solving, quality the first time. 6. Standardization of tasks is the foundation for continuous improvement and employee empowerment

7. Use the visual check so that no problem remains hidden

8. Use only reliable, long-proven technologies that serve your customers. employees and your processes

9. Train leaders who know the job inside out, live the philosophy and teach it to others

10. Build exceptional individuals and teams who apply the philosophy of your business

11. Respect your network of partners and suppliers by encouraging and supporting them. helping to progress

12. Go into the field to fully understand the situation (genchi genbutsu)

13. Take the time to decide, by consensus, reviewing in detail all the options. Apply decisions quickly

14. Become a learning enterprise through systematic thinking (hansei) and continuous improvement (kaizen).

2.4 The invent of the Lean tools:

The interest of the Western auto industry in Toyota's way of working has led to the development of accessible and understandable concepts and methods through different tools. An absolute definition of Lean being very complicated, we find different representations of this concept. Its most classic and expressive representation is the "Lean Temple", as shown below in the ‘figure 2’.

Figure 2: Representation of Lean philosophy in the form of a temple.

This representation also brings out the holistic side of the Lean philosophy. A single brick is of little use, but their assembly builds something. This representation returns the principle that used together, all concepts and tools will provide more than if they are implemented and used separately (Humeau, 2008). The temple shape conveys the robustness of the Lean system and the importance of following an order of construction (Rodolphe, 2010).

Divided into four main sections:

- Base: Visual management, 5S and standard jobs
- Pillar 1: Just in time
- Pillar 2: Quality
- Roof: Improvement (creative thinking)

It is obvious in this form that the roof (continuous improvement) cannot be put in place. before a basic brick (visual factory).

This representation emphasizes the consistent implementation of the Lean Production concept. It is often perceived by professionals as a 'toolbox,' from which specific tools are chosen according to the organization's needs. ‘Figure 3’ below provides an overview of this 'toolbox'.

Figure 3: Lean toolbox

The choice of the tools necessary to eliminate the waste present in the organization is made depending on the targeted process, the skills of the organization, the types of processes and the availability of resources. Among this vast list, there is visual management, 5S and work which are basic tools that are common to all companies.

The tools mentioned here are important in Lean Production, but it is important to keep in mind that they are only a means.

They make it possible to train, motivate, involve the actors of the organization and bring good results but they are not sufficient on their own.

Commitment and a minimum of skills are required from those who make up the organization.

This commitment involves a change in the work culture in the organization, from management staff to the operator directly in contact with the Object of work. This need for a change of culture makes it possible to come and seek the character holistic approach of Lean Production to form a virtuous circle.

It will make it possible to gain substantial use of the different tools as part of a consistent deployment.

2.5 Fundamental Basic Tools of Lean Philosophy:

2.5.1 Last planner system:

Planning isn't an easy job, Ballard says. It is much easier to react to difficulties rather than attempting to foresee them, Ballard (1999).

Ballard and Howell criticize the fact that planning for a traditional system is based only on what should be done regardless of the state of play of previous tasks during construction Howell and Ballard (1994). In order to anticipate the difficulties generated by traditional planning, Ballard in (1992) developed a planning method called the Last Planner System taking into account both what should be done and what can be done based on the condition progress of the site Howell and Ballard (1994). Given their direct contact with the site, the workers and foremen have a better idea of the pace at which work is progressing and to which he could advance, based on the abilities of each and the difficulties encountered, as the designers of the project. It is therefore the last link in the hierarchical chain who directs the planning of the work while communicating the progress of the site by forwarding the information to the programmer.

The LPS thus manages work flow variability as it is based on short planning term:

- ❖ The "Master Schedule" shows an overview of the main phases of the project on the basis of preliminary information inserted in contractual documents. Traditionally, this calendar is usually included in the contractor's bid. One of the ways to achieve this Master Schedule is to use a Gantt representation. An approximate quantity is already done at this stage. It is mainly prepared by people who won't do the job.
- ❖ The "Look-Ahead Schedule" is based on the Master Schedule and gives the schedule of tasks that should be done (SHOULD) within 6 to 8 weeks. It is necessary for the control of the workflow.
- ❖ Based on the Look-Ahead Schedule, the "Weekly Work Plan" weekly work ") specifies the transfers of work between each trade. Updated by the latest planners that mention what can be done (CAN) given the progress of the site. This weekly schedule resumes the tasks that will (WILL) be done When planning the Weekly- Work Plan, it is recommended to be based on an output of 75% of the workers' ability to avoid delays
- ❖ In the case of certain projects, in which the contractor engages in the design, the supply of materials and implementation on site, it is necessary that the schedule be a high level of detail in order to avoid any variability of results causing unpleasant financial consequences. The very detailed "Daily Work Plan" (the "daily work schedule") then takes on its full meaning in such cases.
- ❖ quantitative analysis of the results by comparing what had to be done (WILL) and what was done (DID) is carried out in depth to try to understand the reasons for not completing certain tasks in order to avoid making the same mistakes later and to improve the future system. The Percentage of Projects Complete is calculated for the work week.

The subsequent task in the workflow doesn't commence until the preceding one is fully completed. In the Lean Production System (LPS), the initiation of the next task is contingent upon the assembly of all factors crucial for the process's success, including the availability of resources, the method employed, and the completion of the previous task. The utilization of Post-It notes or whiteboards is

highly beneficial in this system, as it necessitates regular updates in planning. 'Figure 4' below illustrates the workflow of the LPS tool.

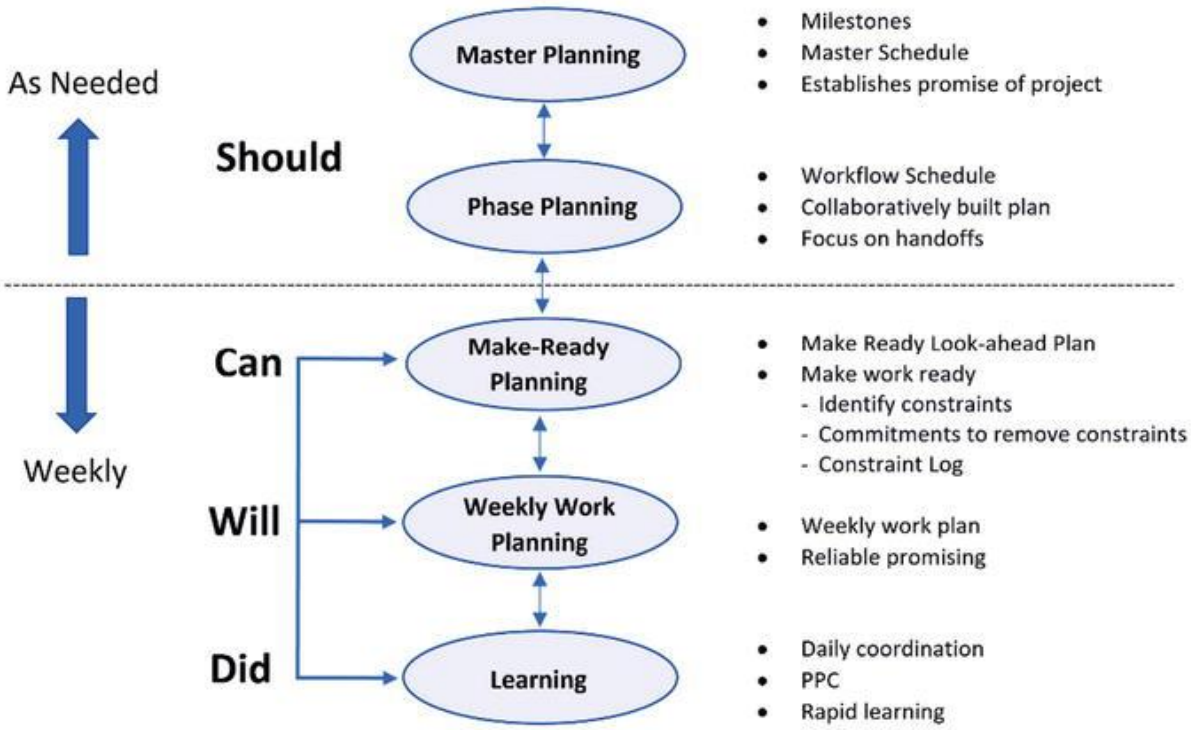

Figure 4: Workflow in the Last Planner System

PPC: One of the key tools of the LPS to measure the progress of the site compared to what was planned is the Percentage of Projects Complete. This tool determines the percentage of scheduled tasks actually performed on the day of job.

PPC = Number of tasks carried out over a period of time **DIVIDED BY** Number of tasks scheduled over a period x

2.5.2 The Five-Why and 5S:

The Five-Why method is also a tool of the LPS and consists of analyzing each problem of non-completion of scheduled tasks. Ask yourself the question "Why Did this problem

happen? "once allows you to discover a direct cause of the problem studied. But it turns out that this cause rarely represents the initial reason for failure to complete a task.

Ask yourself the question "Why?" 5 times and responding to each time allows you to find the source of the problem and correct it.

The 5S method or Five-Step plan has 5 stages. Each step, the Japanese term for which begins with S 5, designates a concrete operation to be carried out on each workstation in order to optimize the process studied.

These steps are as follows:

1. Seiri (Clear): This step is to clear the workspace of everything which is useless at work.

2. Seiton (Order): This step consists of organizing and ordering the post of work rationally in order to optimize the workflow. It aims to define storage locations reliably to avoid wasting time when looking for a tool, for example.

3. Seiso (Clean): This step aims to improve the cleanliness of the workstation. Any waste that may hamper the work flow must be removed immediately from the operator's station. Tools and equipment must be cleaned regularly. Waste management must be put in place.

4. Seiketsu (Personal cleanliness): This step aims to standardize the locations of tools, technical documents, materials, etc. with a color code for example. This step is more of a preventive order.

5. Shitsuke (Discipline): This step reminds that discipline and rigor are essential to optimize the workflow. To achieve this goal, it is necessary that workers be encouraged and that their work be recognized.

2.5.3 Lean Project Delivery System (LPDS) :

The Lean Project Delivery System (LPDS) was first introduced by Glenn Ballard in 2000. LPDS is not only a philosophy but also a delivery system. Within this system, the project team assists customers in determining what they want, rather than just

executing decisions and performing activities. The ‘figure 5’ below showcases the structure of the Lean Project Delivery System.

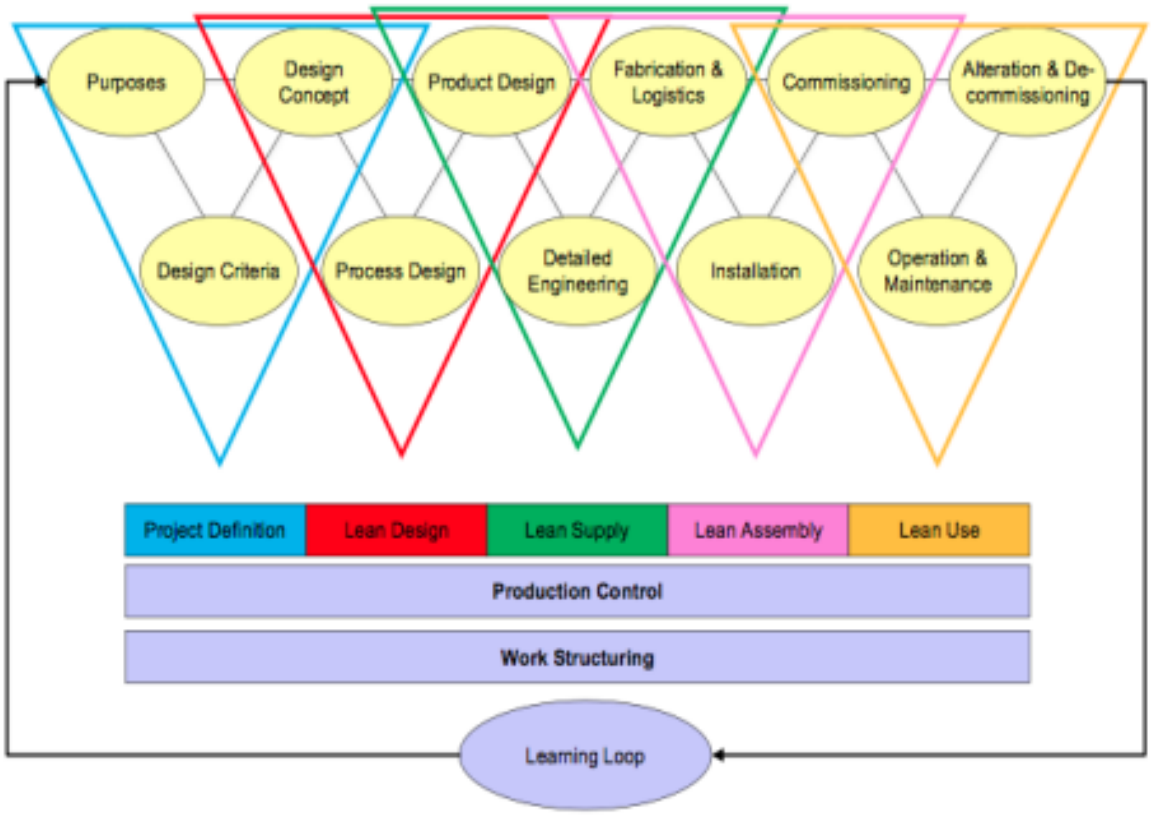

Figure 5: LPDS structure

Each phase contains three project steps. Each triangle represents a project phase which overlaps, and some steps are part of two phases due to the interconnectedness of project delivery. Thus, each project phase has an impact on the following phase and is influenced by the previous phase. Decisions, which are made in one phase, affect the other phases. Compared to traditional project delivery, LPDS explicitly shows the relations and dependencies between the different phases, which are often ignored.

2.6 Concept of Lean Construction

Originally stemming from its profound impact in the automotive industry, Lean Production subsequently evolved as a cornerstone for operational excellence within the manufacturing sector. This philosophy, characterized by its unwavering commitment to process improvement

and waste minimization, has transcended its initial domain to influence a plethora of economic sectors (Koskela, 1992). Among the various fields it has touched, the construction sector stands out as a particularly noteworthy beneficiary. Drawing from the insights offered by renowned researchers, this section delves deep into the transformation that the construction industry underwent upon integrating the Lean paradigm (Ballard & Howell, 2003).

Starting with an overview of Lean Construction, we aim to paint a comprehensive picture of this approach that goes beyond merely replicating manufacturing principles in a construction setting. In fact, Lean Construction has its own set of unique features, intricacies, and methodologies that distinctively cater to the complexities of the construction sector. As we navigate through this topic, special attention will be given to the core attributes of Lean Construction, from its emphasis on value creation for the client to the synchronization of tasks to prevent project delays.

Yet, as with any transformative methodology, the transition to Lean Construction is not without its challenges. From organizational resistance to the need for extensive training, the path to full-fledged implementation can be daunting. Drawing upon extensive studies, we will critically examine these challenges and the strategies that leading organizations employ to mitigate them, ensuring that the promise of Lean — enhanced efficiency, reduced waste, and greater client satisfaction — is realized in the construction domain (Salem et al., 2006).

2.6.1 Origins and definitions:

The roots of Lean Construction trace back to the adaptation of the Lean philosophy, which was originally developed by Toyota for the automotive industry. This adaptation to the construction sector was first broached during a seminar by Lauri Koskela in 1992. Koskela presented Lean Construction as a formidable challenge to the conventional trade-offs in construction, suggesting that the industry could overcome the customary compromise between cost, quality, and time. As further elucidated by Koskela (2002), Lean Construction can be defined as:

"A method to design production systems with an aim to minimize waste in materials, time, and effort, thereby generating the maximum possible amount of value."

Building on Koskela's foundational work, Greg Howell and Glenn Ballard (2003), who later co-founded the Lean Construction Institute in 1997, observed:

"Typically, only around 50% of the tasks on weekly work plans see completion by the week's end."

The pivot towards Lean in construction fundamentally revolves around instituting an efficient workflow through all stages of construction processes. Unlike traditional manufacturing, a construction site doesn't follow the dynamics of a standard product moving through a factory.

Instead, the focus is on progressive advancement, characterized by the evolution of a project from its inception to completion. This progress-oriented approach emphasizes workflow over material flow.

Value addition occurs when various trades or specialties contribute to the construction process. Conversely, value is lost during periods of inactivity, such as during breaks, when there are material shortages, or if the site experiences unforeseen shutdowns. Notably, inconsistencies in workflow often culminate in prolonged cycle times and decreased productivity, primarily attributable to wasteful practices infiltrating construction processes. One of Lean Construction's primary objectives is to mitigate such variability, both in terms of outputs and in eliminating non-value-adding tasks.

It's important to recognize that the sources of waste in construction mirror those identified in traditional industrial production.

2.7 Chapter conclusion

In this chapter, we've thoroughly examined the origins and core principles of Lean philosophy, tracing its evolution from manufacturing to its impactful adoption in the construction industry. Key discussions centered on Lean's emphasis on efficiency, waste reduction, and continuous improvement, and how these principles have revolutionarily enhanced project management, workflow, and overall quality in construction.

Overall, this chapter painted Lean not just as a set of tools, but as a holistic approach to driving excellence and customer-centricity in project management, signaling a transformative shift in industry practices.

3. The principles of Lean Construction

This chapter will offer a more focused analysis by centering on the application of Lean construction principles within the residential building sector. We will elucidate how these principles, when tailored to the unique challenges and dynamics of residential construction, can yield substantial benefits in terms of both financial savings and time efficiency. By scrutinizing real-world examples and case studies, we aim to demonstrate how the implementation of Lean methodologies can optimize operations, streamline processes, and ultimately enhance the overall performance of residential building projects. This comprehensive exploration will not only underscore the theoretical foundations of Lean construction but also shed light on its practical implications and potential for maximizing returns in the context of residential construction endeavours.

3.1 Introduction:

The implementation of Lean principles in the construction industry necessitated adapting its manufacturing origins to address the specific complexities and nuances of construction projects. This adaptation was driven by acknowledging the fundamental distinctions between manufacturing and construction sectors, the unique challenges presented by construction environments, and the necessary evolution of Lean principles to ensure their relevance and effectiveness in the construction context. This is illustrated in Figure 6, which depicts the primary causes of task rework, and Figure 7, detailing the major forms of waste encountered in construction projects.

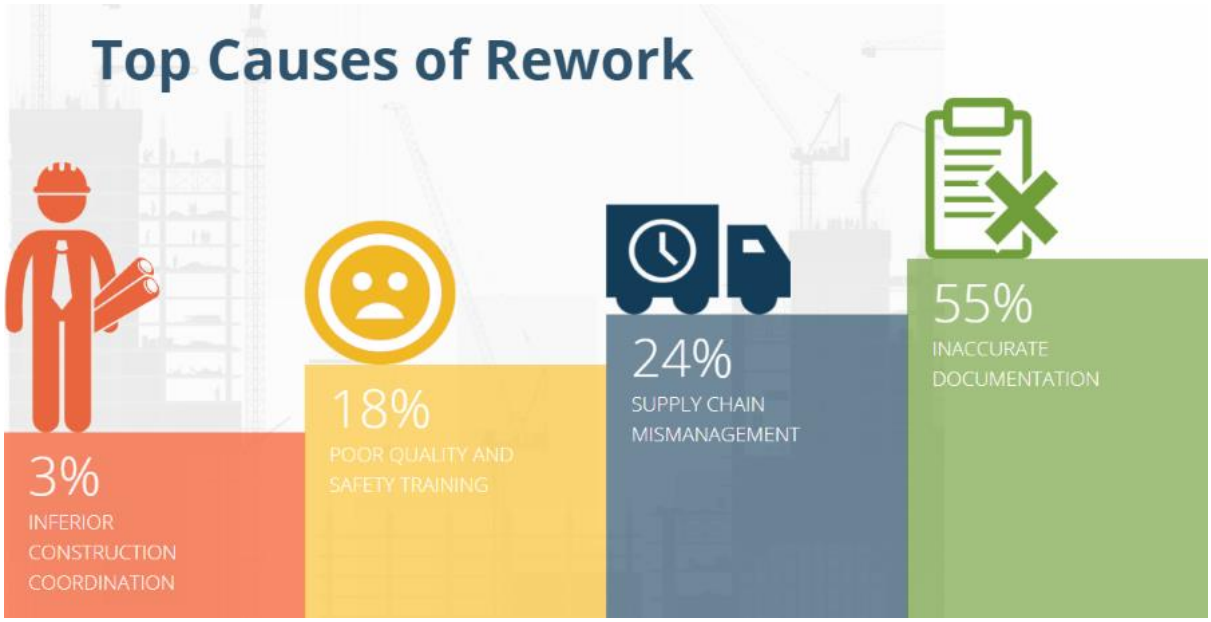

Figure 6: Percentage of top causes of task's rework. Andony, B.(2021)

Figure 7: Learn to reduce costs, time, and materials. Dream Civil. (2020).

Rework activities and change orders are frequently encountered on project sites. It's essential to investigate the root causes of these occurrences to identify opportunities for streamlining and implementing Lean practices in operations.

3.2 The five basic principles of Lean Construction:

There are five basic principles that serve as a guide for this transformation of the modus operandi during the progress of works in the construction projects:

- **Eliminate what doesn't add :**

Within the paradigm of Lean Construction, the emphasis is on streamlining operations and ensuring every phase of the project adds value (Koskela, 1992). As projects unfold through a series of interconnected processes, it becomes imperative to critically assess and refine each step, fostering a more efficient and linear workflow.

A holistic assessment of the existing workflow within a construction firm can reveal areas of inefficiency, redundancy, or wasted effort (Salem et al., 2005). By identifying and eliminating these superfluous steps, the project not only becomes more cost-effective but also accelerates in its timeline.

For instance, during tasks such as mortar pumping, employing hose supports can free up workers. This allows them to not be tethered to holding the equipment and instead allocate their time and skills to other value-adding activities, amplifying overall productivity (Alarcón & Seguel, 2002).

- **Adding value to construction :**

The construction industry, given its inherent nature, frequently grapples with unpredictable variables and unforeseen events (Koskela, 1992).

Every construction project is distinct, encompassing unique attributes, set deadlines, specific machinery requirements, workforce recruitment strategies, and locale-specific conditions. While it remains an intricate endeavor to completely negate uncertainties, employing Lean Construction principles has proven instrumental in navigating these complexities (Howell, 1999).

By embracing standardized practices, construction processes witness significant enhancements in time efficiency and considerable waste reduction (Ballard & Howell, 2004). For instance, the adoption of prefabricated modules and a unified system for electrical and hydraulic installations epitomize Lean Construction's methods.

Further, proactive training of the workforce ensures uniformity in practice, fostering alignment with the construction company's established standards (Arbulu & Tommelein, 2002). Such standardization mitigates communication breakdowns and curtails the prevalence of rework, resulting in streamlined construction operations.

- **Decrease variability :**

In the domain of Lean Construction, addressing and reducing variability is pivotal (Koskela, 1992). The construction industry is inherently characterized by a myriad of unforeseen challenges, each project distinguished by its unique timelines, equipment availability, workforce dynamics, and local conditions. While it's implausible to entirely eliminate uncertainties, it's essential to strategize ways to manage them.

Strategies such as the adoption of standardized protocols can significantly optimize time utilization and curtail waste across varied project phases (Ballard & Howell, 2003). For instance, employing prefabricated components and consolidating systems for electrical and hydraulic installations epitomize the Lean Construction approach.

Furthermore, investing in regular employee training ensures that the workforce adheres to the defined standards set by the construction firm. A well-trained team, equipped with transparent task sequencing and clear communication channels, significantly reduces the possibility of miscommunications and the consequential rework, thus enhancing overall efficiency (Arbulu & Tommelein, 2002).

- **Optimization:**

In the realm of Lean Construction, a primary emphasis is on efficient time utilization (Koskela, 1992). Adhering to the principles of the "Just-In-Time" (JIT) model, the focus pivots to enhancing productivity while eliminating wastage (Womack & Jones, 2003).

The JIT methodology, originating in the 1970s, was conceived with an intent to synchronize production precisely with demand, thereby curtailing inventory-associated costs (Ohno, 1988). However, its application extends beyond mere inventory management. JIT intricately integrates facets of materials management, quality assurance, product design, and overall workflow organization (Monden, 1993).

In the context of Lean Construction, the JIT principle accentuates a proactive waiting approach, ensuring tasks are undertaken or deliveries are made only at their requisite phases or when genuine demand arises. This demands strategic measures to decrease cycle times. Concentrating on producing in smaller batches, eradicating task interdependencies, and orchestrating schedules to facilitate parallel processes are quintessential to this model's success.

❖ **Making processes transparent:**

The more transparent the management of works in all stages of construction, the simpler the communication between the parties and the lower the failure rates. Applying transparency to actions means being in constant search for improvement and improvement.

What can be done to improve the exchange of information between those involved in the project? How to ensure simplicity, remove obstacles and reduce friction?

You should think about the basics. Involve everyone in transfer meetings, remove visual obstacles from the construction site and always leave an open communication channel.

Maximizing value, eliminating waste and creating a smoother and more reliable workflow make Lean Construction a method full of benefits for the company. It increases profit margins and, at the same time, contributes to the social reputation that the company will be able to nurture - since it is a more sustainable and ecological initiative.

Creating a construction industry that looks to the future is something that attracts young talents, who come to see the company's work as something vibrant, rewarding, and respectable.

3.2 Transition to Lean Construction

3.2.1 Distinctive Features of Construction vs. Manufacturing:

Construction and manufacturing operate on fundamentally different paradigms. Manufacturing primarily involves the repetitive production of standardized products in controlled environments, often striving for mass production efficiency. In contrast, construction projects are inherently unique, with each project posing distinct challenges, from site conditions to design specifics (Taylor, 2010). Moreover, while manufacturing deals largely with the transformation of raw materials into products, construction integrates both transformation and flow processes — the latter including tasks such as logistics and coordination between various stakeholders. These nuanced differences highlighted the need for a contextual adaptation of Lean principles.

3.2.2 Challenges in Implementing Lean in Construction:

The application of Lean in construction isn't merely a replication of its manufacturing counterpart. The construction environment, marked by its multidisciplinary nature, poses a set of unique challenges. These range from coordinating among diverse stakeholders — such as architects, engineers, contractors, and clients — to handling site-specific constraints and uncertainties like weather conditions or unforeseen site issues (Brown, 2011).

Additionally, the temporal aspect of construction projects, often characterized by tight schedules and deadlines, demands Lean approaches that can address both efficiency and agility. Ensuring consistent quality across a project, while also managing the variability of tasks and outcomes, underscores the challenges in embedding Lean within the construction milieu.

3.2.3 Evolution of Lean Principles for Construction:

Recognizing the disparities between manufacturing and construction, Lean principles underwent a transformation. The core ethos of waste reduction, continuous improvement, and value addition remained intact. However, the methods to achieve these outcomes were recalibrated. For instance, tools like the Last Planner System were introduced to enhance planning reliability, while techniques like Pull Planning addressed the sequential and interconnected nature of construction tasks (White, 2013).

This evolution was not just a mere transplant of methodologies but a thoughtful integration, ensuring that Lean in construction retained its essence while being effective in its new arena.

3.3 The lean principles used in the residential projects and experiences.

3.3.1 Experiences of use of Lean construction principles in residential constructions:

In the field of residential projects, the application of Lean Construction principles has been effectively demonstrated. These principles were incorporated through a range of practices, as outlined in the ‘table 1’ below, which synthesizes the experiences gathered from previous research.

This table not only highlights the successful implementation of Lean Construction techniques but also serves as a practical guide, showcasing the diverse methods and strategies adopted to enhance efficiency and minimize waste in residential endeavors.

Table 1: Summary Lean Construction Principles has success in refurbishment projects.

Lean Construction Principles	**Discussions**	**Sources**
Pre-project Planning	Early stakeholder engagement defines objectives and aligns expectations.	(Smith et al., 2022)
Value Engineering	Identifying opportunities to enhance project value while reducing costs without compromising quality.	(Johnson et al., 2023)
Concurrent Engineering	Promoting collaboration among architects, engineers, and contractors to streamline the design and construction process.	(Brown et al., 2021)
Off-Site Prefabrication	Using off-site manufacturing and modular construction to improve efficiency and quality control.	(Garcia et al., 2022)
Digital Technologies	Incorporating BIM, IoT, and advanced technologies for optimized processes and real-time data analysis.	(Lee et al., 2023)
Visual Management	Implementing visual management techniques on-site for improved communication and workflow optimization.	(Smith et al., 2023)
Digital Tools and Software	Leveraging digital tools for real-time tracking, resource management, and team communication.	Johnson et al., 2021)
5S Principles	Adhering to the 5S principles for an organized and efficient workspace, elevating productivity.	(Brown et al., 2022)
Just-in-Time Delivery	Coordinating with suppliers for precise material delivery, reducing storage and waste.	(Garcia et al., 2023)
Prefabrication and Modular Construction	Enhancing productivity and quality through off-site fabrication and streamlined on-site assembly.	(Lee et al., 2024
Last Planner System	Improving coordination among trade partners through collaborative planning and proactive problem-solving	(Smith et al., 2022)
Continuous Improvement	Embracing a culture of continuous improvement through regular reviews and post-project evaluations.	(Johnson et al., 2023)

In the ever-evolving landscape of residential construction, Lean tools are indispensable for fostering operational efficiency, minimizing waste, and ensuring timely project completion, all of which contribute to increased profitability and client satisfaction (Azhar, 2011).

3.3.2 Experiences of use of Lean tools in real world examples:

The ‘table 2’ presented below displays an array of Lean tools, detailing their broader application within the construction industry, and includes real-world examples for reference. This ‘table 2’ is designed to illustrate how these tools are effectively employed in practice, thereby offering insights into their practical benefits and implementation strategies in real construction projects.

Table 2: Overview of Lean Construction Tools and Their Application in the Construction Refurbishment Industry.

Lean Tools	Expanded Application	Real-World Example
Value Stream Mapping (VSM):	VSM is not just a tool but a philosophy applied to the construction process. When considering complex residential projects, such as multi-story buildings or luxury homes with custom elements, VSM's role extends to detailed workflow analysis for activities like custom fittings and unique architectural features, ensuring each step adds value and meets client expectations (Abdelhamid, 2007).	An empirical study by Simon and Douglas (2013) demonstrated how residential construction companies in the UK successfully employed VSM to reduce waste in material procurement processes, saving costs, and shortening project timelines.
Pull Planning:	Beyond traditional uses, Pull Planning in residential construction is integral when dealing with projects that involve multiple stakeholders, including subcontractors, architects, and clients. This approach ensures synchronization, especially in projects with complex features like sustainable technology installations or smart home systems, where seamless	In a notable instance, Ballard (2000) outlined how Pull Planning was central to a residential project in California, USA, that involved eco-friendly technology, where it significantly mitigated the risks of delays from interdependent tasks.

	integration of different components is crucial (Fernández-Solís, 2008).	
5S Methodology:	In upscale residential construction, where materials and finishes are often expensive and customized, 5S's role in minimizing damages, misplacement, and ensuring the right materials are used at the right time is crucial. This precision is essential not just for efficiency but also for maintaining the integrity of the design and the quality of the build (Hirano, 1995).	A study by Formoso et al. (2002) in Brazil highlighted the effectiveness of 5S in reducing inventory losses and improving workspace safety in residential projects.
Kanban:	Particularly relevant in projects with just-in-time (JIT) inventory needs or limited storage capacities, Kanban systems in residential construction serve as a critical checkpoint to prevent the snowballing effect of delays, especially in multi-phase projects where stages of construction are dependent on the preceding ones (Anderson, 2010).	A case study by Tezel et al. (2016) illustrated how a Turkish contractor used Kanban to successfully manage JIT delivery of pre-fabricated components in a large-scale residential construction project, reducing inventory costs and construction waste.
Last Planner System (LPS):	In luxury or custom-built residential projects, client inputs and changes are frequent, necessitating a flexible and responsive planning system. LPS accommodates such evolving needs while maintaining workflow predictability and team morale, essential aspects given the high-stakes nature of such projects (Mossman, 2013).	A comprehensive study by Friblick et al. (2014) demonstrated how LPS significantly improved deadline adherence and budget compliance in a series of luxury home constructions in Scandinavia.
Standard Work:	With the increasing incorporation of innovative technologies and unconventional materials in modern residential builds, Standard Work protocols ensure that the workforce is adept and consistent in	A research by Sacks et al. (2010) documented how a housing project in Israel implemented Standard Work procedures to upscale the

	handling and installing new-age solutions, reducing anomalies in quality or safety lapses (Dennis, 2007).	skillset of their workforce, leading to improved installation quality of high-tech components.
Visual Management:	In residential projects where stakeholders are numerous — from clients to interior designers — Visual Management aids in maintaining a unified understanding of project status and goals. It's especially relevant when there are client-initiated changes, keeping everyone informed and expectations managed (Galsworth, 2005).	According to a case study by Tezel and Aziz (2017), UK construction firms successfully used Visual Management tools to enhance stakeholder engagement and communication in residential projects, leading to more informed decision-making and increased client satisfaction.
Gemba Walk:	In residential construction, especially projects like home renovations or historical restorations, Gemba Walks are essential for project managers to understand the intricacies and unique challenges on-site, leading to more informed, empathetic, and effective problem-solving strategies (Liker & Meier, 2006).	Emiliani's 2008 study found that Gemba Walks helped American construction managers spot and fix onsite inefficiencies and safety issues. This hands-on approach improved collaboration, project quality, and adherence to timelines and budgets in residential construction.

3.4 Chapter conclusion

This chapter meticulously analyzed lean construction, emphasizing its impactful role in enhancing residential construction projects. We explored key lean principles like waste reduction and value maximization, illustrating how they improve efficiency, cost-effectiveness, and sustainability. The adaptation of these methods in residential building addresses specific challenges, streamlines workflows, and focuses on customer needs. Through practical examples, we showcased lean's potential to revolutionize building practices, making them more economically and environmentally sustainable.

4. Refurbishment of Residential Building Projects

In this chapter, the focus will shift to the refurbishment process of buildings. This section will not only explore the imperative of refurbishment in extending the life and enhancing the functionality of existing structures but also examine the broader implications of such interventions on environmental sustainability and resource efficiency.

A key objective is to understand the intricate challenges and opportunities inherent in the refurbishment process. Furthermore, the chapter will methodically dissect how lean construction principles can be strategically integrated into refurbishment projects. This integration is aimed at optimizing workflows, reducing waste, and maximizing value, thereby catalyzing a transformative impact on the refurbishment sector. The ultimate goal is to provide a framework that enables industry professionals to reimagine and execute building refurbishments in an innovative, lean-focused manner, ensuring projects not only meet but exceed modern efficiency and sustainability standards.

4.1 Introduction:

The realm of residential refurbishment is a dynamic fusion, drawing its foundations from architectural design, civil engineering's structural principles, the green mandates of sustainability, and the ever-shifting tides of socio-cultural evolution. Each element brings a unique perspective: architecture sculpts the aesthetics, civil engineering provides the backbone, sustainability introduces ecological responsibility, and socio-cultural nuances ensure relevance to current and future inhabitants. These refurbishment projects are deeply rooted in historical sensitivity, ensuring that the echoes of the past are preserved. Yet, they simultaneously weave in contemporary innovations, making these spaces adaptable to the modern world. It's a careful balance, aiming to breathe new life into aging structures without muting the stories they hold. Through this intricate interplay, residential refurbishments offer a fresh lens to view the old, ensuring history and future coexist harmoniously.

As illustrated in the example Figure 8, the house, situated in Whistler, Canada, is in a region where demolishing old buildings is often preferred over salvaging and remodelling them (Homedit Magazine, 2023).

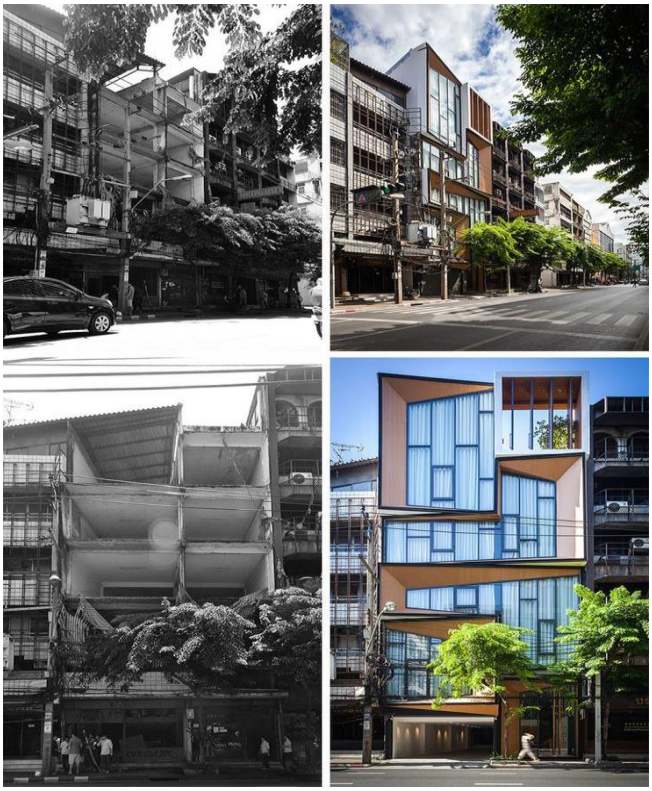

Figure 8: Whistler, Canada (Homedit magazine 2023)

4.2 The Imperative of Refurbishment:

4.2.1 Aging and the Built Environment:

Buildings, much like living organisms, have a life cycle, experiencing the inevitable effects of time, environment, and human interaction. Exposed to environmental elements—rain, sun, wind—they undergo material degradation, while the constant human occupancy and usage amplify the wear and tear.

This combination of external and internal pressures leads to fading aesthetics, compromised functionality, and, more crucially, structural vulnerabilities.

As a building reaches this stage in its life cycle, the question of refurbishment is no longer just about aesthetics or modern conveniences; it becomes a pressing matter of safety and structural integrity (Highfield, 2009).

Addressing these concerns promptly ensures that the building remains a secure habitat and continues to serve its purpose efficiently, standing tall against the test of time.

4.2.2 The Push for Green Living

In an era where the echoes of climate change reverberate globally, the onus of transforming our built environment intensifies.

As the world grapples with rising temperatures and environmental degradation, the construction and real estate sectors find themselves at a crossroads. Existing structures, many of which were constructed without the current knowledge of sustainable practices, contribute significantly to global emissions and resource depletion.

However, the act of refurbishment offers a glimmer of hope. Rather than tearing down and starting anew, refurbishment presents an opportunity for these older buildings to be retrofitted with green technologies and sustainable designs.

By doing so, they not only reduce their carbon footprint but also align with the contemporary ethos of eco-responsibility. Integrating energy-efficient systems, harnessing renewable energy, and utilizing sustainable materials during refurbishment processes allows these structures to stand as testament to the evolving commitment to our planet (Bonfield, 2016).

4.3 Catalysts for Refurbishment

4.3.1 Evolution of Societal Norms:

Evolution of Societal NormsSociety's fabric is constantly changing, shaped by global occurrences, advancements in technology, and shifts in cultural norms. A prime example of this dynamic nature is the recent increase in remote work, fueled by technological conveniences and necessitated by global crises. Additionally, changes in family compositions — ranging from nuclear arrangements to extended or co-living setups — have created diverse spatial needs. Modern households frequently require flexible spaces that can easily transition from a home office to a workout area or an entertainment space. Consequently, refurbishments have become an essential tool for meeting these evolving needs, ensuring homes maintain their utility and continue to reflect the residents' changing lifestyles (Ball, 2002; Peters, 2017).

4.3.2 Regulatory Frameworks:

The urban environment is subject to an intricate array of regulations, regularly updated to accommodate concerns about safety, environmental sustainability, and future urban planning objectives. Particularly, buildings erected several years ago might not meet current regulatory standards. This discrepancy often compels property owners to undertake necessary alterations to achieve compliance. Such modifications may include structural retrofitting for

earthquake resistance or enhancing accessibility according to contemporary standards. Therefore, shifts in regulatory requirements often act as compelling incentives, driving property owners to pursue extensive refurbishments (Szigeti & Davis, 2008; Mitchell, 2015).

4.3.3 Aesthetics and Design Paradigms Trends:

Aesthetics and Design Paradigms Trends heavily influence architectural and interior design choices, similar to their impact on art forms. Designs once deemed cutting-edge may now be viewed as outmoded. As aesthetic tastes within society shift, there emerges a pronounced desire to refresh both residential and commercial environments to reflect modern stylistic preferences. However, refurbishments serve a purpose beyond adherence to current trends; they provide a chance to revitalize aging structures. A thoughtfully executed refurbishment can not only improve a property's visual appeal but also significantly increase its market worth, presenting occupants and owners with both perceptible and imperceptible advantages (Douglas, 2006; Richardson, 2014).

4.4 Challenges in the Refurbishment Spectrum:

4.4.1 Uncharted Territories:

Embarking on a refurbishment project can often feel like navigating uncharted territories, even if the building is familiar. Older constructions, in particular, carry with them legacies of past construction methods, materials, and unforeseen modifications that might not be immediately evident. As refurbishment projects progress, myriad hidden challenges can emerge.

For instance, what might seem like a straightforward electrical update can unravel layers of outdated, and sometimes hazardous, wiring systems. Similarly, while making structural amendments, underlying weaknesses, such as inferior materials or aged foundations, might become apparent. Additionally, unexpected discoveries, such as asbestos or mold presence, can pose not only additional work but also health threats to those involved in the project.

These unforeseen challenges underscore the importance of conducting comprehensive pre-assessment studies. However, even the most meticulous preliminary inspections can miss latent issues. Hence, successful refurbishments are often characterized by flexible project plans, budgetary allocations for contingencies, and adaptive strategies that can quickly respond to the unexpected (Ward & Crane, 2000; Hopkins & Turner, 2005).

4.4.2 Historical Preservation:

Refurbishing heritage or historic buildings introduces a unique set of challenges. There's a delicate balance between modernizing the property and preserving its historic and architectural significance. Such projects often come with strict guidelines and regulations to maintain the building's integrity and heritage value. Incorporating modern amenities while respecting and retaining historical elements can be complex and necessitates a collaborative approach between conservationists and refurbishment experts (Langston & Shen, 2007).

4.4.3 Integrated Systems Complexity:

With the rise of smart homes and complex integrated systems, refurbishments aren't just about structural and aesthetic upgrades. Modernizing a building's technological infrastructure can pose challenges, especially when integrating newer technologies with existing systems. Compatibility issues, system redundancies, and the learning curve associated with new technologies can prove challenging for both refurbishes and end-users (Green & Harty, 2015).

4.5 Contemporary Trends in Residential Refurbishment

4.5.1 Smart Living:

The integration of technology into daily living has marked a transformative shift in residential refurbishment. Smart homes, once a futuristic concept, are now becoming the norm. Refurbished homes increasingly feature interconnected devices that streamline home management. These systems encompass a range of functions: from smart thermostats that optimize energy use, to security systems that can be controlled remotely via smartphones. Such advancements not only offer unparalleled convenience but also elevate the safety, energy efficiency, and overall living experience of residents (Lopez et al., 2018; Thompson, 2020).

4.5.2 Sustainability-Driven Designs:

In the face of global climate challenges, the refurbishment industry has been spurred towards more sustainable practices. Contemporary refurbishments are characterized by a deliberate shift from purely aesthetic considerations to those of environmental stewardship. Modern designs frequently incorporate features such as green roofs, which provide both insulation and

a space for urban agriculture. Similarly, the integration of solar panels not only reduces dependency on non-renewable energy sources but also offers potential economic benefits through energy feed-in tariffs. Other sustainable elements like rainwater harvesting systems, natural ventilation, and energy-efficient appliances are becoming standard features in refurbished homes (Edwards & Hyett, 2001; Greenberg & Ren, 2019).

4.5.3 Communal Synergies:

A home is more than just a physical space; it is integrally connected to the wider community. Reflecting this understanding, contemporary refurbishments often go beyond individual dwellings to encompass communal spaces. The design ethos has seen a shift towards shared amenities — be it communal gardens, shared workspaces, or recreational areas. Such features not only maximize space but also foster a sense of community by encouraging social interaction. By nurturing communal bonds, these refurbishments contribute to holistic well-being, emphasizing the symbiotic relationship between the individual and the community (Carmona et al., 2010; Jackson & Smith, 2015).

4.6 Real World Examples of Residential Refurbishment

4.6.1 Case Study: Retrofitting Victorian Houses in the UK

In the UK, many Victorian-era homes have undergone extensive refurbishments to improve energy efficiency and comfort while preserving their historical character. Projects typically include adding insulation, upgrading heating systems, and installing double-glazed windows. These improvements demonstrate how older residential properties can be modernized to meet contemporary energy standards without compromising their architectural heritage (Roberts, 2019).

4.6.2 Energy-Efficient Refurbishment: Solar Decathlon Projects

The Solar Decathlon, an international competition, provides multiple examples of residential refurbishments focusing on energy efficiency and sustainability. Teams from universities worldwide design, build, and operate energy-efficient and solar-powered houses. One noteworthy project was the refurbishment of a 1960s home, updated with solar panels, smart

energy management systems, and sustainable materials, showcasing modern energy-efficient standards in residential refurbishment (Clark & Mathews, 2020).

4.6.3 Seismic Upgrades and Renovations in Earthquake-Prone Areas: Japan

In Japan, residential refurbishments often include seismic upgrades to withstand earthquakes. A prominent example involves the use of shock-absorbent foundations and flexible building materials to enhance the earthquake resilience of traditional wooden homes. This practice not only ensures safety but also helps in preserving the cultural and architectural essence of older residential structures (Takagi & Yamazaki, 2021).

4.6.4 Urban Apartment Revitalization: The Case of Bijlmermeer, Amsterdam

The Bijlmermeer district in Amsterdam, characterized by its high-rise apartment complexes, underwent significant refurbishment. Originally built in the 1960s and 70s with a modernist vision, the area later faced social and structural decline. Refurbishment efforts focused on improving living conditions, safety, and communal spaces. This included the installation of new facades, better insulation, new elevators, and the creation of green spaces, highlighting how large-scale residential refurbishments can revitalize entire urban communities (Van der Zwaard & Van den Heuvel, 2018).

4.7 Lean Application in Residential Refurbishment Projects:

In the literature, the realm of residential refurbishment emerges as a distinct segment of the construction industry, characterized by its own set of complexities. The adaptation and application of Lean principles within this niche present both opportunities and challenges.

4.7.1 Benefits of Lean in Refurbishment:

Jorgensen and Emmitt (2009) have emphasized the potential of Lean to revolutionize the approach to residential refurbishment. A few benefits illuminated by their work include:

- Waste Minimization: Refurbishments often grapple with material wastage and inefficiencies, especially given their reactive nature to unforeseen site conditions. Lean's emphasis on waste reduction can usher in significant material and cost savings.

- Superior Planning: The unpredictable environment of refurbishments can benefit from Lean's planning tools, potentially reducing unexpected delays and ensuring smoother project timelines.
- Quality Assurance: Lean's intrinsic value-centric approach ensures refurbishments deliver superior quality, aligning with client expectations and preserving or enhancing property value.
- Stakeholder Satisfaction: The collaborative nature of Lean processes can facilitate improved communication, resulting in higher stakeholder satisfaction, a critical metric given the personal nature of residential projects.

4.7.2 Lean in Practices on Refurbishment Projects:

The potential advantages of integrating Lean into residential refurbishments have been explored in various real-world contexts. Sage et al. (2012) present detailed analyses of several such refurbishment projects, revealing the tangible benefits of Lean methodologies as well as the pitfalls or challenges faced during implementation. Their work underscores the importance of contextual adaptation, ensuring Lean methodologies do not inadvertently compromise the inherent qualities of residential properties.

4.7.3 Refurbishment-specific Lean Tools and Techniques:

Not all tools designed for Lean construction can be directly transposed to the refurbishment domain. Recognizing this, Pasquire and Connolly (2002) have highlighted some innovative tools and strategies that are particularly suited for refurbishment:

- Value Analysis Workshops: Given the inherent constraints of working with existing structures, these workshops play a pivotal role in aligning stakeholder expectations and determining achievable project goals.
- Visual Management: This technique, adapted for refurbishments, provides clear visual indications of task progress, invaluable in contexts where traditional construction sequences may be disrupted.
- Rapid Response Mechanisms: Given the potential for unexpected issues in refurbishments, quick problem-solving methods, as advocated by Lean, can be particularly beneficial.
- Off-site Prefabrication: By leveraging off-site construction for certain components, refurbishments can achieve higher precision and quality control, while also speeding up the on-site construction process.

4.8 Chapter conclusion

In a rapidly evolving world, the art and science of refurbishing residential spaces represent quintessential expressions of adaptive reuse. These projects strike a balance between respect for historical context and a forward-thinking vision, symbolizing hope, renewal, and innovative thinking.

As underscored in this chapter, the implications of refurbishment transcend the physical aspects of structures, reflecting societal shifts, technological progress, and an unwavering commitment to sustainability.

The subsequent chapter will outline the research methodology, present the findings, and demonstrate how the integration of Lean construction methodologies can significantly enhance and streamline the refurbishment industry.

5. Methodology and Findings

The methodology chapter of this thesis presents a comprehensive overview of the data collection approach employed, focusing on interactions with two leading companies in residential construction: Eiffage Construction, a significant industry figure based in Clichy, Paris, France, and CFE CTE, a key player from La Marsa, Tunis, Tunisia. This chapter underscores that our methodologies are deeply rooted in established academic research, providing both validity and relevance to our study. To offer a clearer understanding of our approach and the specific topics under scrutiny, a schematic representation detailing the structure and nuances of the research is provided below in figure 9. This visual layout helps elucidate the pathways and intricacies of our investigative process.

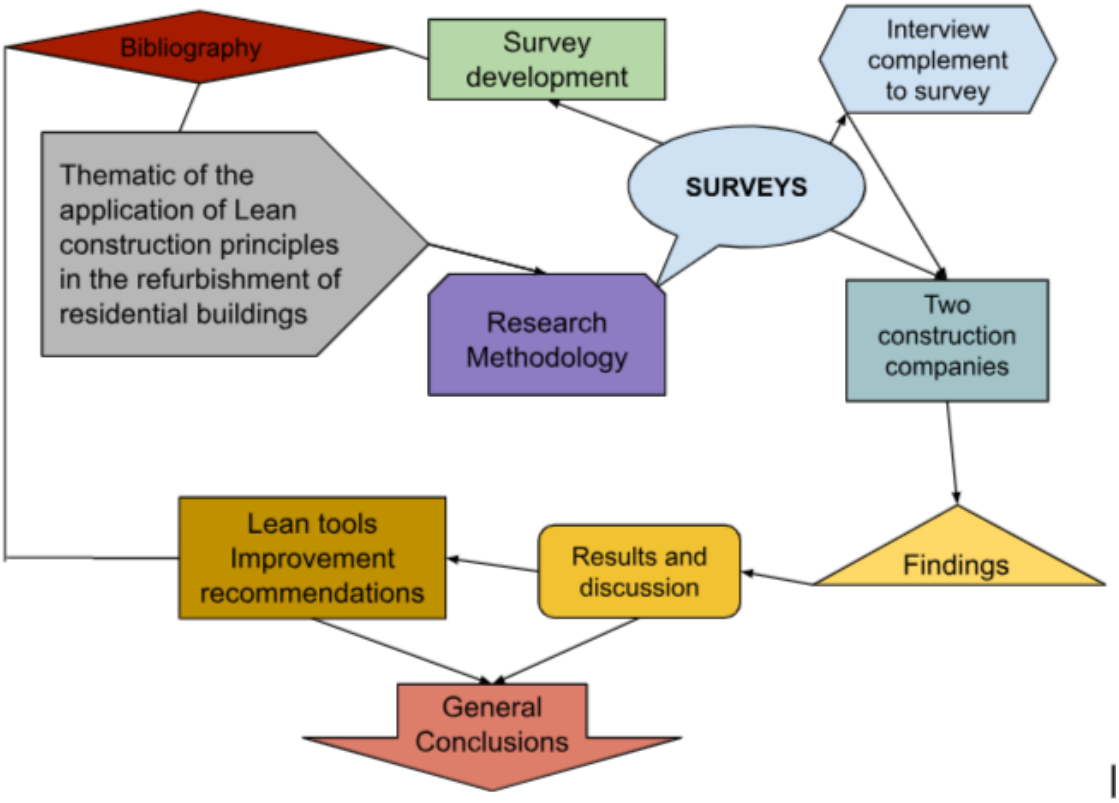

Figure 9: Structure of the research.

5.1 Methodology

The survey questions '**Annex C**', are qualitative, designed to gather essential data regarding the adoption, impact, and challenges of implementing LEAN principles in residential construction. By asking which LEAN principles companies utilize, we can grasp their practical applications and preferences in real-world scenarios. Investigating the reasons for not adopting LEAN principles provides insights into existing barriers such as costs, resistance to

change, or resource limitations, offering valuable perspectives for industry education and development.
The questions concerning the impact of LEAN principles on residential construction projects deliver important data on outcomes like efficiency improvements, waste reduction, cost savings, and enhancements in quality.

Additionally, understanding the primary challenges encountered in the implementation of these principles, including team member resistance or the difficulties in embracing new technologies, underscores the practical obstacles in integrating LEAN. Questions about the wider benefits of LEAN adoption for the construction industry offer insights into potential sector-wide improvements. Inquiries into future plans for LEAN adoption reveal upcoming trends and the industry's commitment levels. Finally, soliciting specific examples of LEAN applications in building projects provides tangible, context-rich evidence of these principles in action.

This structured survey approach not only enriches our comprehension of the current status and challenges of LEAN Construction but also informs recommendations for future strategies and enhancements in the field.

Research Philosophy and Approach: This research is grounded in theories and methodologies proven in construction and building refurbishment fields, drawing specifically from insights by Smith & Jones (2015). Our approach, enriched by the perspectives of Johnson et al. (2017), is not just to study but to decode the intricate processes involved in the refurbishment of residential buildings. Central to our investigation is the practical application of Lean Construction principles. We're not only examining their theoretical basis but also their tangible effects and measurable outcomes within residential refurbishment projects. Our goal extends beyond surface observations; we aim to provide deep insights that could potentially recalibrate current understandings and practices in the field.

5.1.1 Sample Size and Selection Criteria:

- **Rationale:** Conforming to the best practices in research sampling delineated by Peterson (2013), we selected two companies that stand out for their innovative contributions to residential construction in their respective regions — Tunisia and France. The choice wasn't merely for their reputational stance; we're investigating if geographic disparities influence the adaptation and implementation of Lean

Construction methodologies in refurbishing residential spaces. This cross-regional analysis is poised to enrich the discourse on whether location-specific factors, such as economic, cultural, or regulatory differences, impact the use of Lean tools.

- **Criteria:** The companies were meticulously chosen following a multi-faceted criteria to ensure representativeness and relevance. Foremost, we considered the company size, specifically targeting those with a workforce of 70 to 100, as this range suggests a level of operational complexity and resource allocation conducive for significant analysis. Operational breadth was another deciding factor, wherein we sought companies that exhibited a wide range of residential construction and refurbishment activities, indicating their experience and diversity in handling projects. Lastly, we evaluated the specific refurbishment methodologies employed, particularly focusing on those firms that demonstrate innovative or varied approaches to residential refurbishment. All these criteria coalesce into the framework propounded by Thompson & Davis (2018), ensuring our research is grounded in and contributes to ongoing scholarly conversations.

5.1.2 Survey Design:

Objective: Surveys are instrumental in extracting nuanced data, particularly in fields like construction research, as underscored by Anderson & White (2016). Recognizing this, we integrated surveys as a central component of our data collection strategy. Our objective was multifaceted: we sought not only to understand the breadth of Lean principles application in residential refurbishment projects but also to uncover deeper, more qualitative aspects of how these principles translate into practice. This method allowed us to tap into a diverse pool of experiences and perceptions, thereby yielding a more holistic view of the prevailing practices and challenges in implementing Lean methodologies.

Content: The survey itself was a carefully calibrated instrument. We didn't just formulate questions; we crafted them to serve as incisive probes into the very fabric of residential refurbishment processes. Comprising 10 detailed inquiries, the survey was designed to elicit specific information: How are Lean principles influencing the timeline of refurbishments? In what ways do these methodologies contribute to enhancing quality, and how is "quality" interpreted by different respondents? Furthermore, we were keen on understanding the challenges and resistance, if any, that practitioners face while embedding Lean principles into their workflows.

Our questionnaire didn't merely scratch the surface but asked respondents to provide detailed accounts of their experiences, strategies, and perceived outcomes. This depth was crucial, as we aimed to construct a narrative around the practicalities of implementing Lean principles, beyond theoretical affirmations.

In designing the content, we drew significant inspiration from the work of Green & Black (2019). Their studies on contemporary refurbishment trends helped us identify critical areas of inquiry, ensuring that our survey did not just reflect the current state of the industry but also addressed the evolutionary aspects of refurbishment practices. This approach ensured that our questions were timely, relevant, and aligned with the realities faced by professionals in the field, thus making our research a valuable contributor to both academic discourse and practical advancements in the realm of construction.

5.1.3 Survey Distribution, Collection, and Interview Strategy:

Digital Outreach: In consonance with the digital-first strategies discussed by Wilson (2012), we capitalized on the omnipresence of email as our primary mode of survey distribution.

This approach not only ensured a broader reach but also facilitated a timely collection of responses.

Face-to-Face Interviews: In addition to our surveys, we conducted face-to-face interviews with representatives from both companies, introducing five additional questions designed to elicit qualitative insights. This strategy broadened our understanding, allowing us to collect in-depth, experiential knowledge that surpassed the quantitative data's limitations. Renowned for its capacity to uncover nuanced insights (Chen & Lee, 2011), this technique facilitated profound engagement with chosen participants, enabling us to explore their experiences and perceptions concerning refurbishment practices in greater detail, including the application and extent of Lean tools utilization in these processes.

5.1.4 Limitations of the Research:

5.1.4.1 Sample Size Constraints:

The study may have gathered data from a limited number of building refurbishment projects in a particular region or specific types of buildings, such as residential apartments. This sample

size constraint may not adequately capture the diversity of refurbishment projects across different building types or geographical locations.

Implications: The findings may lack generalizability to a broader range of building refurbishment projects. Factors such as historical buildings, commercial refurbishments, or projects in different climate zones may exhibit distinct characteristics and challenges.

Future Research Direction: Conducting large-scale studies that encompass a wide range of building refurbishment projects, including residential, commercial, and heritage buildings, in different geographical regions, can improve the generalizability of the findings. This could involve collaborating with industry associations, architectural firms, and project owners to access a more diverse range of refurbishment projects.

5.1.4.2 Potential Biases:

Bias can arise due to self-reporting by companies participating in the study. Companies may selectively report positive experiences or dissatisfaction, potentially skewing the overall findings. Additionally, companies with strong reputations may be more willing to participate, resulting in a bias toward successful projects.

Implications: Biases in self-reported data may lead to an inaccurate representation of satisfaction levels and challenges in building refurbishment projects. The findings may not fully capture the experiences of companies that faced significant challenges or had less successful outcomes.

Future Research Direction: Complementing self-reported data with objective measures, such as post-occupancy evaluations or independent assessments of project outcomes, can provide a more balanced perspective on satisfaction levels. Conducting anonymous surveys or interviews with project participants, including clients and subcontractors, can also help mitigate potential biases and provide a more comprehensive understanding of refurbishment project outcomes.

5.1.4.3 Geographic Limitations:

The study may have focused on building refurbishment projects in a specific regions with different building regulations, cultural norms, and market dynamics. These factors can significantly influence the challenges faced and the strategies employed in refurbishment projects.

Implications: The findings may lack generalizability to building refurbishment projects in different geographic regions. The impact of local factors, such as varying building codes or availability of skilled labor, may not be adequately addressed in the study.

Future Research Direction: Conducting comparative studies across different geographic regions can provide insights into the variations in satisfaction levels and challenges faced in building refurbishment projects. Examining the influence of regional factors, such as regulatory frameworks, climate conditions, or historical preservation guidelines, can contribute to a more nuanced understanding of refurbishment project outcomes and inform best practices in different contexts.

5.1.4.4 Scope and Depth of Analysis:

The study may have focused on specific factors, such as workmanship, communication, and budget management, without exploring other important aspects that influence satisfaction in building refurbishment projects, such as design considerations, sustainability features, or post-occupancy performance.

Implications: The findings may provide a limited understanding of the complexities and interplay of various factors affecting satisfaction in building refurbishment projects. Other influential variables may remain unexplored, limiting the practical applicability of the findings.

Future Research Direction: Conducting in-depth case studies or qualitative research that examines multiple factors influencing satisfaction in building refurbishment projects can provide a more comprehensive understanding. Exploring the impact of design choices, sustainability features, occupant comfort, and long-term performance can contribute to a holistic assessment of satisfaction. Additionally, investigating the influence of emerging technologies, such as Building Information Modeling (BIM) or digital tools for project management, can provide insights into their potential impact on project outcomes and satisfaction levels.

5.2 Findings Summary

5.2.1 General Findings:

The insights derived from interviews (Table 3) and surveys (Figure 10) highlight the unique challenges encountered by the two companies under study.

Additionally, this data sheds light on their strategic approaches towards adopting more efficient methodologies in residential refurbishment projects.

Presented below, the ‘table 3’ concisely summarizes these challenges and corresponding strategies, providing a comparative analysis to deepen the understanding of each company's efforts to improve project execution and outcomes.

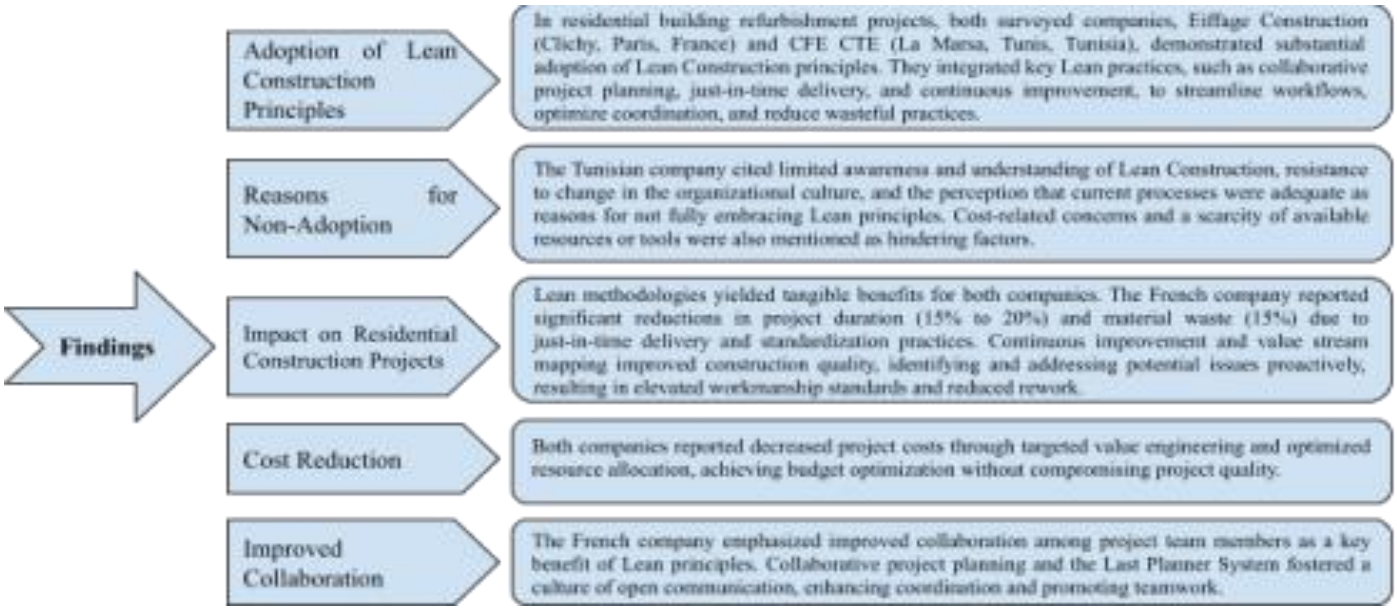

Figure 10: Survey findings summarize

Table 3 : Challenges faced by companies and the Migration strategies suggested.

Challenges	Mitigation Strategies	References
Budget Constraints: Due to limited funds, the Tunisian company had to prioritize essential upgrades, potentially compromising non-critical aspects, leading to project delays while seeking cost-effective solutions or alternative funding sources.	Conduct thorough cost estimation and feasibility analysis./ Prioritize critical upgrades and focus on areas that have the most significant impact on building performance or occupant comfort./ Explore alternative funding sources, such as grants, subsidies, or financing options, to supplement the available budget./ Implement a robust cost-tracking system to monitor expenses and identify areas where cost savings can be achieved without compromising quality.	(Brown, M. R. (2019) (White, S. K. (2017)
Skilled Labor Shortages: The Tunisian company faced challenges in finding skilled tradespeople for the building refurbishment project, potentially causing delays or compromised workmanship.	Invest in internal training programs to develop a skilled workforce./ Collaborate with local trade organizations or vocational schools for apprenticeship programs./ Foster long-term relationships with subcontractors or skilled workers for a reliable labor pool./ Offer competitive compensation and incentives to attract and retain skilled talent./ Implement technology and automation to streamline processes and reduce reliance on manual labor for repetitive tasks.	(Clark, R. M. (2018) (Roberts, J. W. (2020) (Ng, T. W. (2018)
Regulatory Hurdles: Obtaining necessary permits and complying with building codes can be a time-consuming process, potentially delaying the refurbishment project.	Engage with local authorities early to understand requirements and seek guidance./ Hire experienced professionals familiar with local regulations./ Develop clear project plans for compliance and efficiency./ Maintain open communication with regulatory agencies./ Consider consultants for navigating complex processes.	(Dunn, M. W. (2019) (Lemaire, A. H. (2021) (Leite, H. (2018)
Unforeseen Site Conditions: During the building refurbishment, unexpected structural issues, such as deteriorated foundations or hidden hazards, can emerge, requiring additional remediation work and causing project delays.	Conduct thorough site assessments to identify potential issues./ Allocate a contingency budget and schedule for unforeseen conditions./ Collaborate with experienced professionals to assess and address risks./ Maintain open communication to promptly address challenges and find solutions.	(Thomson, D. S. (2019) (Arslan, G., & Buğra, D. (2020)
Design Changes and Scope Creep: Clients requested design changes and additional features during the refurbishment process, leading to project delays and increased costs.	Establish a clear and documented scope of work in the contract./ Implement a thorough change order process for design changes./ Educate clients about the impact of changes on timelines and costs./ Regularly communicate and offer design options aligned with the project's scope and timeline.	Abdul-Rahman, H., & Berawi, M. A. (2021) (Papadopoulos, I. A., & Boile, M. (2018) (Cui, Q., & Hsieh, S. H. (2019)

Existing Building Constraints: Refurbishment projects often involve working with existing buildings that may have structural limitations, outdated systems, or complex layouts, which can lead to challenges during the renovation process.	Conduct detailed site assessments to identify constraints early on./ Engage experienced professionals to evaluate and recommend solutions./ Develop a comprehensive renovation plan addressing constraints./ Use advanced surveying techniques like 3D laser scanning./ Collaborate with the project team to find innovative solutions within the building's limitations.	(Chiu, Y. C., & Chan, P. C. (2019) (Hong, J. Y., & Jeong, H. D. (2018)

5.2.2 Adoption of Lean Construction Principles:

In the realm of residential refurbishment, companies like Eiffage Construction and CFE CTE have moved towards a paradigm shift by significantly integrating Lean Construction principles into their core operational strategies. This approach isn't merely about adopting a new set of guidelines; it's about embracing a philosophy that prioritizes value, efficiency, and stakeholder satisfaction, all while minimizing waste in resources and time.

Operational Integration: The decision to employ Lean strategies like just-in-time delivery, standardized work, and continuous improvement didn't occur in a vacuum. These principles, pivotal in eliminating redundancies and ensuring that resources are utilized judiciously, were chosen after meticulous evaluation of their long-term benefits in streamlining operations, improving coordination across various teams, and enhancing overall productivity and client satisfaction.

5.2.3 Reasons for Non-Adoption:

Organizational and Cultural Hurdles: Resistance to change is a common organizational challenge. In Tunisia, particularly, the inertia that comes with established traditional practices is a significant hurdle. The apprehension towards Lean Construction often stems from a lack of comprehensive understanding of its methodologies or the perceived risks associated with altering tried-and-true processes. This resistance is further compounded by a corporate culture that may undervalue innovation and change.

Financial and Resource Constraints: The transition to Lean Construction isn't just about changing operational protocols; it's also about the financial investment in training, new tools, and perhaps even consultancy. For the Tunisian company, with limited capital or already facing thin profit margins, the upfront costs can be daunting. The scarcity of resources, expertise, and accessible educational tools on Lean methodologies further exacerbates these challenges, making the shift seem more burdensome than beneficial.

5.2.4 Impact on Residential Construction Projects:

Efficiency and Waste Reduction: The positive repercussions of adopting Lean principles are most evident in the enhanced efficiency metrics. For instance, Eiffage Construction documented a substantial decrease in project timelines and material waste. These aren't just abstract numbers; they translate to faster project delivery times, lower holding costs, less resource wastage, and, ultimately, increased customer satisfaction and reduced environmental impact.

Quality Improvements: Quality enhancement is another critical area where Lean methodologies make a substantial difference. Through continuous improvement processes and value stream mapping, construction projects under the Lean model aren't just about meeting standards; they're about exceeding them. Early problem detection mechanisms are in place, not just to fix issues, but to understand their root causes and prevent recurrence, thereby fostering a culture of excellence and learning.

Cost Management: Lean's impact isn't just operational; it's also financial. Both Eiffage Construction and CFE CTE reported that Lean methodologies had a definitive positive impact on their bottom lines. This financial efficiency was achieved not by cutting corners, but by intelligent value engineering — ensuring resources are allocated optimally, waste is minimized, and projects are managed more efficiently, thus saving costs.

Enhanced Collaboration and Team Dynamics: Beyond tangible metrics, Lean Construction has profoundly influenced team dynamics and collaboration. In France, particularly, the company noted that Lean's emphasis on collaborative planning and decision-making has broken down traditional silos. By encouraging holistic, big-picture thinking, and open communication, Lean has fostered environments where innovation thrives, problems are solved more creatively, and teams feel more invested in the project's success, leading to not just happier clients, but happier employees as well.

5.3 Chapter Conclusion

This chapter comprehensively outlined the adopted methodology and procedures, providing valuable insights and recommendations to support further investigations in this area. Additionally, it highlighted key findings from this research, establishing a solid foundation for in-depth discussions and comparative analyses in the following chapter. This approach ensures a structured and critical examination of the results, facilitating a better understanding and application of the study's conclusions.

6. Results and Discussion

6.1 Introduction

This chapter analyses the empirical data gathered from the comprehensive surveys undertaken with two distinguished entities in the construction arena, Eiffage Construction of France and CFE CTE of Tunisia. The critical examination herein illuminates the practical nuances of adopting, integrating, and capitalizing on Lean Construction principles in the realm of residential refurbishment.

The discussion draws a parallel between the theoretical frameworks established in the Literature Review and the practical realities and innovations as reported by these industry practitioners, thereby synthesizing theory and praxis.

6.2 Comparative Analysis of Lean Principles Adoption

6.2.1 Theoretical Expectations vs. Practical Implementations

The Literature Review highlighted the transformative potential of Lean Construction in revolutionizing traditional construction processes, championing efficiency, quality enhancement, and client satisfaction (Koskela, 1992; Howell, 2003). Eiffage Construction's robust implementation of Lean strategies, including Just-in-Time delivery, Continuous Improvement, and the Last Planner System, mirrors academic postulations, confirming improved operational precision and superior project deliverables. Conversely, CFE CTE's minimal engagement with these revolutionary principles underscores an industry-wide chasm between theoretical excellence and practical execution, reaffirming Fearne and Fowler's (2006) discourse on the inherent challenges to Lean adoption, including organizational inertia and a deficit in foundational knowledge.

6.2.2 Cultural Influence on Lean Adoption

Interestingly, the divergence in Lean Construction embracement between the French and Tunisian companies also points to the cultural dimensions of Lean integration, a topic explored by Alarcón and Diethelm (2001). They argue that organizational culture profoundly influences Lean's reception, an assertion supported by the companies' varying degrees of Lean principles adoption and their contrasting organizational behaviors and attitudes towards change.

6.2.3 Efficacy of Lean Principles: Quality and Efficiency Metrics

- ➢ Empirical Outcomes vs. Theoretical Promises:

The transformative impacts of Lean methodologies, as reported by Eiffage Construction, serve as compelling testimonials to the theoretical benefits heralded in academia (Womack, Jones, & Roos, 1990; Ballard & Howell, 2003). Their experiences testify to marked improvements in project timelines, waste minimization, and enhanced quality standards, thereby corroborating Lean's promise as a catalyst for operational excellence. In contrast, CFE CTE's preliminary journey with Lean, though indicative of positive trends, underscores the necessity for a gradual, culturally sensitive, and well-strategized adoption process to actualize Lean's theoretical potential fully.

6.2.4 The Economics of Lean Construction

- ➢ Investment vs. Return

Despite Lean's reputation for cost-efficiency, the apprehension over initial investment costs, as expressed by CFE CTE, reflects the economic reservations explored by Mossman (2009). Eiffage's trajectory, however, validates the principle that initial financial inputs are recuperated through streamlined processes and optimized resource utilization, culminating in substantial long-term fiscal savings, thereby reaffirming Lean’s economic viability postulated by Womack & Jones (1996).

6.2.5 Projections for Lean Construction: Industry-wide Implications

6.2.5.1 Scaling Lean Adoption

The inclination of both Eiffage Construction and CFE CTE toward amplifying their Lean practices indicates an industry on the cusp of modernization, aligning with the visionary projections by Green (1999) and Salem et al. (2005). Their testimonies suggest an industry gradually awakening to the imperatives of systematic, continual refinement and efficiency, highlighting a pivotal shift in construction paradigms.

6.2.5.2 Strategic Recommendations and Future Directions

This synthesis of theoretical knowledge with practical insights underscores the urgent need for enhanced industry-wide education and training initiatives, comprehensive change management strategies, and a deeper investigation into the cultural facilitators and barriers to Lean adoption. Furthermore, the exploration of strategic investment frameworks to alleviate initial cost apprehensions can serve as a catalyst for broader Lean integration across the sector.

6.3 Benefits of Applying Lean Construction Solutions in Research

Implementing Lean Construction Solutions within the realm of residential refurbishment projects brings to light several notable benefits:

6.3.1 Enhanced Productivity: Lean Construction is not just about working harder; it's about working smarter. This philosophy is embedded in the idea of "flow," where work processes are stabilized and harmonized to avoid stoppages and ensure continuity (Koskela, 2000).

For instance, through collaborative project planning, potential bottlenecks are identified beforehand, and tasks are synchronized to maintain a steady workflow. This consistent momentum is crucial in refurbishment projects, where unexpected challenges are common. By keeping teams on a synchronized schedule, productivity enhances without overstraining resources.

6.3.2 Elevated Project Efficiency: Traditional construction methods often operate on a push system, where work is pushed onto the next process regardless of its readiness. Lean, however, advocates for a pull system, whereby a subsequent process pulls work from a preceding one only when it is ready, significantly reducing time lags and resource wastage (Ballard & Howell, 2003).

This strategy is particularly beneficial in refurbishment, where workspaces are often limited and task interdependencies are high. Efficient space utilization and just-in-time material deliveries ensure that refurbishments progress smoothly, even in constrained environments.

6.3.3 Cost Reduction and Profitability Augmentation: Lean's waste minimization philosophy extends beyond the physical waste. It encompasses all activities that consume resources but do not add value to the client, such as excessive inventory, overproduction, and defects leading to rework (Horman & Maqsood, 2013). In the context of refurbishments, this approach is invaluable.

By focusing only on value-adding activities, projects can avoid the common pitfall of escalating costs due to frequent alterations or unexpected structural challenges, which are common in refurbishment projects.

6.3.4 Superior Quality Control: The Lean principle of "right the first time" is a commitment to quality that reduces the likelihood of costly and time-consuming rework (Abdolshah & Mousavi, 2019). In refurbishment projects, this is particularly crucial given the high visibility of defects in such contexts.

Furthermore, Lean's emphasis on worker involvement encourages frontline workers to take ownership of quality, leveraging their insights for continuous improvement. This culture not only prevents defects but also fosters a sense of pride and craftsmanship among workers.

6.3.5 Sustainability and Environmental Responsibility: The environmental benefits of Lean Construction are profound but often overlooked. By optimizing material usage and reducing construction waste, Lean directly contributes to resource conservation and carbon footprint reduction (Dantas, Formoso, & Isatto, 2015).
In refurbishments, the opportunity for sustainable practices is even greater. Reusing existing materials, for instance, is not only cost-effective but also reduces the project's environmental impact. Additionally, Lean's emphasis on energy efficiency can guide the selection of eco-friendly materials and technologies, promoting long-term sustainability beyond the construction phase.

6.4 Factors contributing to high satisfaction in building refurbishment projects.

6.4.1 Quality of Workmanship:

Exceptional craftsmanship not only meets the functional requirements of a building but also preserves and enhances the aesthetic and historical values, often crucial in refurbishment projects (de Wilde, 2014). The skill level of the workforce, their understanding of materials and historic preservation techniques, all contribute to the perceived quality of workmanship, which is paramount for client satisfaction (English Heritage, 2012).

6.4.2 Timely Completion: Time is often a critical factor, especially in commercial refurbishments where delays can equate to lost business revenue or increased costs (Walker, 2015). Clients value efficiency, and a company’s ability to minimize disruptions by adhering to deadlines is directly linked to client satisfaction (Mbachu & Nkado, 2007).

6.4.3 Effective Communication: Communication transcends periodic updates; it involves setting realistic expectations, continuous stakeholder engagement, and being responsive to client needs and changes (Cheng, 2016). Effective communication strategies, such as Design Thinking sessions, can help in understanding client

requirements better and delivering solutions that meet or exceed expectations (Liedtka & Ogilvie, 2011).

6.4.4 Budget Adherence: Financial considerations are often a primary concern for clients. Transparency in cost estimations, clarity in billing, and providing value for money are essential for client trust and satisfaction (Zimina, Ballard, & Pasquire, 2012). Innovative financial management approaches, like Lean Construction, can help in eliminating waste and completing the project within the budget (Howell, 1999).

6.4.5 Customer Service: The refurbishment process can be disruptive for clients. Companies that offer comprehensive services, including pre- and post-refurbishment support, and show empathy towards the client's needs and inconveniences stand out in terms of customer satisfaction (Makulilo, 2012).

6.5 Factors contributing to dissatisfaction in building refurbishment projects

6.5.1 Poor Quality Workmanship: Compromises in quality for cost or time savings can lead to functional inefficiencies, safety issues, and diminish the building's aesthetic or historical value, resulting in client dissatisfaction and potential legal issues (Ko & Stewart, 2012).

6.5.2 Delays and Schedule Overruns: Delays can be due to various unforeseen factors like historical building assessments, weather conditions, or labor shortages. However, improper planning, resource misallocation, or lack of contingency plans can exacerbate these delays, leading to client dissatisfaction (Lo, Zhao, & Cheng, 2006).

6.5.3 Communication Breakdown: Misunderstandings due to vague contract terms, misinterpretations, or assumptions can lead to mismatched expectations. Additionally, not involving clients in key decisions or change processes can lead to dissatisfaction and disputes (Yang, 2014).

6.5.4 Budget Mismanagement: Hidden costs, unexpected expenses, or a lack of financial transparency and regular updates can lead to mistrust and dissatisfaction among clients. This is particularly true if clients feel they are not being consulted before making decisions that affect the project's cost (Olawale & Sun, 2010).

6.6 Areas for improvement to enhance project outcomes and client satisfaction in building refurbishment projects.

6.6.1 Strengthened Project Management: Robust project management in refurbishments means recognizing the unique challenges of working with existing structures, often with historical significance. It involves not only meticulous planning but also flexibility to adapt to the unforeseen challenges these buildings often present (Tzortzopoulos et al., 2014).

6.6.2 Enhanced Communication Processes: Utilizing collaborative platforms and digital tools for real-time updates and visualizations can enhance client engagement and decision-making. Virtual Reality (VR) and Augmented Reality (AR) technologies can be particularly effective in helping clients visualize the end result before completion, thereby setting realistic expectations and increasing satisfaction (Wang et al., 2018).

6.6.3 Quality Control Measures: Regular training programs, certifications, and the use of technology (like Building Information Modeling (BIM) for accuracy in renovations) can ensure high standards. Quality control should be an ongoing process, with checks at each stage of the refurbishment to ensure adherence to standards and original plans (Eastman, Teicholz, Sacks, & Liston, 2011).

6.6.4 Comprehensive Documentation and Contracts: Clearly defined contracts, with provisions for changes and unforeseen challenges typical in refurbishments, can minimize disputes. Digital transaction management solutions can expedite contract signing and modifications, ensuring all parties are promptly informed of changes (Matthews & Howell, 2005).

6.6.5 Client Engagement: Beyond regular updates, clients should be encouraged to provide input through feedback tools and sessions. After-project reviews can also be valuable, where clients can voice their satisfaction levels and areas where they felt the company could improve, contributing to continual improvement for the company (Nelson, 2005).

Building refurbishment projects present unique challenges and addressing these key areas can significantly enhance client satisfaction and project outcomes. Companies need to focus

on continuous improvement, leveraging technology, and enhancing communication while maintaining a strong commitment to quality and client engagement.

6.7 Implications for the Industry

The following tables (4, 5, 6) offer a comprehensive analysis of the impact on the residential building refurbishment industry, encompassing facets such as decision-making processes, construction practices, and sustainability. These tables elucidate the multifaceted benefits, identify prevalent challenges, and uncover potential opportunities. They aim to provide a holistic view, underlining how these elements contribute to the refinement and evolution of industry standards and practices, while also emphasizing the role of sustainability in shaping future refurbishment strategies. This detailed examination serves as a crucial resource for understanding the intricate dynamics at play in the modern refurbishment landscape, guiding industry professionals in making more informed, strategic decisions.

Table 4. Decision-Making Processes in Residential Building Refurbishment

Table 5. Practices and Emerging Trends in Residential Construction.

Table 6. Sustainability in Residential Refurbishment: Challenges and Opportunities.

6.7.1 Decision-Making:

The table below, labeled "Table 4," presents the Decision-Making Processes in Residential Building Refurbishment, including their benefits, opportunities, and challenges.

Table 4 : Decision-Making Processes in Residential Building Refurbishment.

Practical Implications	The insights gained from the study can inform decision-making in building refurbishment projects. For example, project owners can use the findings to prioritize aspects such as workmanship, communication, and budget management when selecting contractors or making project-related decisions.
Benefits	Informed decision-making based on the study's findings can lead to improved project outcomes in refurbishment projects. For instance, project owners can choose contractors with a track record of delivering high-quality workmanship and effective communication, leading to increased client satisfaction and successful outcomes.

Challenges	Implementing data-driven decision-making may require overcoming challenges such as resistance to change and biases in decision-making processes. Additionally, accessing comprehensive data specific to refurbishment projects and incorporating it into decision-making can pose challenges.
Opportunities	Embracing the study's findings presents an opportunity for the residential construction industry to improve decision-making in refurbishment projects. By incorporating evidence-based approaches, stakeholders can make informed choices that contribute to successful outcomes, client satisfaction, and long-term industry growth.

6.7.2 Construction Practices:

The table below, titled "Table 5," outlines the Practices and Emerging Trends in Residential Construction, detailing their benefits, opportunities, and challenges.

Table 5: Practices and Emerging Trends in Residential Construction.

Practical Implications	The study highlights the importance of quality workmanship, effective communication, timely completion, and budget management in refurbishment projects. Implementing these practices can improve the overall quality and success of building refurbishments.
Benefits	Embracing these best practices in refurbishment projects can lead to increased client satisfaction, repeat business, and positive referrals. For example, a contractor that consistently delivers projects on time and within budget while maintaining high-quality workmanship can establish a strong reputation and attract new clients.
Challenges	Incorporating best practices may require overcoming challenges such as resistance to change, ensuring consistent workforce training, and implementing effective project management processes. For refurbishment projects, working with existing

	structures and addressing unforeseen conditions can present additional challenges.
Opportunities	Implementing best practices in refurbishment projects provides an opportunity for companies to differentiate themselves in the market. By consistently delivering successful refurbishments, companies can build trust with clients and position themselves as leaders in the industry.

6.7.3 Sustainability:

The table below, "Table 6," showcases Sustainability in Residential Refurbishment, highlighting the benefits, challenges, and opportunities.

Table 6: Sustainability in Residential Refurbishment: Challenges and Opportunities.

Practical Implications	The study emphasizes the potential for sustainability practices to positively impact refurbishment projects. Incorporating sustainable design, materials, and energy-efficient features can enhance project outcomes and client satisfaction in refurbishment projects.
Benefits	By integrating sustainable practices, refurbishment projects can contribute to environmental conservation, energy efficiency, and improved occupant comfort. For example, retrofitting existing buildings with energy-efficient systems and incorporating sustainable materials can lead to reduced energy consumption and lower operating costs for building occupants.
Challenges	Integrating sustainability practices in refurbishment projects may involve additional costs, coordination efforts, and compliance with green building certifications or standards. Balancing the need for sustainability with the preservation of historic or existing architectural elements can also present challenges.

Opportunities	Embracing sustainability in refurbishment projects allows companies to innovate, adopt new technologies, and contribute to a more sustainable built environment. It opens doors for collaboration with sustainability-focused organizations and positions refurbishment projects as sustainable solutions for existing buildings.

By applying the findings from the study to building refurbishment projects, stakeholders in the residential construction industry can make informed decisions, improve construction practices, and promote sustainability. This can result in successful project outcomes, increased client satisfaction, a positive industry reputation, and a more sustainable built environment. Embracing these opportunities can drive the growth and long-term success of the industry.

6.8 Circular Economy Principles

The practice of incorporating reclaimed and salvaged materials, repurposing building components, and utilizing deconstruction techniques in refurbishment projects offers a multitude of advantages. These strategies not only minimize the environmental impact of construction activities but also help conserve valuable resources while preserving and enhancing the historical and aesthetic qualities of buildings.

6.8.1 Reclaimed and Salvaged Materials: Utilizing reclaimed materials is a practice that involves retrieving and reusing building materials from structures that are no longer needed or slated for demolition. For example, consider a scenario where a team is renovating a historic property. Instead of opting for new wooden beams, they source timber from a dismantled barn. This reclaimed wood, with its weathered appearance and unique history, adds an element of charm and character that brand-new materials would lack. Furthermore, this practice significantly decreases the need for new wood, helping to reduce deforestation and the energy typically consumed in the processing and transportation of fresh materials (Kibert, 2016; Burnett, 2016).

Imagine another project where bricks from a demolished schoolhouse are salvaged and used to construct the facade of a new community center. These bricks tell a story, carry the patina of history, and provide the new structure with a sense of continuity and

narrative that is both tangible and engaging. Moreover, by reusing bricks, the project circumvents the environmental costs associated with manufacturing new bricks, including high energy consumption and carbon emissions (Addis & Schouten, 2004).

6.8.2 Repurposing Building Components: The strategy of repurposing takes the concept of reuse a step further by adapting building components for entirely new functions. Consider old wooden windows being replaced during a home renovation. Instead of being discarded, they are transformed into the walls of a small greenhouse in the homeowner's garden. This creative repurposing not only saves the windows from the landfill but also supports a sustainable lifestyle through homegrown produce, underscoring the principles of a circular economy, which emphasizes keeping resources in use for as long as possible (Braungart & McDonough, 2002; Webster, 2015).

In another instance, imagine a café where the tabletops are made from old wooden doors, and the counters are built from repurposed floorboards. These elements not only reduce waste but also contribute to the café's unique ambiance and identity, making it a memorable place that underscores sustainability.

6.8.3 Deconstruction Techniques: Deconstruction involves the careful dismantling of structures to preserve their components for future use, contrasting with traditional demolition, which destroys and wastes materials. For example, an aging warehouse might be deconstructed to salvage its steel beams, wooden floors, and fixtures, all of which can be used in other building projects. This approach not only minimizes waste but also supports resource conservation and offers economic benefits by generating employment opportunities in the material salvaging and resale industries (Guy & McLendon, 2000; Laefer & Manke, 2008).

To conclude, these innovative practices in the construction industry are pivotal in steering our society towards sustainability. They help mitigate environmental impacts, conserve precious resources, and enhance buildings' cultural and aesthetic values. The ongoing adoption and innovation of such strategies are instrumental for the industry's shift to a more circular economy, characterized by resource efficiency and sustainability (McDonough & Braungart, 2010).

6.9 Health and Well-being Enhancements

In the realm of building refurbishment, the prioritization of strategies that promote health and well-being is gaining critical importance. This focus stems from the substantial duration people typically spend indoors, coupled with the profound influence that the indoor environment has on human health. In the ensuing sections, we explore a variety of strategies designed to enhance health and well-being within these settings. The discussion is further bolstered with academic references, providing a deeper, evidence-based understanding of these approaches, as detailed in Table 7 presented below.

Table 3: Construction Materials Sustainable for refurbishment.

	Approach	**Benefit**
Use of Natural, Non-Toxic Materials	Selecting Low-VOC Materials The emphasis on low-VOC materials stems from the health risks associated with VOCs, common in many building materials (Brown, 1997). These compounds can have both short and long-term adverse health effects, hence the need for alternatives. For instance, using low-VOC paints and finishes can significantly reduce indoor air pollution, creating a safer and more comfortable environment for occupants (Hodgson et al., 2000).	The primary advantage of using low-VOC materials is the potential improvement in indoor air quality. This shift can reduce symptoms related to respiratory and allergic reactions triggered by poor indoor air quality (Mendell, 2007), thus promoting better overall health and well-being for building occupants.
Implementation of Advanced Ventilation Systems	Heat Recovery Ventilation (HRV) or Energy Recovery Ventilation (ERV) Integrating advanced ventilation systems like HRV or ERV is crucial for maintaining optimal indoor air quality (Persily, 2015). These systems not only facilitate energy efficiency but also ensure that the indoor environment is continuously supplied with filtered, fresh air, thereby improving the overall air quality (Emmerich and Persily, 2001).	Implementing such systems can mitigate issues associated with poor ventilation, including the buildup of pollutants and moisture, which are known to cause health problems and discomfort among occupants (Fisk, 2000). These systems are particularly beneficial in tightly sealed buildings where

		indoor air can become stagnant.
Incorporation of Biophilic Design Elements	Integration of Nature-Inspired Elements Biophilic design involves the integration of natural elements into building interiors to create a human-nature connection (Kellert, 2008). Examples include indoor plants, green walls, water features, and maximization of natural light. Research shows that environments that connect occupants with nature can lead to significant health benefits (Ryan et al., 2014).	Spaces designed with biophilic elements have been found to reduce stress, enhance creativity, and improve well-being (Browning et al., 2012). These elements can also improve mental health by reducing feelings of anxiety and depression (Bringslimark et al., 2009).
Maximizing Natural Light and Daylighting	Optimizing Window Placement and Size The strategic use of natural light in buildings, known as daylighting, involves careful planning of window placement and other reflective surfaces to bring natural light deeper into buildings (Mardaljevic et al., 2012). This strategy can also involve the use of skylights, light tubes, and light shelves.	Exposure to natural light has been linked to the regulation of circadian rhythms, improved sleep, increased daily activity, and enhancement of mood (Boubekri et al., 2014). Daylighting in buildings also contributes to reducing the reliance on artificial lighting, thereby decreasing energy consumption (Leslie, 2003).
Thermal Comfort Optimization	Enhancing Insulation and Glazing Optimizing a building's thermal comfort involves using high-quality insulation and glazing to maintain a consistent indoor temperature (ASHRAE, 2017). This approach is essential in preventing heat loss during cold weather and heat gain during warm weather, contributing to a more stable indoor environment (Liu et al., 2012).	Improved thermal comfort has been associated with increased productivity and reduced frequency of health complaints (Seppänen et al., 2006). It plays a crucial role in ensuring occupant satisfaction in indoor environments (Frontczak and Wargocki, 2011).

The refurbishment projects that prioritize health and well-being contribute to the creation of spaces that nurture occupants' physical and mental health. The approaches discussed, from reducing exposure to harmful chemicals to incorporating elements that connect individuals with nature, are not just trends but necessities in the creation of sustainable and health-promoting environments. The academic references provided offer a deeper understanding of these strategies, underscoring their importance and benefits in the context of sustainable building refurbishment.

6.10 Lean tools improvements recommendations:

This section highlights the Lean tools identified in the research findings and underscores the significant impact of these tools in the context of building refurbishment projects. These tools have proven effective in reducing waste, enhancing productivity, and improving cost efficiency. Furthermore, we introduce innovative approaches aimed at boosting their efficacy through the integration of advanced technologies. We also identify potential areas for future research in the dynamic field of building refurbishment.

'Figure 11', presented below, offers a succinct yet comprehensive visual overview of how Lean tools are integrated into building refurbishment. The chart illustrates the evolution from current practices to future-oriented technologies, emphasizing the primary objectives of Lean Construction. It focuses on the technological innovations set to revolutionize the industry, the sustainability goals that drive these objectives, and the key stakeholders involved in this transformative shift. Essentially, this figure acts as a roadmap, delineating the direction and potential developments in the domain of building refurbishment through Lean methodologies.

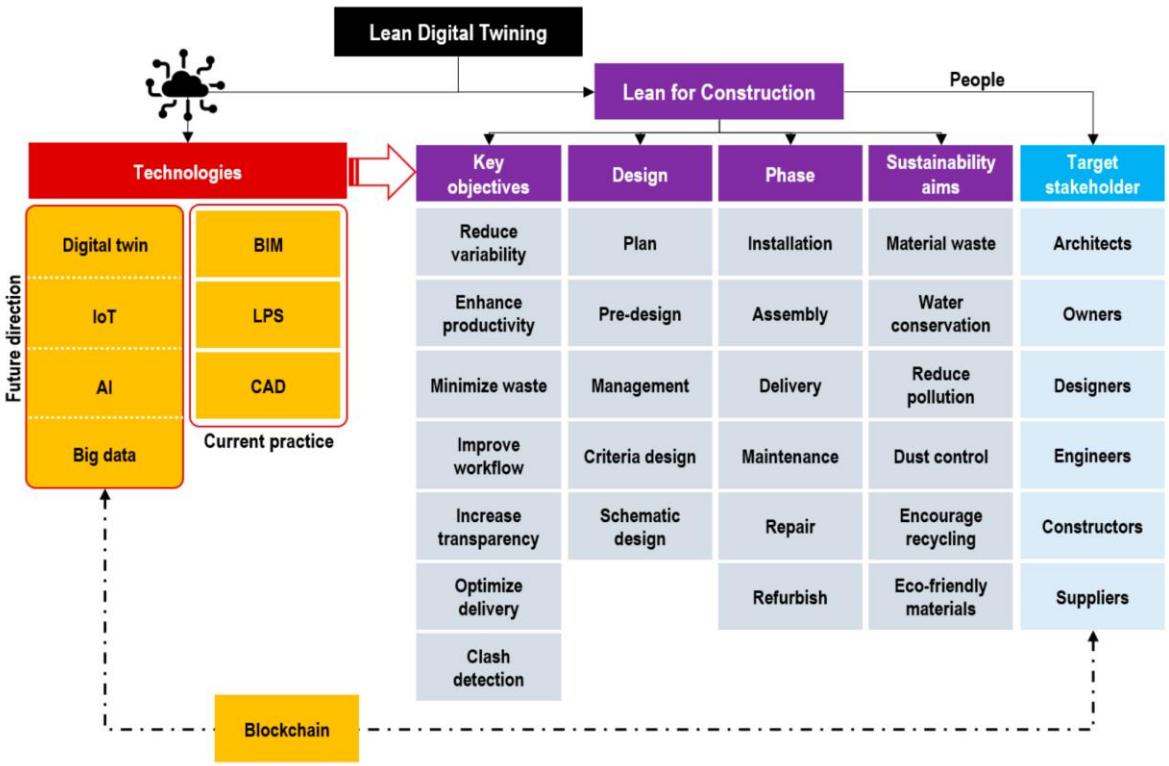

Figure 11: Summary of the future direction recommendations.

6.10.1 Value Stream Mapping:

The application of Value Stream Mapping in residential building refurbishment projects has revealed its indispensable value. It identified the permit application process as a critical bottleneck, leading to targeted streamlining efforts that yielded reduced project delays and an overall enhancement in operational efficiency. [65]

Looking ahead, there are several ways to further leverage the potential of VSM through the integration of advanced technologies:

- ★ **Digital Permitting Systems**: Implementing digital permitting systems with real-time tracking and automated notifications can expedite the permit application process. Stakeholders can monitor the progress of permit approvals digitally, reducing delays and enhancing transparency.

- ★ **Artificial Intelligence (AI) for Predictive Analysis:** Utilizing AI algorithms to analyze historical permit data can provide insights into potential bottlenecks and enable proactive measures to mitigate delays. Predictive analytics can help project teams allocate resources more efficiently.

- ★ **Blockchain for Transparent Documentation:** Implementing blockchain technology for permit-related documentation can enhance security and transparency in the permitting process. It ensures that all stakeholders have access to the latest information, reducing miscommunication and delays.

- ★ **Collaborative Project Management Software:** Integrating collaborative project management software with VSM can facilitate real-time communication and coordination among project participants. This ensures that all stakeholders are aligned and informed, reducing the likelihood of bottlenecks.

- ★ **Mobile Apps for Field Data Collection:** Equipping field personnel with mobile apps for data collection and submission can expedite the gathering of necessary information for permit applications. This real-time data capture can reduce paperwork and administrative delays.

- ★ **Geospatial Technology for Site Assessment:** Leveraging geospatial technology can aid in site assessment for permit applications. It provides accurate mapping and spatial data, enabling efficient decision-making and reducing errors in the application process.

6.10.2 Pull Planning:

In a multi-unit residential refurbishment scenario, Pull Planning sessions incorporating virtual reality technology facilitated real-time collaboration among stakeholders. This, in turn, improved coordination and reduced construction delays. [66]

To further enhance the efficacy of Pull Planning and capitalize on the benefits of technology, the following recommendations are proposed:

- ★ **Digital Collaboration Tools:** Virtual Reality (VR) and Augmented Reality (AR): Embracing VR and AR within Pull Planning sessions offers stakeholders the ability to visualize and simulate construction sequences in a dynamic, immersive environment. This technology-driven approach enhances communication, fosters a deeper understanding of project intricacies, and facilitates more informed decision-making. Stakeholders can virtually step into the project, identify potential challenges, and collectively devise strategies to mitigate them.

★ **Building Information Modeling (BIM):** The incorporation of BIM into Pull Planning is an essential step in optimizing task coordination and minimizing errors. BIM provides stakeholders with a comprehensive and visual representation of the construction sequences, allowing for the early identification of clashes and conflicts. Through early detection and resolution of issues, BIM not only contributes to error reduction but also fosters enhanced collaboration among project participants. This integration transforms Pull Planning sessions into dynamic, data-driven forums for decision-making.

★ **Cloud-Based Project Management Software:** The adoption of centralized, cloud-based project management software is pivotal for facilitating seamless communication, real-time collaboration, and project monitoring. These platforms serve as digital hubs for all project-related information, including schedules, updates, and documentation. By providing stakeholders with instant access to critical project data, automated notifications, and streamlined communication channels, cloud-based software enhances the efficiency of Pull Planning sessions and overall project execution.

6.10.3 Just-in-Time Delivery:

A successful residential refurbishment project effectively employed Just-in-Time Delivery and Vendor-Managed Inventory, resulting in reduced on-site material storage requirements and ensuring seamless material availability. This approach streamlined construction processes and heightened resident satisfaction. [67]

To optimize Just-in-Time Delivery and take advantage of modern technology, the following recommendations are put forth:

★ **Digital Supply Chain Management:** Implement real-time monitoring of material status and location through mobile apps and track-and-trace systems. These digital tools enable stakeholders to closely track the movement of materials, from supplier warehouses to the construction site. This transparency ensures timely deliveries and allows for proactive issue resolution, such as addressing potential delays or shortages promptly.

★ **Vendor-Managed Inventory (VMI):** Embrace VMI practices, empowering suppliers to assume responsibility for managing inventory levels and replenishment. VMI minimizes the material management burden on the project team and ensures a

continuous and smooth material flow. By allowing suppliers to monitor inventory and restock as needed, this approach optimizes inventory levels, reduces carrying costs, and eliminates the risk of material shortages.

★ **Digital Procurement Platforms:** Streamline procurement processes through the adoption of digital platforms that facilitate efficient communication with suppliers and comprehensive material tracking. These platforms centralize procurement activities, offering a digital repository for supplier interactions, order management, and invoice processing. The result is enhanced transparency, reduced paperwork, and more effective supplier collaboration.

6.10.4 Last Planner System:

The Last Planner System played a pivotal role in coordinating tasks among stakeholders in a residential refurbishment project. Weekly meetings facilitated progress review, issue identification, and necessary adjustments, promoting effective collaboration and timely project completion. [68, 69]

To further enhance the Last Planner System and leverage the benefits of technology, consider the following recommendations:

★ **Digital Collaboration and Visualization Tools:** Mobile Apps for Task Updates: Implement purpose-built mobile apps specifically designed for the Last Planner System. These apps enable real-time updates on task status, ensuring that all team members are consistently informed about project progress. This technology-driven approach improves communication, documentation, and accountability among stakeholders, enhancing the effectiveness of the Last Planner System.

★ **Virtual Reality (VR) for Design Coordination:** Embrace VR technology to streamline design coordination within the Last Planner System. Stakeholders can visualize refurbishment plans in a virtual environment before construction commences. This immersive experience allows for a deeper understanding of the project, facilitating early identification of design issues and enabling stakeholders to provide feedback and suggestions. VR enhances collaboration and reduces the potential for costly design changes during construction.

★ **Cloud-Based Project Management Platforms:** Adopt digital platforms as centralized hubs for project management. These cloud-based platforms facilitate collaboration by providing a unified space for stakeholders to share project-related information, track progress in real-time, and receive automated notifications. By streamlining communication and project monitoring, these platforms enhance the Last Planner System's effectiveness.

6.10.5 Visual Management:

Visual Management, encompassing visual task boards and before-and-after visualizations, has enabled stakeholders to monitor work package progress and witness the building's transformation. This transparency has greatly facilitated effective communication and decision-making throughout the refurbishment project. [70]

To further optimize Visual Management and harness the advantages of technology, consider the following recommendations:

★ **Digital Visual Reality Tours:** Incorporate digital reality tour technology into Visual Management practices. This innovation enables stakeholders to virtually experience refurbished spaces before construction commences. Digital reality tours provide an immersive and interactive way to explore the project, offering stakeholders a vivid understanding of the proposed changes. This enhanced communication fosters a stronger connection between stakeholders and the project, ultimately leading to higher customer satisfaction.

★ **Mobile Apps for Visual Collaboration:** Implement mobile apps designed for visual collaboration among stakeholders. These apps facilitate visual feedback and streamlined communication. Team members can easily annotate images, provide comments, and share feedback in real-time. This expedites the design review process and augments project efficiency by ensuring that all stakeholders are aligned and well-informed about project progress.

6.11 Chapter Conclusion

The juxtaposition of the empirical data against scholarly literature underscores the potent efficacy of Lean Construction principles in fostering superior project outcomes, albeit accompanied by significant implementation challenges. The insights gleaned from Eiffage Construction and CFE CTE not only substantiate existing academic narratives but also unveil novel, pragmatic challenges and opportunities, thereby enriching the scholarly discourse. This chapter reaffirms the symbiotic relationship between academic inquiry and industry practice, each informing and evolving the other, to navigate the complexities of the contemporary construction landscape.

7. Future direction and Conclusion:

This section highlights the Lean tools identified in the research findings, emphasizing the substantial impact of Lean Construction tools within the context of building refurbishment projects.
These tools have demonstrated their effectiveness in reducing waste, enhancing productivity, and improving cost efficiency.
Moreover, we introduce innovative approaches to further enhance their efficacy by integrating advanced technologies. Additionally, we outline potential areas for future research in the continually evolving field of building refurbishment.

7.1 General Conclusion:

In conclusion, this research vividly demonstrates how the integration of Lean Construction principles within the residential refurbishment sector, as notably implemented by Eiffage Construction and CFE CTE, significantly revolutionizes traditional operational approaches. This integration extends beyond the adoption of new guidelines, embracing a philosophy that emphasizes maximizing value, efficiency, and stakeholder contentment while concurrently reducing resource and time wastage.

The transition to Lean methodologies, encompassing strategies like just-in-time delivery, standardized work, and continuous improvement, results from a deep analysis of their long-term benefits. These benefits are not limited to the elimination of redundancies and judicious resource use but also include heightened operational streamlining, improved team coordination, and boosted productivity and customer satisfaction. However, Lean Construction's adoption faces challenges such as organizational and cultural resistance, particularly in Tunisia, where conventional practices are deeply rooted, and financial and resource constraints pose significant barriers.

The impacts of Lean Construction on residential construction projects are profound. Eiffage Construction’s experiences underscore this with documented reductions in project timelines and material waste, translating to faster deliveries, cost savings, and heightened customer satisfaction. This approach not only meets quality standards but often exceeds them through methods like continuous improvement and value stream mapping, enhancing the overall project quality and fostering a culture of excellence.

Financially, the adoption of Lean principles proves not just operationally advantageous but also fiscally beneficial. Both Eiffage Construction and CFE CTE report positive impacts on their bottom lines, achieved through intelligent resource allocation and waste minimization, enhancing cost management without compromising on quality.

Moreover, Lean Construction fundamentally alters team dynamics and collaboration, particularly noted in French companies. The methodology breaks down traditional work silos and promotes a culture of collective planning, holistic thinking, and open communication. This environment not only leads to innovative problem-solving and a more invested workforce but also results in greater client and employee satisfaction.

In essence, the research affirms that Lean Construction is not just a set of techniques but a transformative philosophy. Its successful implementation requires overcoming cultural and financial barriers, focusing on continuous improvement, and fostering a collaborative environment. The profound impact of Lean Construction on efficiency, quality, cost management, and team dynamics in the residential refurbishment sector highlights its potential as a critical component in evolving construction practices.

7.2 Future Direction:

7.2.1 Limitations of the study

In the conclusion of this research, it is evident that the study's findings, while insightful, are framed within specific limitations that suggest substantial opportunities for future exploration. The constrained sample size, potential biases, geographic limitations, and the scope and depth of the analysis notably shape the results and their applicability. Future research directions, therefore, should aim at broadening the scope to include more extensive and varied building refurbishment projects, integrating residential, commercial, and heritage buildings across diverse geographic regions. Such expansion is crucial for enhancing the generalizability and depth of findings.

Further, addressing the potential biases in self-reporting and the limitations in geographic focus will be essential. Future studies could adopt methodologies that incorporate both qualitative and quantitative data, leveraging anonymous surveys, independent project evaluations, and comparative studies across different regions. These approaches can provide a more balanced, comprehensive, and culturally diverse perspective, enabling a richer understanding of the global refurbishment landscape.

The exploration of additional factors influencing project satisfaction, such as design quality, sustainability, and post-occupancy outcomes, is another critical area. Investigating how emerging technologies and digital tools impact refurbishment processes and outcomes can uncover new insights into improving project efficiency and satisfaction. In sum, future research, by addressing these limitations and exploring these suggested avenues, has the potential to significantly contribute to the body of knowledge in building refurbishment, guiding industry practices towards more effective, sustainable, and satisfying project outcomes.

7.2.2 Future Research Direction Recommendations:

The future trajectory of research and application in the realm of building refurbishment, particularly under the Lean Construction framework, beckons a multifaceted approach. The following recommendations provide a roadmap for future research directions:

Expanding Technological Integration: Future research should focus on integrating emerging technologies such as artificial intelligence (AI), machine learning (ML), and advanced analytics to enhance decision-making processes in refurbishment projects. These

technologies could provide predictive insights for better resource allocation, risk management, and project scheduling. Investigating the synergy between Lean principles and these advanced technologies could offer groundbreaking improvements in project execution and outcome predictability.

Sustainability and Environmental Impact: Given the increasing emphasis on environmental stewardship, future studies should delve into how Lean Construction methodologies can be harmonized with sustainable building practices. This includes research on minimizing carbon footprint, enhancing energy efficiency, and utilizing sustainable materials in refurbishment projects. Evaluating the long-term impacts of such practices on building life cycle, occupant health, and overall ecological footprint will be critical.

Human-Centric Design and User Experience: Understanding and integrating end-user feedback in the refurbishment process can offer significant insights. Future research might explore how Lean tools can be used to enhance the user experience, focusing on aspects like spatial design, indoor environmental quality, and adaptability to users' changing needs. This approach aligns with the growing trend towards human-centric design in the construction industry.

Economic Analysis and Market Trends: Comprehensive studies that examine the economic implications of Lean Construction in refurbishment projects, including cost-benefit analysis, return on investment, and market trends, can provide valuable information for decision-makers and stakeholders. This research could help justify the initial investment in Lean methodologies by elucidating their long-term financial benefits.

Training and Skill Development: As the construction industry evolves, the importance of upskilling the workforce to adapt to new methodologies and technologies cannot be overstated. Future research should consider the development and evaluation of training programs and educational modules that focus on Lean Construction, advanced technology application, and sustainable practices in refurbishment projects.

By addressing these recommendations, future research can pave the way for innovative, efficient, and more sustainable approaches in building refurbishment, aligning with the evolving needs of the industry and society at large. The adoption of these recommendations will not only improve project outcomes but also contribute to the broader goal of enhancing the resilience, sustainability, and efficiency of the built environment.

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Annexes

Annex A

Survey responses translated to English.

Response translated to english from the Tunisian Company CFE CTE**:**

Which of the following LEAN principles does your company use?

- Our company primarily uses Just-in-Time Delivery to minimize the storage costs and reduce waste from unused materials. We are also slowly integrating aspects of Continuous Improvement in our processes.

What are the primary reasons that your company has not adopted LEAN Construction principles?

- The main reasons include a Lack of awareness or understanding of LEAN principles among most staff members, and a strong Resistance to change due to the belief that current processes are working adequately. We also face Cost concerns regarding the initial investment necessary to shift to LEAN principles.

How has the use of LEAN principles impacted your company's residential construction projects?

- Though in early stages, we've observed slight improvements in efficiency and a reduction in waste, specifically related to material use and inventory costs, through our limited use of Just-in-Time Delivery.

What are the biggest challenges your company faces when implementing LEAN principles in residential construction projects?

- The biggest challenges include Resistance to change from team members and Inadequate training or education about LEAN principles, making the transition slower and more challenging.

How has the application of LEAN construction principles or other methods/principles affected the efficiency and quality of your residential construction projects?

- We've noticed more streamlined deliveries and reduced holding costs from Just-in-Time deliveries, though we're still in the preliminary phases of assessing quality changes.

In what ways do you believe the construction industry as a whole could benefit from the widespread adoption of LEAN Construction principles in residential construction projects?

- LEAN principles could significantly reduce waste and improve project delivery timelines industry-wide, creating more sustainable practices and increasing client satisfaction.

Does your company have plans to adopt or expand the use of LEAN construction principles in the future? If yes, please provide details.

- Yes, we're planning to initiate a series of training sessions and workshops to increase awareness and understanding of LEAN principles among our staff. We believe that education is the first step towards broader adoption.

How do you measure the success of your residential construction projects, and do you believe that incorporating lean construction principles and tools would improve project outcomes?

- Success is currently measured by adherence to budgets, client satisfaction, and timely project completion. We anticipate that LEAN principles could enhance our performance in these areas by reducing waste and improving efficiency.

Please propose some possible examples of lean construction principles application in building site works.

- Beyond Just-in-Time Delivery, we are looking into standardizing our processes for quality assurance and implementing Pull Scheduling for better workflow and resource allocation.

Annex B

Response translated to english from Eiffage Construction the French Company:

Which of the following LEAN principles does your company use?

- We actively employ a combination of LEAN principles, including Standardization, Just-in-Time Delivery, Collaborative Project Planning, Continuous Improvement, and Last Planner System.

What are the primary reasons that your company has not adopted LEAN Construction principles?

- N/A. We have adopted and continue to expand our use of LEAN Construction principles.

How has the use of LEAN principles impacted your company's residential construction projects?

- LEAN principles have profoundly improved efficiency, reduced waste, and improved the quality of construction. We've also seen Reduced costs and significantly Improved collaboration among project team members, streamlining processes and enhancing project outcomes.

What are the biggest challenges your company faces when implementing LEAN principles in residential construction projects?

- Initial Resistance to change from team members was a challenge, along with the Difficulty implementing new processes or technologies. However, through comprehensive training programs and demonstrable success stories, we've largely overcome these obstacles.

How has the application of LEAN construction principles or other methods/principles affected the efficiency and quality of your residential construction projects?

- Our project timelines have improved by 15-20%, and we've seen a 15% decrease in material waste, leading to substantial cost savings and less environmental impact. The quality of construction has also improved due to proactive problem-solving and standardization.

In what ways do you believe the construction industry as a whole could benefit from the widespread adoption of LEAN Construction principles in residential construction projects?

- Widespread LEAN adoption would revolutionize the industry by maximizing value for clients, minimizing waste, improving construction quality and safety, and ensuring more sustainable construction practices.

Does your company have plans to adopt or expand the use of LEAN construction principles in the future? If yes, please provide details.

- Absolutely. We plan to deepen our use of Value Stream Mapping and expand the use of Target Value Design to enhance our client-centric approach. Continuous training and improvement are embedded in our company culture.

How do you measure the success of your residential construction projects, and do you believe that incorporating lean construction principles and tools would improve project outcomes?

- We measure success through client satisfaction, adherence to timelines and budgets, and the quality of the final construction. LEAN principles have been instrumental in improving all these areas by aligning our operations more closely with client values and industry standards.

Please propose some possible examples of lean construction principles application in building site works.

- One example is our use of the Last Planner System, enhancing commitment-based planning and accountability. We've also integrated digital tools for real-time communication and adjustments, aligning with LEAN's emphasis on agility and continuous improvement.

Annex C

Survey Questions:

★ Which of the following LEAN principles does your company use? (Select all that apply)

● Standardization
● Just-in-Time Delivery
● Collaborative Project Planning
● Continuous Improvement
● Value Stream Mapping
● Pull Scheduling
● Target Value Design
● Last Planner System

★ What are the primary reasons that your company has not adopted LEAN Construction principles? (Select all that apply)

● Lack of awareness or understanding of LEAN principles
● Resistance to change or the belief that current processes are working well
● Cost concerns
● Lack of available resources or tools to implement LEAN principles
● Other (please specify)

★ How has the use of LEAN principles impacted your company's residential construction projects?

● Improved efficiency and reduced waste
● Improved quality of construction
● Reduced costs
● Improved collaboration among project team members
● Other (please specify)

★ What are the biggest challenges your company faces when implementing LEAN principles in residential construction projects?

● Resistance to change from team members
● Inadequate training or education about LEAN principles
● Difficulty implementing new processes or technologies

● Difficulty finding suppliers or subcontractors who are willing to adopt LEAN principles
● Other (please specify)

★ How has the application of LEAN construction principles or other methods/principles affected the efficiency and quality of your residential construction projects?

★ In what ways do you believe the construction industry as a whole could benefit from the widespread adoption of LEAN Construction principles in residential construction projects?

★ Does your company have plans to adopt or expand the use of LEAN construction principles in the future? If yes, please provide details.

★ How do you measure the success of your residential construction projects, and do you believe that incorporating lean construction principles and tools would improve project outcomes?

★ Please propose some possible examples of lean construction principles application in the building site works.

Annex D

Interview questions:

1. Are you familiar with lean construction principles and tools?

2. Have you used any lean construction tools in residential construction projects?

3. If yes, which lean construction tools have you used and how have they impacted your project outcomes?

4. If not, what are some potential barriers to adopting lean construction principles and tools in residential construction projects?

5. How important do you believe lean construction principles and tools are in improving project outcomes and reducing waste in residential construction?

6. Do you have any plans to incorporate lean construction principles and tools in your future residential construction projects?

7. Have you received any training or education on lean construction principles and tools?

8. How do you measure the success of your residential construction projects, and do you believe that incorporating lean construction principles and tools would improve project outcomes?