

Tailoring a management model and on-site planning at a construction company

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“Believe you can and you’re halfway there”

Theodore Roosevelt

Abstract

The construction sector is historically recognised for delays in project completion. There are several reasons why this can happen, including planning failures, lack of resources and adverse weather conditions. To counter-tradition, the Lean Construction methodology, which has been gaining popularity since the beginning of the 21st century, proposes collaborative planning methods that make execution more predictable, which leads to waste minimisation, to increase value for the client.

This dissertation project describes a consultancy service provided by the Kaizen Institute in a construction company. The project's objective is to improve the final margin of the construction projects and comply with the deadline for completion.

To achieve the objectives, a customised model was proposed according to the size of the project (small and large construction projects). This typification has not yet appeared in the literature. Throughout the project, a phase-gate model was developed for the stages preceding the execution of the work, an on-site planning model and a lessons-learned session. The present dissertation proposes to study the creation of a more robust model for large construction projects and to analyse its influence on compliance with the completion deadlines and the final margin of the project.

The implementation of the model, customised for large projects, was carried out by piloting a project of ten months duration. In the context of the dissertation, the results of the first two months were analysed. The methodology implemented, namely the creation of an Obeya room, resulted in a 6.1% increase in the construction margin. Regarding the fulfilment of the expected date of conclusion, the work presents a delay of five days, which despite not corresponding to the achievement of the objective, is seen as positive given the adverse weather conditions.

Customização do modelo de gestão e planeamento em obra numa Empresa de Construção

Resumo

O setor da construção é historicamente reconhecido pelos atrasos na conclusão dos projetos. Existem várias razões pelas quais isso pode acontecer, nomeadamente falhas no planeamento, falta de recursos e condições climáticas adversas. Com o objetivo de contrariar a tradição, a metodologia Lean Construction, que tem vindo a ganhar popularidade desde o início do século XXI, propõe métodos de planeamento colaborativo que tornam a execução mais previsível, que conduz à minimização do desperdício, numa tentativa de aumentar o valor para o cliente.

O presente projeto de dissertação descreve um serviço de consultoria numa empresa de construção, prestado pelo Kaizen Institute. O objetivo do projeto prende-se com a melhoria da margem final das obras e do cumprimento do prazo de conclusão.

No sentido de concretizar os objetivos, foi proposto um modelo customizado à dimensão da obra (obras pequenas e obras grandes), uma tipificação que até ao momento não surge na literatura. Ao longo do projeto, desenvolveu-se um modelo phase-gate para as etapas que antecedem a execução da obra, um modelo de planeamento em obra e sessão de lições aprendidas. Neste sentido, o presente trabalho de dissertação propõem estudar a criação de um modelo mais robusto para obras grandes e analisar a sua influência no cumprimento dos prazos de conclusão e da margem final da obra.

A implementação do modelo customizado a obras grandes, foi realizado através da pilotagem de uma obra de dez meses de duração. No contexto de dissertação, foram analisados os resultados dos primeiros dois meses. A metodologia implementada, nomeadamente a criação de uma sala Obeya, resultaram num incremento de 6,1% da margem de obra. Relativamente ao cumprimento da data prevista de conclusão, a obra apresenta à data um atraso de cinco dias, que apesar de não corresponder ao atingimento do objetivo, é visto como positivo dadas as condições climáticas adversas.

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Acronyms and Symbols

KPI – *Key Performance Indicator*

LC – *Lean Construction*

LPS – *Last Planner System*

PDCA – *Plan, Do, Check, Act*

PPC – *Percent Plan Complete*

QCD – *Quality, Cost and Delivery*

QSE – *Quality, Safety, Environment*

TA – *Tasks Anticipated*

TMR – *Tasks Made Ready*

VSA – *Value Stream Analysis*

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Chapter 1

1 Introduction

The present work emerges in the scope of the Master's Dissertation in Mechanical Engineering Degree. The project was developed at a construction company by Kaizen Institute.

The main goal of the present work is to customize the management methodologies of a construction company based on their duration and typology to improve the lead time and the margin of the construction projects.

In this chapter, the Kaizen Institute will be presented and contextualization of the project that allowed the realization of the present work will be made. For contractual reasons, it was decided to omit the customer's real name, from now on referred to as Build Company.

1.1 Kaizen Institute

The history of the Kaizen Institute dates to the 1950s, when Masaaki Imai, its founder, started working at the Japan Productivity Center. At the time, Japan was destroyed and in economic recession due to the Second World War. Together with world-renowned quality figures such as Shoichiro Toyoda and Taiichi Ohno, they developed a business model, currently known as the Toyota Production System, which allowed the automotive brand to launch faster, at a lower-cost and high-quality cars to the market. Masaaki Imai explained the extraordinary competitiveness of the Japanese brand in the book “Kaizen: The Key to Japan's Competitive Success”, where the Kaizen principles were explained for the first time. “Kai” that means change and “Zen” that means better form the expression “change for the better”.

Founded in 1985, the Kaizen Institute's mission is to help companies “change for the better” by providing consulting services. It operates in the Process Industry, Logistics, Retail, Health, Shared Services, Public Sector and Production and Assembly Industry.

1.2 Construction Sector

In this section, an analysis is made of the sector of activity and the company in which the consulting project that served as the basis for the realization of this work was inserted.

1.2.1 Sector Analysis

The construction sector, an integral part of a country's economic apparatus, differs from other sectors in terms of production and the labor market. It is characterized by a very extensive value chain and a wide variety of customers. These can range from the government and local authorities to the individual client, which makes the projects unique. (Maria Ioannis Baganha 2000).

In recent years, construction has been under pressure to reduce construction prices while shortening construction cycles and increasing quality. Added to this difficulty is the uncertainty currently experienced by inflation, which vehemently affected the price of building materials by 10.1% and total construction costs by 8.6% compared to the same period last year (Varzim 2022). Additionally, the recurrent shortage of qualified labour imposes a limitation on the execution of works (Rosado 2022).

Regarding the future, it is expected that construction companies will continue to digitize the business to integrate all activities in the value chain, which will allow not only better control of project deadlines, but also enhance data analysis to introduce improvements. Even so, the biggest challenge for the coming years is to make buildings more sustainable to satisfy consumer demands and constitute a differentiating factor against the competition (Rosado 2022).

Regarding trends, it is worth highlighting the growing popularity of the Lean Construction methodology, particularly in the United States of America. In Portugal, despite publishing articles and dissertations dating from the beginning of the century, there still needs to be more knowledge about the methodology.

1.2.2 Build Company presentation

Build Company's history dates to the 70s when the company was dedicated to the rental of trucks and construction equipment. Over the years, it began to carry out small construction works, taking advantage of its machines' availability, until the company's core activity became construction. It is a reference company in the sector that carries out projects that can last from days to months.

Build Company divides operations into three types: Bituminous, Infrastructure and Civil. Each one with unique specificities from the planning stage to the execution stage. Nowadays, these projects are managed undifferentiated but simultaneously dependent on who manages them. The monetary advance for each type of operation is shown in figure 1.

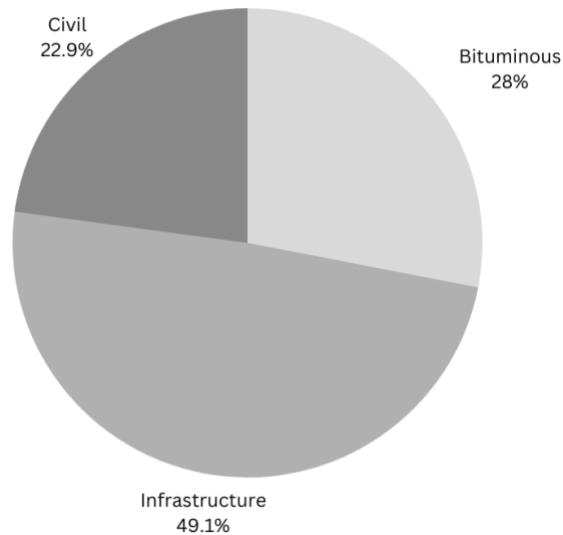


Figure 1- Share of production type in Build Company

It was concluded, together with the company's management, that redesigning the construction management model and the management of planning on-site would be opportunities for improvement with disruptive gains for the company.

On the other hand, improving maintenance management and leveraging external equipment rental are other company improvement opportunities. Despite the significant estimated gains using these improvements, this project will not be focused on these initiatives.

1.3 Objectives of the Project

The dissertation aims to create a customized model for the size of the construction project (small and large construction projects). The customization includes the processes that precede the work and the management of the on-site planning.

The goal of the Kaizen Institute is the achievement of a final margin of 15% (a 4% increase over the 2021 average) and to complete the construction project within the stipulated deadline. Therefore, the objective of the dissertation, which corresponds to two months of the construction project, is to achieve a 4% increase in the expected margin for the period under analysis. In addition, the objective is to meet the planned completion deadline for the period under study.

1.4 Methodology

The methodology used in this project is divided into two phases: planning and implementation.

The planning phase comprises carrying out a Value Stream Analysis (VSA), where the various levels of activity of the company are mapped from the macro process to a specific activity. Complementarily, brainstorming sessions are held to collect feedback from those in daily contact with the processes. The solution principles that positively impact the company are identified based on the information collected. Then, a timetable is created with the solution principles grouped into workshops and initiatives to improve processes. The present

dissertation focuses on the workshops “Construction Management Model” and “Management Planning in-site”, defined in this phase.

The implementation phase consists of executing the proposed initiatives. Initially, processes are changed to make them more consistent, and efficient and mitigate problems identified in the planning phase. With well-defined processes, the implementation of measures follows, which are monitored to ensure correct execution and future sustainability. A nine-step A3 is a project management methodology and communication tool throughout this phase.

1.5 Document Structure

This document is organized into five chapters. In Chapter 1, the main objectives and context of the project are outlined. Chapter 2 provides theoretical support to introduce the most relevant concepts for the characterization and implementation phases: Process Mapping, Pareto analysis the Kaizen Business System, Project Management, and Lean Construction. After doing the literature review, Chapter 3 presents the current situation of the company, where the aspects that motivated improvement actions for the writing of this dissertation will be emphasized. Chapter 4 intends to deliver the solution design defined to trigger improvements. Following the implantation design, Chapter 5 presents the results and Chapter 6 takes the main conclusions and describes future works.

Chapter 2

2 Literature Review

This Chapter aims to expose the theoretical component that supports the characterization of the company's current situation and the implementation phase. For the characterization phase, it is essential to understand the process mapping tools, the meaning of the key performance indicators analyzed and the Pareto Analysis. For the implementation phase, it is vital to present the approach used to create value in this project, the Kaizen Business System, and the methodologies that supported the development of the project, Project Management, and Lean Construction.

2.1 Kaizen Business System

The Kaizen Business System is a continuous improvement tool created by the Kaizen Institute and based on holistic principles. The objectives of this system are Growth, QCD (*Quality, Cost, and Delivery*), and Motivation.

2.1.1 Kaizen Change Model

The Kaizen Change Model comprises three competencies, Daily Kaizen, Value Stream Kaizen, and Strat Kaizen. Although they do not necessarily work together, these three competencies complement each other. The Kaizen Institute flag, depicted in figure 2, consists of three parts. Each of them corresponds to one of the competencies listed.

Daily kaizen is a continuous improvement philosophy that involves identifying and addressing minor, incremental improvements in work processes daily. This approach empowers employees to make small changes that can significantly improve efficiency, productivity, and quality over time. Daily kaizen can lead to increased efficiency and overall organizational performance by encouraging a culture of continuous improvement (K. Institute 2018a).

VSA Kaizen is a continuous improvement approach that focuses on eliminating waste and streamlining processes in the value stream or the series of activities required to bring a product or service from concept to customer. This approach engages employees at all levels to identify and eliminate non-value-added activities and improve efficiency, leading to increased productivity and overall organizational performance (K. Institute 2018a).

Strategic kaizen is a continuous improvement approach that focuses on making long-term, organization-wide improvements to processes, systems, and structures. This approach involves setting clear goals and objectives, identifying critical areas for improvement, and implementing and tracking the results of improvement initiatives. As a result, strategic kaizen can lead to increased efficiency and overall organizational performance (K. Institute 2018a).



Figure 2 - Kaizen Institute flag meaning (K. Institute 2018a)

In figure 2, it is also possible to visualize the involvement of each functional level of a company in the different competencies. By drawing a horizontal line through each management level, the degree of participation of each is indicated by the length of each competency. The flag is in line with what was said by the founder of Kaizen Institute, the essential aspect for the development of an improvement project is the involvement of the top management (Graban 2012).

2.1.2 Kaizen Principles

While developing a kaizen project, it is vital to know and apply the pillars of the Kaizen Institute. The five fundamental principles that support the implementation of projects are (Imai 2014):

- **Focus on Customer Value** – Implementation of projects focused on delivering quality to customers, meeting their needs and objectives, and continuously improving their experience.
- **Create an Efficient Flow** – Eliminate non-add value activities and variability in the customer processes while implementing pull methodologies.
- **Be Gemba Oriented** – Gemba, is a Japanese word that means “place where the value is created”. To improve the processes and lead the transformation, it is crucial to observe and go to the Gemba and talk with the people involved in those processes every day to identify the root causes and their improvement opportunities.
- **Involve all People** – Involve everyone in the company, from top management to employees. It is crucial to transmit trust to everyone and consider their ideas and concerns for improvements.
- **Be Scientific and Transparent** – Always rely on data to make improvements and evaluate the impacts. Use the PDCA or SDCA to structure the improvement meetings.

Simultaneously, data must be displayed using visual management to communicate information clearly and transparently.

2.1.3 The Seven Wastes

To eliminate non-add value activities, it is necessary first to be conscious of the seven types enunciated by the Lean methodology. Recognizing them makes it easier to drill down to the root causes and change for the better. Activities that are considered waste are (Zandy 2019; Pereira 2009):

- **Transportation** – Unnecessary movement of material or equipment between job sites. Although this waste cannot be eliminated, it can be minimized through better planning, coordination, and daily communication.
- **Inventory** – Overproduction that results in excess. Although it is necessary to have some inventory to keep the work proceeding, too much inventory should be minimized as it occupies space and represents handling costs.
- **Motion** – Movement of people that do not represent value added to the project. An example is searching for a tool due to a poor work area layout.
- **Waiting** – People inactivity by not being able to execute the task due to late delivery of material, equipment, or information.
- **Overproduction** – Building something too soon or placing an order of material before it is necessary rather than building and delivering the right amount when needed. If there is a change in plans, it is necessary to change the materials.
- **Overprocessing** – Redundant steps, such as double handling or transforming material, are made. Administrative tasks are frequently an excellent example of this type of waste in construction as it is necessary to double data entry like signatures.
- **Defects** – Work that is done incorrectly or damaged material. That means rework, repair, or replacement of material will be necessary.

In consonance with Zandy (2019), an eighth waste is commonly made in the construction sector, inefficiently using workers' skills instead of focusing on activities they can create value.

2.2 Process Mapping

Process mapping is a tool that visually represents the steps and decisions involved in a business process (Michael L. George 2004). It helps to understand the workflow, identify bottlenecks and inefficiencies, and improve the overall efficiency of the process (Thomas Pyzdek 2013). According to Faria (2015), the first step in process analysis and modelling is the mapping of the current situation, called “as is model”. After the analysis of the current situation, is prepared an improved version, named “to be model”. There are several ways to create a process map, including flowcharts, swim lane diagrams, and value stream maps (Michael L. George 2004). Focusing on *the swim lane diagram* a process map tool that shows the workflow between different organisational departments or functions (Michael L. George 2004). It is called a swim lane diagram because the process steps are arranged in horizontal lanes, as shown in figure 3, with each lane representing a different department or function (Thomas Pyzdek 2013).

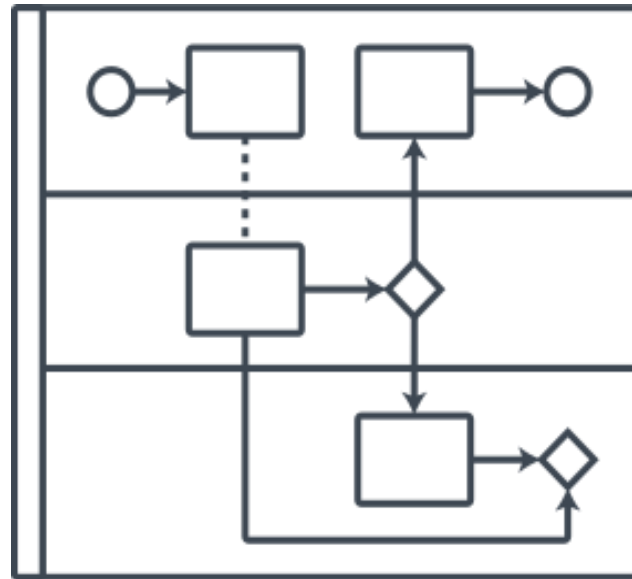


Figure 3 - Swimlane Diagram example (Lucidchart 2022b)

The main advantage of using a swim lane diagram is that it clearly shows the roles and responsibilities of each department or function in the process (Hunt 1996). This can be particularly useful for identifying bottlenecks and inefficiencies and developing process improvements (Thomas Pyzdek 2013).

The first step to creating a swim lane diagram is identifying the different departments or functions involved in the process (Michael L. George 2004). Then, map out the steps in the process, including the inputs, outputs, and decision points. Finally, standard symbols represent different steps, such as rectangles for process steps, diamonds for decision points, and arrows for flow.

To complement the analysis of the process mapping, it is possible to analyze the root causes of a specific problem using the Ishikawa diagram, also known as a fishbone diagram. An Ishikawa diagram is used to identify the causes of a problem or issue by breaking it down into smaller, more specific categories. It is structured as a diagram with a central spine representing the problem or issue and branches representing the various contributing factors or causes. The branches are organized according to a category, such as people, materials, methods, machines, and environment, to help identify the root cause of the problem (Lucidchart 2022a).

2.3 Pareto Analysis

The *Pareto analysis*, also known as the 80-20 rule, identifies and prioritises the most critical factors in each situation. Vilfredo Pareto, an Italian economist who observed that a small number of factors often accounted for most outcomes, is the creator of the Pareto analysis. Pareto analysis is applied in various fields, including construction, engineering, and healthcare. The Pareto analysis involves creating a chart, as shown in figure 4, which is a bar chart showing each factor's relative contribution to the overall outcome. The factors are ranked in descending order, with the most critical factors appearing on the left. The chart also includes a line for the cumulative percentage of the total outcome accounted for facilitating the analysis (Ali Gorener 2013)

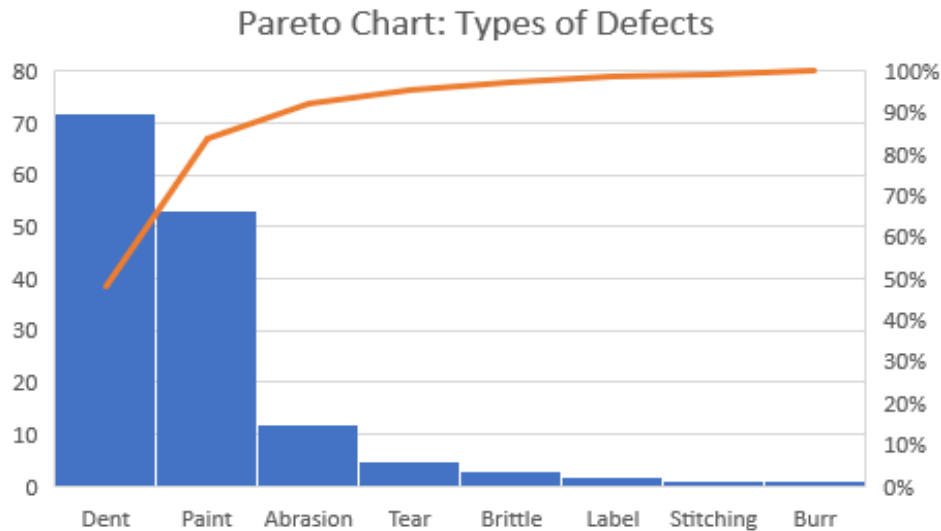


Figure 4 – Example of a Pareto chart for Defects (Frost 2022)

This analysis is commonly used in the construction industry to identify the most common causes of project delays. However, according to Zhang, it can also be used to prioritise and allocate resources on a construction project, ensuring that the most critical tasks are completed first. For these reasons, Pareto analysis is a powerful tool to identify and prioritise different works and activities. As a result, it can help construction firms focus their resources on the areas with the most significant impact, leading to improved efficiency and effectiveness (Ali Gorener 2013).

2.4 Project Management

Project Management is a tool to facilitate planning, managing resources, and organizing to complete the project objectives and goals successfully.

Project managers oversee the various tasks and activities involved in a project, ensuring the project is completed on time, in less than the budget, and fulfills the level of quality. This often involves coordinating the efforts of a team of people and managing any risks or challenges that arise throughout the course of the project (Williams 2022).

Projects can fail for a variety of reasons. Some common reasons why projects fail include insufficient planning, lack of clear objectives and goals, poor communication, lack of resources, and unrealistic deadlines. Also, poor risk management and the expected performance of the solution can influence projects to fail.

When risks are not assessed at the beginning of the project, problems tend to arise when the project starts, compromising start-up time and time-to-market, as shown in figure 5 (K. Institute 2018b).

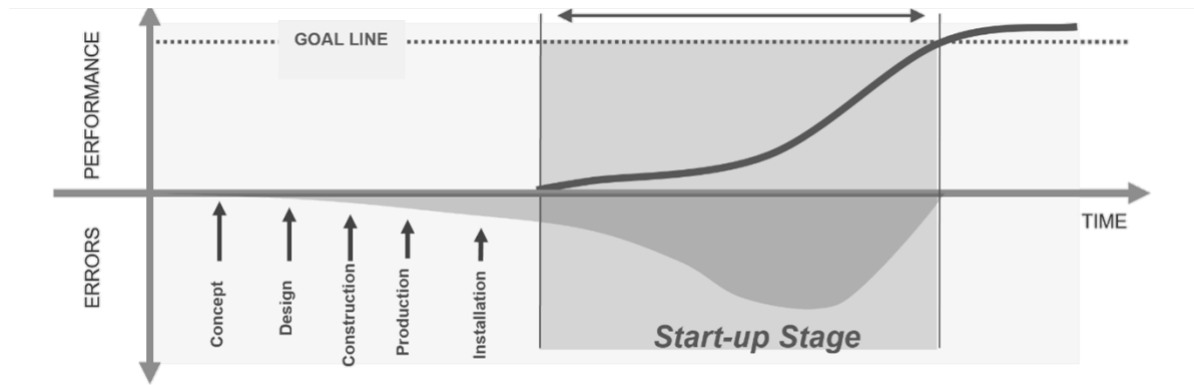


Figure 5- Late assessment of risks (K. Institute 2018b)

Preventing and managing risks at the beginning of the project reduces or even eliminates problems that occur during start-up, which allows for a vertical start-up curve and a reduction in time-to-market, as shown in figure 6. In addition, these objectives increase the team's motivation and a sense of accomplishment of tasks with added value (K. Institute 2018b).

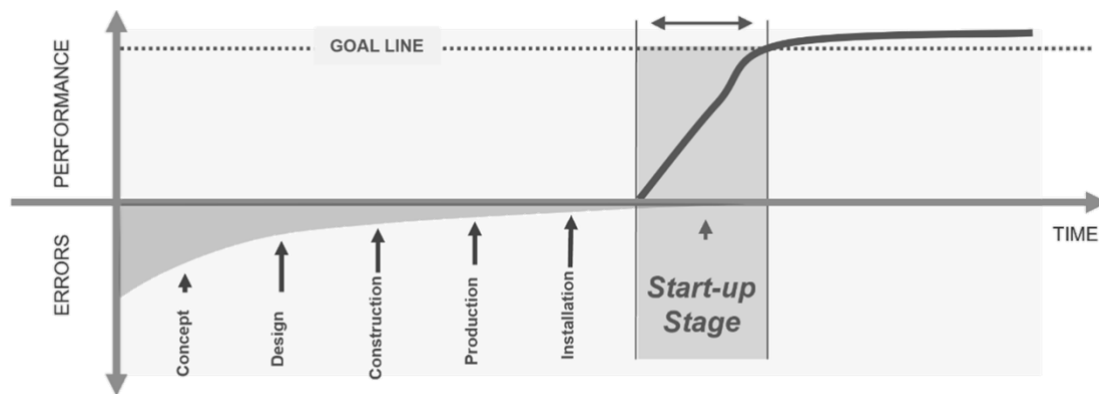


Figure 6 - Early assessment of risks (K. Institute 2018b)

In 2009, Garcia (2009) published in the Portuguese court of accounts the audit of public works undertakings by direct management. The document identified the ranking of failed projects. For example, the emblematic building "Casa da Música", located in the city of Porto, was the first on the list, with a financial slippage of 295.5% and a deadline for completion with a deviation of 4.6 years.

To overcome fails like this, Kaizen institute proposes the Kaizen Lean Project Management that consists of a series of sequential steps (K. Institute 2018b):

1. Project Design
2. Project Initiation
3. Planning Optimization
4. Obeya Control
5. Portfolio Management

2.4.1 Project Design

Stage-Gate is a commonly used project management methodology that involves dividing a project into distinct phases or stages and requires that specific criteria are met before proceeding to the next stage, as shown in figure 7. In this methodology, the stage is seen as the set of

decisions that must be taken during a stage. The gate is the evaluation of compliance with the mandatory criteria.

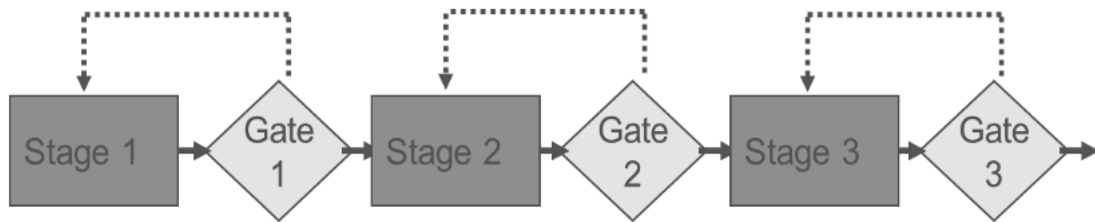


Figure 7 – Example of a Stage-Gate Flowchart (K. Institute 2018b)

This process is designed to help ensure that a project progresses logically and orderly and that key decision points are identified and addressed along the way. Each phase of the project typically includes a series of tasks or activities. Each gate represents a point at which the project team must review the project's progress and decide whether to continue to the next phase (K. Institute 2018b).

Implementing this methodology eliminates the waste and rework that arises due to decisions not taken, wrong decisions, extensive decisions, and lack of decisions taken. Furthermore, when intermediate decision points are created, it promotes reflection on processes and more effective management of critical issues for the different phases of the project.

2.4.2 Project Initiation

Project initiation is an essential phase in Project Management as it sets the foundation for the rest of the project. During the initiation phase, the project team identifies the project's goals, objectives, resources, and stakeholders involved. This phase also consists in creating a high-level plan for how the project will be delivered, which will serve as a reference point throughout the rest of the project (Kerzner 2017).

All the information defined during the project initiation should be addressed in the initiation A3, a communication tool used by Kaizen Institute. An example of an initiation A3 is shown in figure 8 (K. Institute 2018b).

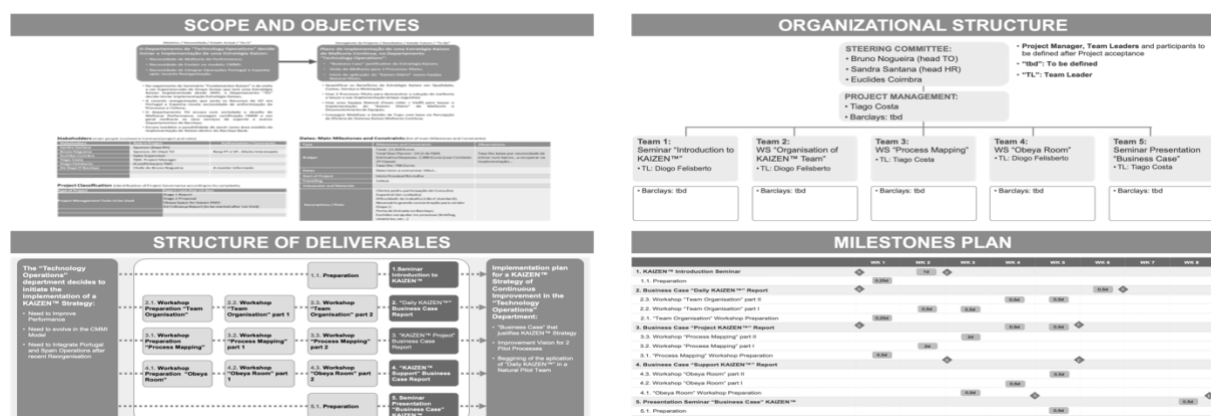


Figure 8 - Example of an Initiation A3 (K. Institute 2018b)

Risk management is also carried out at this stage, an important step to identify, assess, and prioritize potential risks that may affect the project's success. It is essential to know the difference between a problem and Fuguai. A problem is characterized by a situation happening at the moment and, through immediate action, can be solved. Fuguai, a Japanese word meaning "risk factor", is a situation that can occur and have an impact, although it is controllable through early identification. By doing so, it is possible to mitigate the risks and prevent significant problems that could impact the project's success (K. Institute 2018b).

Furthermore, the awareness of the risks makes it possible to allocate resources and plan contingencies, which can help the project to be completed successfully.

2.4.3 Planning Optimization

Plan optimization refers to the process of identifying and implementing changes to a plan to make it more efficient and effective. This optimization can involve analyzing and revising various aspects of the plan, including the tasks and activities involved, the resources required, and the sequencing of those tasks and activities.

2.4.3.1 Critical Chain

The critical chain, a concept part of the plan optimization, is a modified version of the critical path. The definition of a critical path is the sequence of tasks in a project that determines the minimum time to complete the entire project. In other words, the tasks that have the most extended duration. The critical chain is the longest chain through the network, also considering the dependencies at the task level but also dependencies at resources.

Goldratt (1997) suggests that traditional planning almost always fails due to behaviour syndromes. His research proposes that the problem with conventional project management is the inclusion of a contingency within each task, named security at the task level. Although the expected output is the completion of the task on time, in practice, the opposite occurs due to human factors that affect the expected completion of project tasks. The syndromes are (Goldratt 1997):

- **Parkinson's Law:** Pacing the completion of the task throughout the entire duration assigned to improve the work rather than reporting early completion. The combination of this syndrome with security at the task level results in never delivering before the planned date, although it could be possible.
- **Student Syndrome:** Starting the job at the latest possible moment. The combination of this syndrome with security at the task level results in never delivering before the planned date due to the consumption of security buffer at the beginning of the project.
- **Multitasking:** Working on multiple tasks simultaneously and not being fully committed to any task. Figure 9 shows that multitasking takes longer than focusing on tasks at the time due to setups.

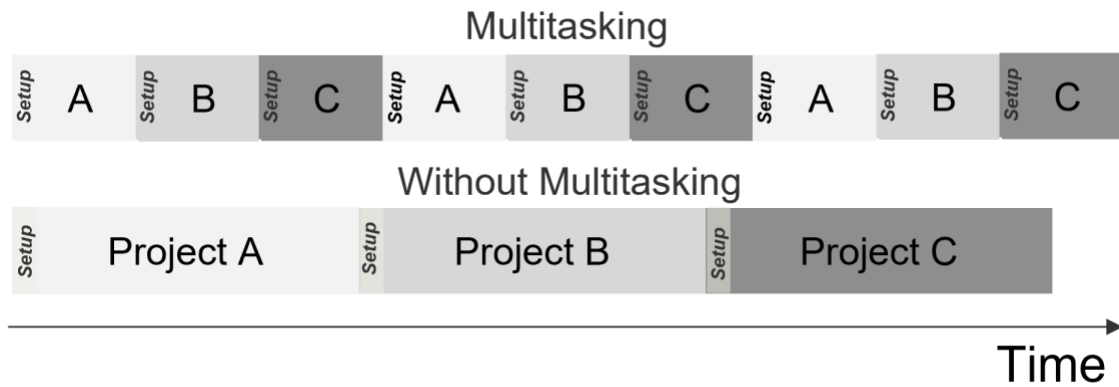


Figure 9 - Multitasking effect on time delivery

These syndromes show that allocating security to tasks makes problems invisible and hidden in the people who perform the tasks. Therefore, to fix the problem, safety should be taken from the tasks to make problems visible and allow people to act in advance.

In his book, Goldratt (1997) proposes the critical chain method based on five steps:

1. **Identify:** The first step of the method is identifying the critical chain and possible safety at the task level.
2. **Correct:** Because putting safety at the task level is ineffective, the method relies on removing all the safety from the task level and creating a buffer at the project's end.
3. **Define:** Project buffer as the project's main key performance indicator. In parallel, project managers should create a buffer for non-critical tasks to protect the critical chain. This buffer should be created because the critical chain can easily change if a single non-critical task gets delayed. By doing so, the critical chain at the start of the project is more likely to be the critical chain at the end of the project, making the management of the project easier.
4. **Safeguard:** Avoid multitasking and eliminate constraints.
5. **Monitor:** Keep watch on project buffer and feeding buffer consumption by analyzing the chart presented in figure10. The chart is in concordance with visual management methodologies, being the consumption of the project Buffer described by the formula 1:

$$Buffer\ Consumption(\%) = \frac{Cumulative\ Lateness}{Project\ Buffer\ Size} \quad (1)$$

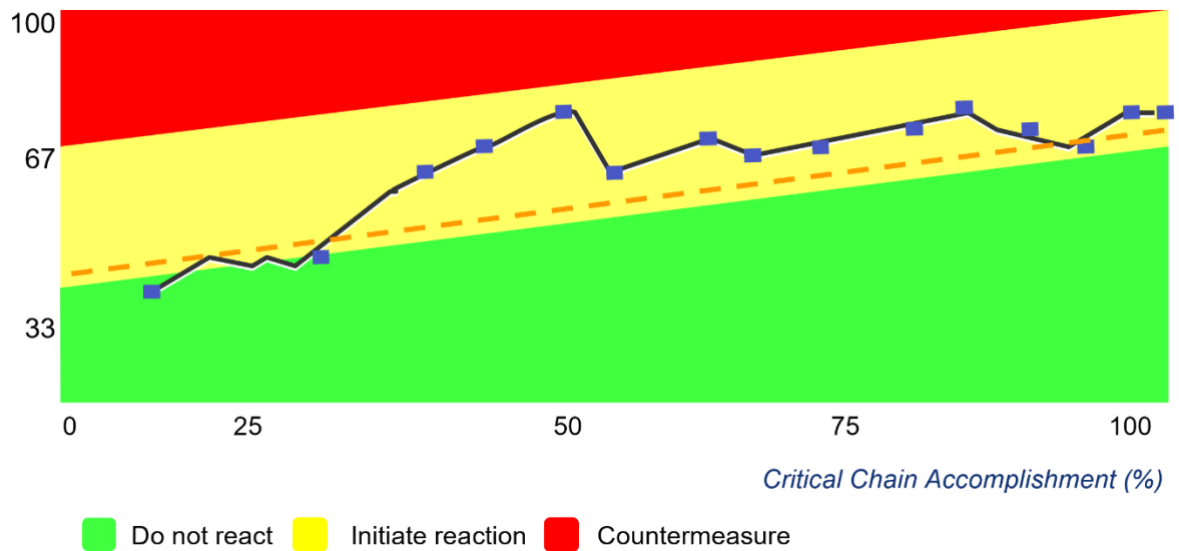


Figure 10 – Example of a Project Buffer Indicator (K. Institute 2018b)

The critical chain method results in the transfer of safety from individual tasks to the project. It is important to mention that the completion date determined after the buffers are positioned is used as the project completion date passed on to the stakeholders. Although the project completion date coincides with the completion date in the traditional planning model, the team is aware of the buffers and is driven by the actual task durations.

When the project buffer is above the target, the manager can choose one of two techniques to reduce the lead time. The first is Crashing, allocating more resources to a particular task, which increases costs. The second technique is fast-tracking, which consists of transforming sequential tasks into parallel tasks, which, despite the benefit, represents greater risk due to the greater coordination difficulty (Laoyan 2022).

2.4.3.2 Last Planner System®

According to the Lean Construction Institute, Lean Construction is an oriented project delivery that uses lean methods to eliminate or reduce the activities that do not add value to the project and improve the activities that increase profits, productivity, and innovation in the industry (L.C. Institute 2016). To increase and improve value-added activities, Lean Construction defends vital planning and control of the works. The most used tool to this effect is the Last Planner System® (LPS), which is another important concept of planning optimization.

First, it is essential to understand the traditional way of construction. The planning is identified based on what should be done without trying to forecast eventual constraints that might arise. As a result, projects end up doing less than expected, as seen in figure 11, where the intersection of what can be done and what will be done represents a short area due to unexpected problems. Using the LPS means that the teams are planning in advance, being able to anticipate constraints and make the necessary efforts to liberate them, as seen in figure 11, where the intersection is now more significant (Juan Felipe Pons 2019). This problem-solving makes the workflow as smooth as possible.

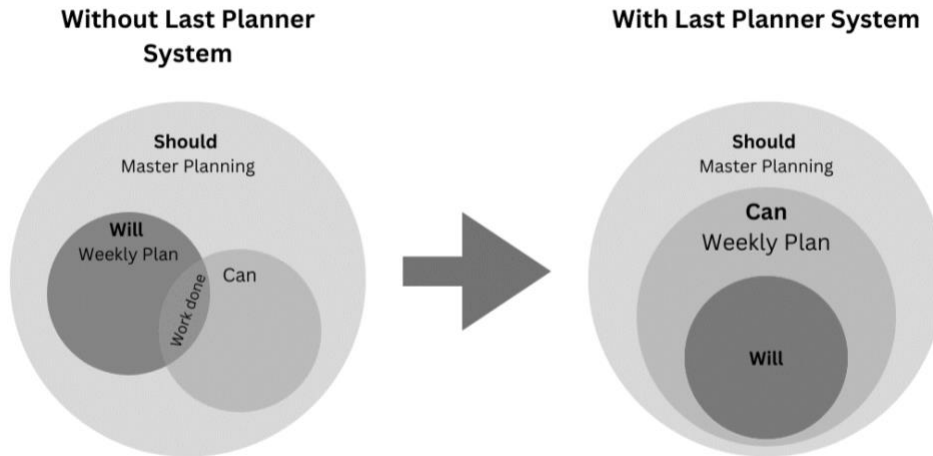


Figure 11 - Traditional versus LC approach (Adapted from (Juan Felipe Pons 2019))

The LPS is a holistic system used to absorb the variability associated with the construction sector. It is a planning tool that creates a predictable workflow and reduces uncertainty (Hernán Porras Díaz 2014). This system is divided into five parts: master planning, phase planning, make-ready planning, weekly work planning, and learning, as shown in figure 12.

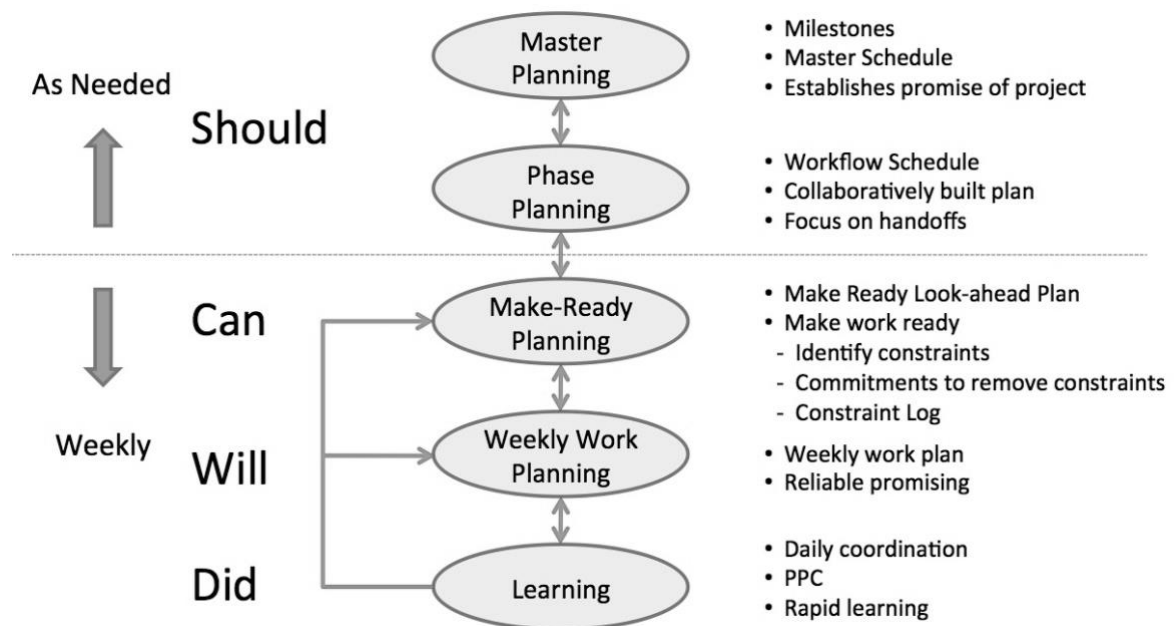


Figure 12 - Last Planner System methodology (Richert 2017)

Master planning is the first part of the system, which is a collaborative session consisting of defining the project's overall aspects to ensure that the interests and needs are met. In this part, the significant milestones and delivery dates are specified, resulting in a Gantt chart. It is essential to involve everyone in the discussion (Richert 2017).

Phase planning, a collaboratively meeting with the foreman and the superintendents, serves to plan the activities according to the pull plan approach, from the end to the beginning. By doing

so, they must establish the performances, and resources needed and identify constraints. These constraints should be discussed to make commitments to one another on the tasks, durations, and handoffs (Zandy 2019).

After identifying the plan, the last planners must gather regularly to look four to six weeks ahead to ensure the work can be done. By identifying and discussing each task's start and the field handoffs in more operational detail, they are more likely to predict upcoming constraints. Each participant is committed to removing the constraint within a certain period to ensure a smooth and predictable workflow (Richert 2017). To ensure that tasks are remembered, they are posted on an action plan board. The board should identify the person responsible and the completion date.

In the weekly work planning part, each last planner exposes the daily tasks from the pull planning map on a board. This way, they are converting the tasks into commitments. According to Richert (2017), at this part is extremely important to have reliable shared plans.

The system's last part consists of sharing the team's progress in a daily huddle. When the targets are not accomplished, they collaboratively make adjustments to maintain the shared goal achievable. To potentiate the lessons learned in the daily meetings, it is essential to analyze some key performance indicators. According to Richert (2017) and Zandy (2019), the most pertinent for the construction are:

- **Percent Plan Complete (PPC):** Measure how well the planning system is working, indicating the percentage of assignments that are 100% complete as planned.
- **Tasks Made Ready (TMR):** Measures the performance of lookahead planning in identifying and eliminating constraints to make activities ready for implementation.
- **Tasks Anticipated (TA):** Measures the percentage of anticipated activities on the look-ahead plan.

In summary, the Last Planner System is a waterfall planning method that starts with a general schedule and drills down to a shorter and specific weekly plan with a high probability of being done (Hernán Porras Díaz 2014).

2.4.4 Obeya Control

The Obeya Room, which means "big room" in Japanese, is a tool used at Toyota as a part of the Lean Project Management methodology. The purpose of the Obeya Room is to simplify the management of projects by having all relevant information and stakeholders in one place, which helps to speed up decision-making and improve the efficiency and effectiveness of the project. This is achieved through the collaborative work of a cross-functional team, which can lead to shorter project lead times, improved project quality, and better control over the project. Five principles are followed in the Obeya Room (K. Institute 2018b):

1. **Everything is in the same place:** All relevant information and resources are easily accessible and located in one central location.
2. **Physically visible:** Information is displayed visually on whiteboards or charts, so it is easy to understand and track progress.
3. **Regular and periodic updates:** Information is updated regularly and periodically to ensure that all stakeholders are aware of the current status and progress of the project.

4. **The appropriate level of detail:** Only necessary and relevant information to the project is included, while unnecessary or irrelevant details are minimized.
5. **Only relevant information:** Information necessary to the project is included, and any unnecessary or irrelevant information is excluded.

In the context of Lean Construction, the Obeya Room is where all meetings from the Last Planner System (LPS) happen. The boards in this room are oriented in a sequence based on the PDCA (Plan, Do, Check, Act) cycle, which is a continuous improvement tool. As shown in figure 13, the first two boards in the typically Obeya room contain the look ahead plan created in the LP and the master schedule. Then stands the operational map (do), the project indicators (check) and the actions plan (act) (Juan Felipe Pons 2019).

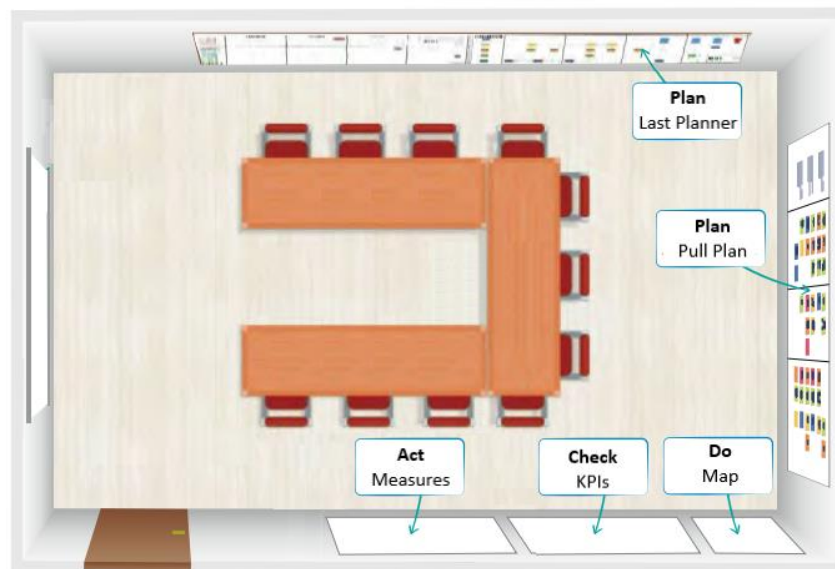


Figure 13 - Obeya Room Layout (adapted from (Juan Felipe Pons 2019))

Following the principles of the Obeya Room in the context of LC, project lead times and quality can be improved, resulting in a more efficient and effective project management process.

2.4.5 Portfolio Management

Portfolio management refers to aligning an organization's resources and investments with its strategic goals and objectives. In the context of project management involves identifying, prioritizing, and managing a portfolio of projects that contribute to the organization's overall strategy.

According to Burgan (2014), one size does not fit all. The author argues that each project is unique. Although some might be predictable, others could be complex and carry risks. For this reason, project management should not be the same for all types of projects but instead, should represent an effort and suitability to the type or size of the projects in question. Project tailoring facilitates project planning and capacity management (Burgan 2014).

Prioritizing projects in a portfolio involves evaluating and comparing each project's potential value, risk, and feasibility and deciding which ones should be given higher priority (P.M. Institute 2021). There are several approaches to prioritization, including:

- **Benefit measurement:** This involves evaluating the potential benefits of each project and prioritizing those that offer the greatest potential return on investment (ROI), either in financial or non-financial terms.
- **Risk assessment:** This involves evaluating the potential risks associated with each project and prioritizing those that pose the most significant risk to the organization.
- **Feasibility analysis:** This involves evaluating the resources, skills, and other constraints that may impact the ability to successfully deliver each project and prioritizing the most feasible given the organization's current capabilities.
- **Strategic alignment:** This involves evaluating the alignment of each project with the organization's overall strategy and prioritizing those that contribute most directly to the organization's goals.
- **Portfolio balance:** This involves considering the overall mix of projects in the portfolio and ensuring that the portfolio is balanced in terms of risk, complexity, and other factors.

Prioritization is dynamic and may require regular review and adjustment as circumstances change (P.M. Institute 2021).

Another important part of portfolio management is being able to create lessons learned. This involves actively seeking out and documenting the key insights and lessons learned from past projects (Rowe 2006). By doing this, the aim is to identify and capture the knowledge and experience gained from past projects and to use this information to improve the effectiveness of future projects (Rowe 2006).

The lessons-learned process typically involves reviewing the successes and improvement opportunities at the end of each project, identifying the key factors that contributed to these outcomes, and documenting these insights in a structured and accessible way (Rowe 2006). This may involve creating a dedicated database or repository for storing and organizing lessons learned and establishing a process for regularly updating and revising the lessons learned information.

According to Rowe (2006), lessons learned should include five steps: identify, document, analyze, store, and retrieve, as shown in figure 14.

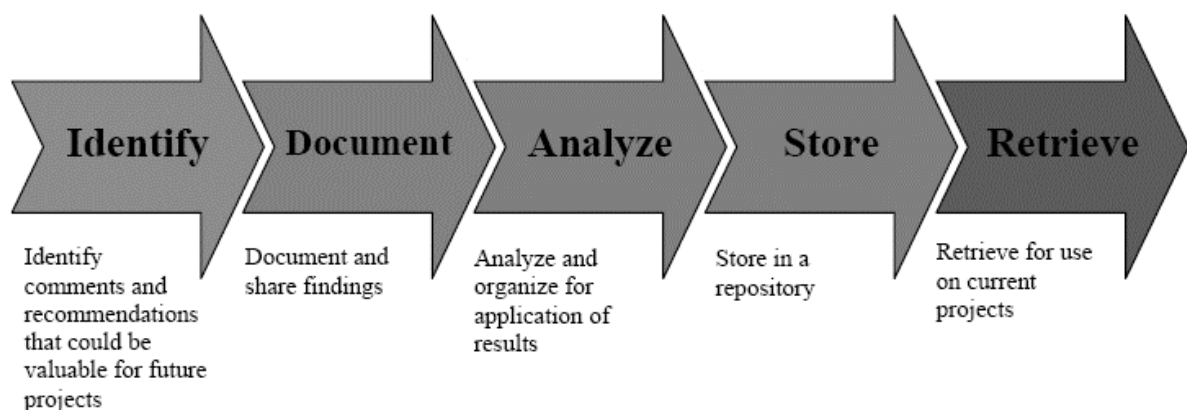


Figure 14 - Steps of Lessons Learned (Rowe 2006)

The first step is to identify comments and recommendations that should be considered in future projects. The identification should be an activity prior to the joint session.

The second step is to document the lessons learned recognized in the session. This step aims to get the best practices out to all stakeholders.

The third step is to analyze the lessons learned to verify the feasibility of their application.

In the fourth step, the lessons learned are stored. Usually done on a shared drive, this allows the lessons learned to be available to other project teams.

The last step is to retrieve the lessons learned for application in ongoing projects.

2.5 Key Performance Indicators

The construction industry is dependent on deadlines protected by contractual issues and profit margins. As a result, many companies in the industry use key performance indicators (KPIs) to track progress and identify improvement areas. According to Ward (2023), the criteria to choose a KPI should be the smart rule, which stands for Specific, Measurable, Attainable, Relevant and Time-bound KPIs. In parallel, their characteristics should be the alignment with the goals and relevance to the stakeholders. On-Time-Completion and the Construction Net Margin are common indicators to measure in the construction industry.

On-Time-completion refers to the completion of a project within the agreed-upon time frame. This KPI is important because delays can lead to cost overruns and customer dissatisfaction. In addition, several factors can impact timely completion in the construction industry, including weather conditions, the availability of materials and labour, and the efficiency of project planning and management. When timely completion is achieved, the indicator takes a value of 1 and otherwise a value of 0. To monitor and control the project's timely completion during its execution, the Construction Delay indicator can be used, which is obtained by marking the critical path of the project (Ahmed Mohamed Omar 2021).

Construction Net Margin is another important KPI for construction companies. It measures the amount of profit earned on a project relative to the total cost of the project. By monitoring the margin, companies can identify opportunities to improve efficiency and increase profitability (Ahmed Mohamed Omar 2021). The formula for calculating the margin is:

$$\text{Construction Net Margin (\%)} = \frac{\text{Total Revenue} - \text{Total Cost}}{\text{Total Revenue}} \times 100 \quad (2)$$

On-Time-Completion and Construction Net Margin are essential KPIs for construction companies to track progress and identify areas for improvement. By regularly monitoring these indicators, companies can ensure timely and profitable project completion.

Chapter 3

3 Characterization of the Current Situation

The present chapter aims to describe in detail the company's current situation, through process mapping, from the handover to the execution of the construction. Although the budgeting team is not directly associated with the aim of the present project, it includes a current situation to consider the impact of the main problems downstream. The characterization is divided into two stages, the Handover, Planning and Kickoff and the Execution, to facilitate the reader's comprehension.

To collect the information presented in this chapter, a team of people was involved in the process in intensive sessions to map the current situation. This team consisted of the administrator, the CEO, a budget analyst, the bituminous production director, the civil production director, the infrastructure production director, the accounts manager, the equipment responsible, and the QSE director.

In the following chapter, the improvement opportunities are presented.

3.1 Process Mapping

3.1.1 Handover, Planning and Kickoff

As schematically represented in figure 15, the first step is market prospecting. When prospecting results in lead conversion, the client invites the company to participate in a tender for the execution of the construction project, and the winner is decided by evaluating both the technical quality of the budget and the proposed price. Before executing the budget, the administration and the budgeting department check whether the project is interesting to Build Company. However, at the time, this decision is not so meticulous. Having decided to go ahead with the tender, the company studies the process and then consults values for materials and subcontracts. In this processing activity, technical doubts arise recurrently regarding materials and subcontracting due to a lack of feedback from past experiences. Finally, the proposal is closed after the price reception and sent to the customer. Later, there may be proposal review loops until the client decides to adjudicate. The main reasons for the loss of tenders at this stage

are the lack of involvement of the purchasing and production departments and the involvement in many tenders simultaneously. These reasons are reflected in a loss of competitiveness.

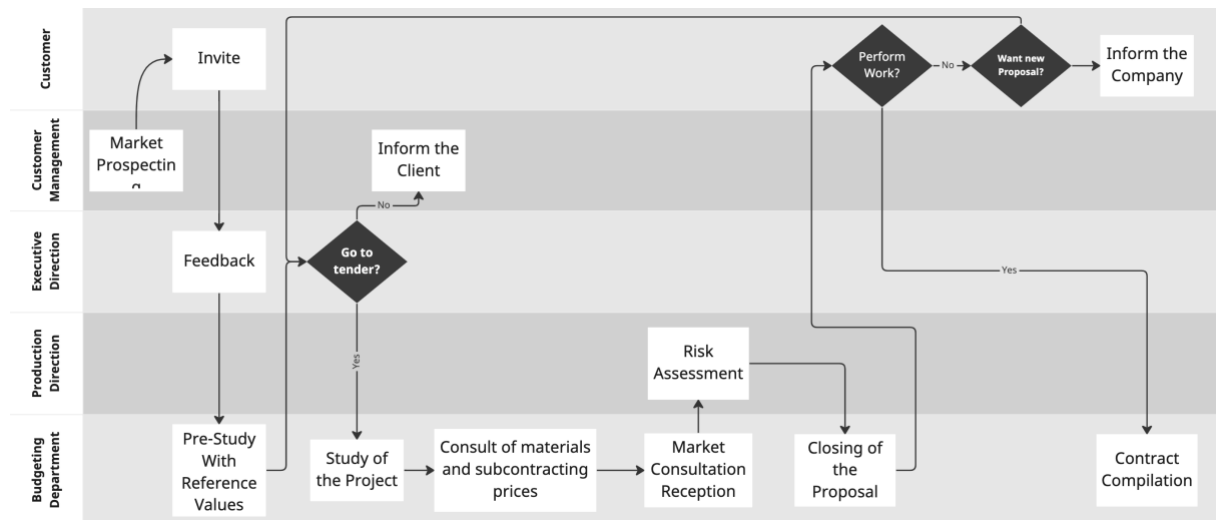


Figure 15 - Information Flow from the handover to the contract compilation

Then, the budgeting department compiles the contract, introduces the project into the Enterprise Resource Planning used by the company, and does the handover to the production department as shown in figure 16.

Through the observation of handovers, it was possible to verify that there are no standard rules for what should be transmitted to the production teams. The various meetings took different paths, which is why they are characterised by a great variability of the issues addressed. In this context, it is common to have failures in the passing of information, which sometimes leads to doubts on the part of those who receive the project. At the end of the meeting, the documents used for the budgeting process are handed in and a sheet with project observations is passed around for signatures collection.

Returning to the flow of information presented in figure 16, the team is only defined after the handover due to the lack of qualified labour and high turnover. Once the team has been determined, the production department hands over the folder to the construction director, who studies the construction project and plans the execution. The study phase of the project is very dependent on who executes it and, again, there is great variability in the process. Some directors carry out a re-budgeting that will be analysed in detail later in this chapter and some say that reading the contract is fundamental. Those who do not follow good practice claim not to do so due to lack of time and assume the study to be insufficient. Following the study phase, the planning involves creating a schedule in *Ms Project* that defines the project's critical path and expected dates for the entry of material and equipment on site.

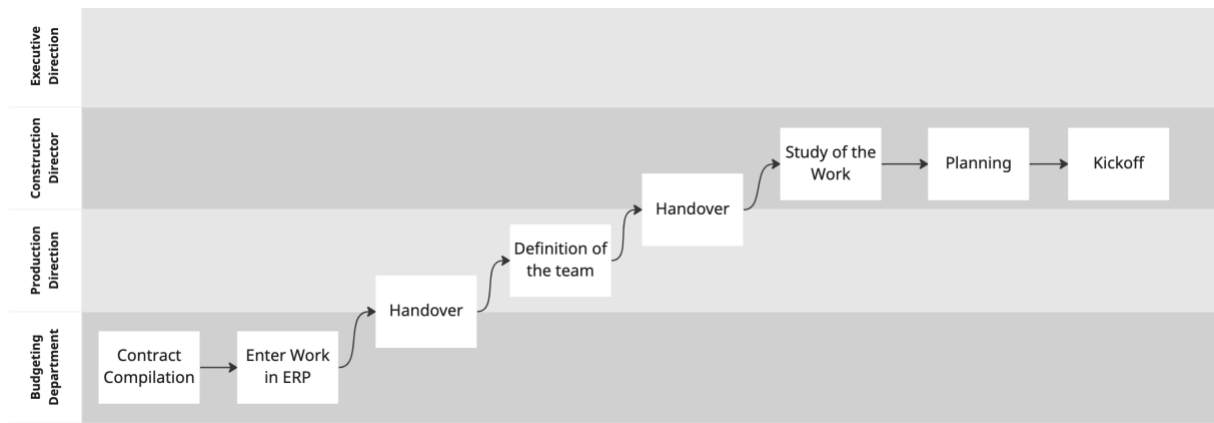


Figure 16 - Information Flow from the contract compilation to the Kickoff

The last stage of figure 16 is the Kick-off, a meeting, similar to the handover but with respect to planning and re-budgeting defined by the site manager. At this meeting, the site strategy, the equipment plan, the subcontracting plan, and the general outlines of the contract should be transmitted. Once again, it was found that there are no standards for the meeting and not always all the information necessary for a good understanding of the strategy is transmitted. In addition, the kick-off meeting is not always held.

3.1.2 Execution

Nowadays, construction management and execution depend on who manages it but generally focus on maximising the occupation of resources and minimising costs. This can be achieved, for example, by increasing labour hours and reducing the material used.

Additionally, projects are managed using a top-down approach, in which the project manager makes the decisions and communicates with the workers. The lack of involvement impacts the motivation and productivity of the workers.

It is also possible to identify common and recurrent aspects during the execution of the project. The way relationships with stakeholders and material requisition are managed a pattern as described below:

- Monthly meetings with subcontractors
- Weekly requisition of materials
- Weekly equipment requisition
- Monthly production meeting

The extended period between meetings is often critical, resulting in a lack of communication and coordination between the different parties.

The management method generally shows a high probability of waste due to a lack of communication and coordination between the various parties involved. It very often results in delays and extra costs.

3.2 Pareto Analysis

Pareto analysis was conducted to find a pattern regarding the invoicing over the amount of work done. The graph resulting from this analysis is shown in figure 17, where is possible to see all the construction projects conducted in 2021.

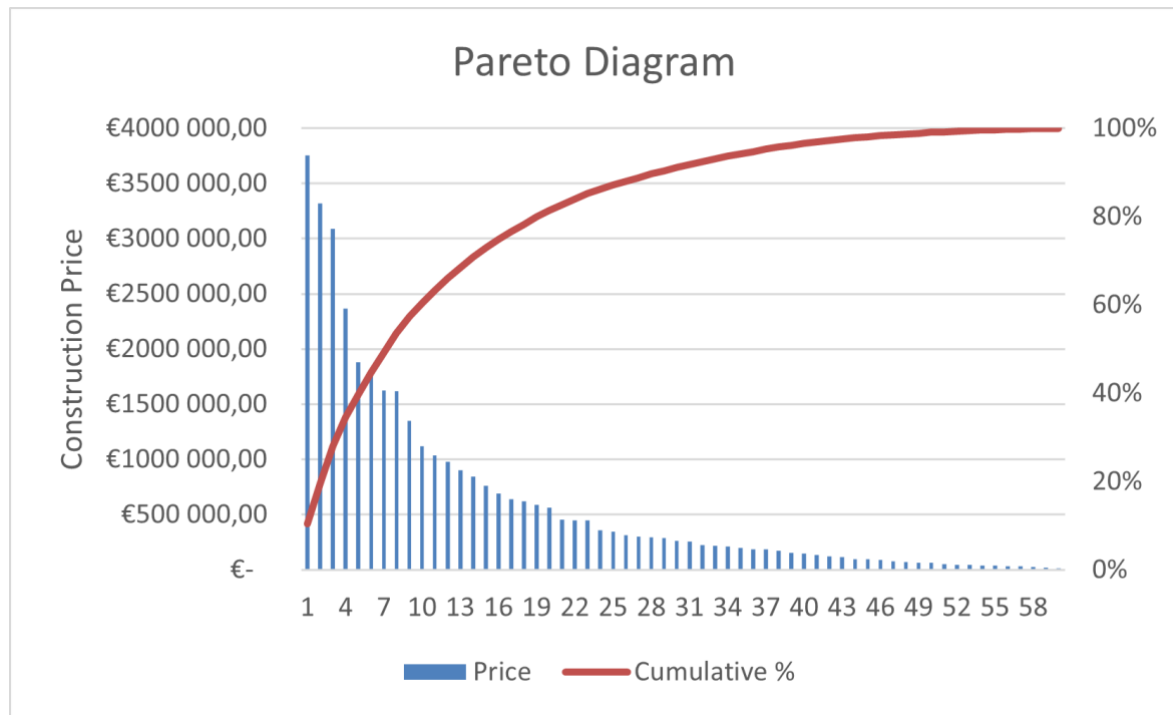


Figure 17 - Pareto Analysis of the price of all construction projects conducted in 2021

From the visual analysis of figure 17, it is possible to conclude that 80% of the company's turnover is found approximately in construction projects over 500,000€, which corresponds approximately to 20% of the constructions made in the company. In turn, projects under 500,000€ correspond to around 80% of the number of projects carried out by the company in 2021, which allows us to conclude that a low percentage of projects is responsible for the majority of the company's turnover.

3.3 Key Performance Indicators

Key performance indicators (KPIs) are a way to measure the performance of a business or organization. By using KPIs, Build Company can make data-driven decisions that can help improve the efficiency and profitability of the projects. Additionally, KPIs help construction companies monitor their compliance with industry regulations and standards.

In this session, the KPIs proposed to improve the scope of the current project will be used to characterize the current situation, the Construction Net Margin, and the On-Time Delivery.

3.3.1 Construction Net Margin

The Construction Net Margin, presented in table 1 for the year 2021, is the indicator that measures the efficiency and profitability of each construction margin. In 2021, the global Business Margin was 11%.

Table 1 - Construction Margins of 2021

<i>Type of Construction</i>	<i>Construction Margins 2021</i>
<i>Bituminous</i>	11%
<i>Infrastructure</i>	11%
<i>Civil</i>	15%
<i>Global Business</i>	11%

Although the average margin of 2021 is positive, it is noteworthy that by analysing the data of 2021, 22% of the construction projects delivered in 2021 had a negative margin, representing losses. For example, a project budgeted at €623k had a margin of -17% and a job at €19k had a margin of -67%.

In a collaborative session with the prominent participants in the process, it was possible to identify the leading causes of the insufficient construction net margin by filling in an Ishikawa diagram represented in figure 18. This diagram allows the identification of the root causes that will help improve the margins.

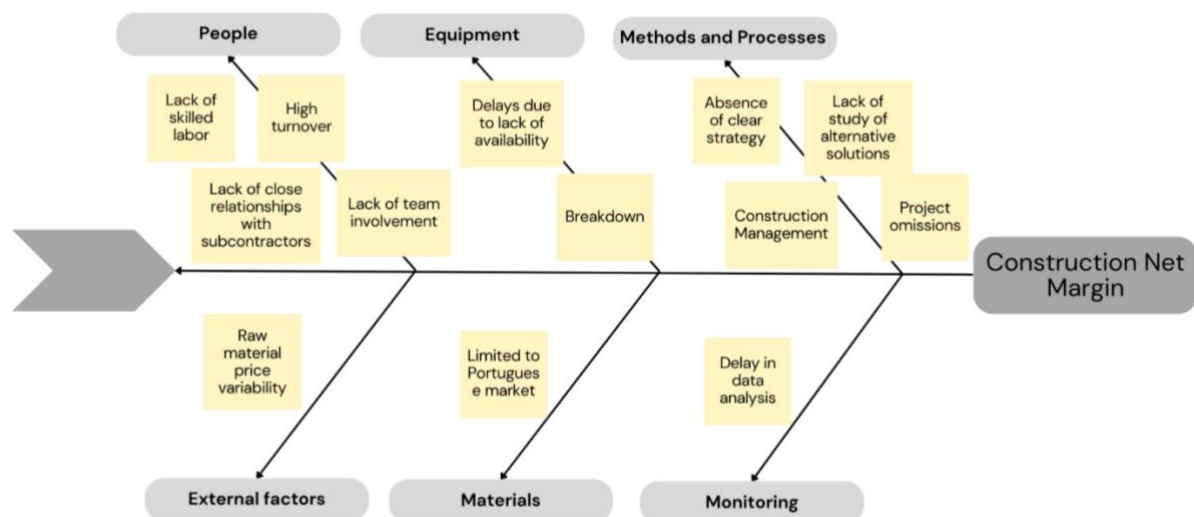


Figure 18 - Ishikawa Diagram for the construction Net Margin

The group started by focusing on the methods and processes to identify the leading causes that prevent the execution of a higher margin. The lack of a study stage to identify alternative

solutions at a lower cost was the one that gathered the most remarkable consensus. The group also pointed out the need for a clear and well-defined strategy during the planning and execution phase of the project and also project omissions.

Concerning equipment, the group pointed out the lack of available equipment and recurring breakdowns. The high dependence on equipment to carry out the tasks is a cause that strongly affects the delay of the project and, consequently, the project costs.

In concern to people, this document has already mentioned the lack of qualified labour and the high turnover of workers. The group concluded that, in addition to the causes already identified, the lack of close relationships with subcontractors and the lack of worker motivation are causes that interfere with the net margin of construction.

Regarding materials, the group concluded that the company is limited to the Portuguese market, so purchasing abroad could benefit the final net margins.

Regarding monitoring, it was mentioned that the company could not react to the data due to the collection and late analysis of the data, so they cannot take countermeasures to improve the profitability of the business.

Finally, the external factor that the group identified most impacts the net margin of the projects is the volatility of the price of raw materials.

3.3.2 On-Time Completion

Currently, the on-time completion indicator is an unreliable metric. The prevailing culture in the company consists of executing the construction projects, most of the time late, and resorting to bureaucratic or legal processes to justify the delay of the job with reasons related to the client. Minutes expose problems such as the non-mobilization of the project due to the client and weather conditions. Through this process, the company subtracts the bureaucratically justified days from the delay and assumes the completion without delay.

Since the on-time delivery indicator measured to date is a metric based on processes that go against the concept that it is intended to measure and, in most cases, the project is delayed for reasons related to poor planning, lack of coordination of activities, and changes, the indicator will be considered as approximately zero.

3.4 Analysis of Alternative Solutions

After mapping the processes and surveying the level of the proposed indicators to be improved within the scope of this document, it was concluded that there was a need to improve the analysis of more economically favourable alternative solutions. Therefore, in this section, the impact that this measure had on past cases of the company will be studied to understand the effects of their use.

Historically, Build Company has not usually carried out the study of alternative solutions due to alleged overhead. However, analysing the 2021 data made it possible to verify that a study of alternative solutions was carried out in three of the sixty-two projects. Therefore, the data

relating to the three construction projects are shown in table 2, and, for reasons of confidentiality, the corresponding project is not specified.

Table 2 - Historic data related to the analysis of alternative solutions

<i>Construction</i>	<i>Budget</i>	<i>Savings</i>	<i>Saving Margin</i>
<i>Construction x</i>	186 929.57€	66 083.23€	35%
<i>Construction y</i>	294 939.20€	10 484.17€	4%
<i>Construction z</i>	172 544.95€	2 611.66€	2%

Despite the small sample of data available, it is favourable as it represents a margin of savings over budget. One of the re-budgeting achieved 35% savings, which is quite positive. Although it is impossible to conclude in isolation the impact of the study of alternative solutions on the final margin, the data leads to the conclusion that off-field strategies can impact the net margin.

To identify the root causes that impact the execution of re-budgeting, a session was held with the main participants to develop an Ishikawa diagram, represented in figure 19.

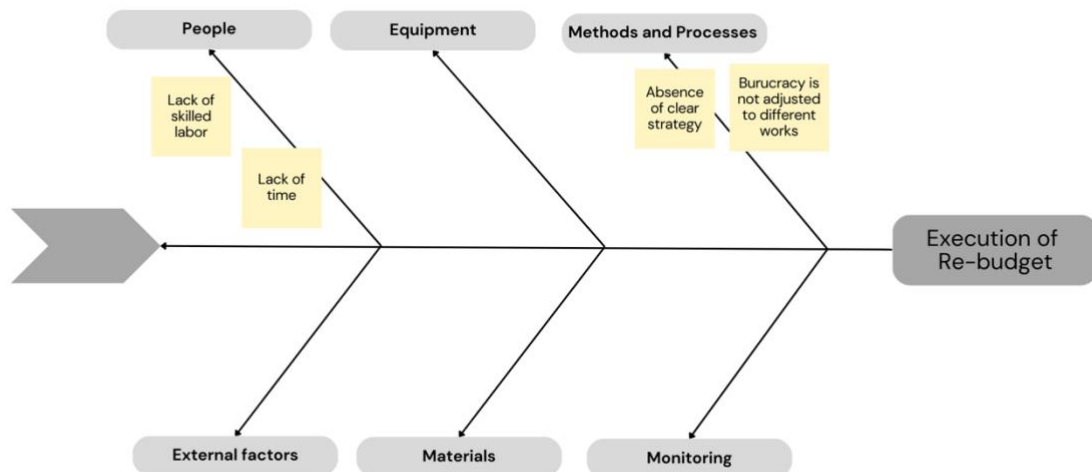


Figure 19 - Ishikawa Diagram for the execution of re-budgeting

Regarding methods and processes, the participants identified as critical points the lack of a well-defined strategy and bureaucratic processes that are not adjusted to the different types of projects. Turning to people, the critical points are the lack of availability and skilled labour.

A second Ishikawa diagram was carried out to complement the information in figure 20 to understand the reasons for preventing savings.

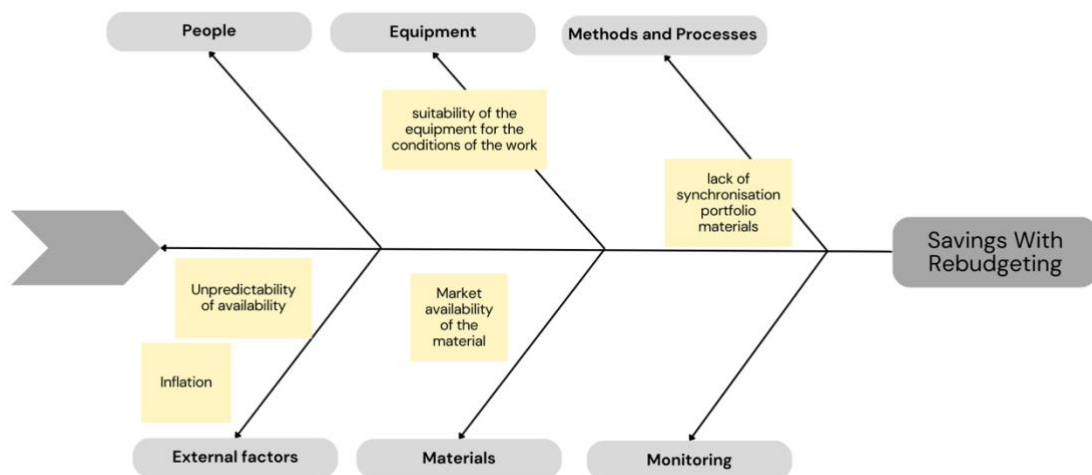


Figure 20 - Ishikawa Diagram for savings with re-budgeting

Regarding methods and processes, it was mentioned that the lack of synchronization in managing the materials portfolio difficult its execution.

Regarding equipment, the participants agreed that the cause that most hinders savings through budgeting is the suitability of the equipment to the work conditions.

As for external factors, inflation is a current issue that causes that at the time of re-budgeting, possible alternative solutions represent lower savings. Additionally, the disruption of the supply chain results in the unpredictability of the availability of materials.

Concerning materials, the leading cause that prevents savings from being achieved through re-budgeting is the constant stock rupture of materials from suppliers.

3.5 Improvement Opportunities

After the characterization of the current situation, the present sub-chapter presents the main improvement opportunities identified. The identification is divided into two areas: Handover and Planning, and Execution.

3.5.1 Handover and Planning

The main improvement opportunities identified at the handover and planning were:

- Focus efforts on the big construction projects, which represent a small portion of the projects and are responsible for a large part of the company's results;
- Creation of lessons learned, which would improve budgeting performance and competitiveness;
- Definition of the construction director before the Handover to mitigate communication problems;

- Uniformize the scripts and deliverables of the handover, and kickoff meetings;
- Standardize the execution of re-budgeting to find more economical alternative solutions.

3.5.2 Execution

The main improvement opportunities identified at the execution were:

- Focus efforts on the big construction projects, which represent a small portion of the projects and are responsible for a large part of the company's results;
- Use of visual management tools;
- Implementation of an Obeya Room based on Lean Construction methodology to identify upcoming constraints, create a collaborative culture and monitor the performance;
- Measuring and discussing of KPIs.

After characterizing the current situation and identifying opportunities for improvement, the next step involves creating the solution design and implementation, presented in the next chapter, where solutions will be designed to improve on-time-completion and margin improvement.

Chapter 4

4 Solution Design and Implementation

After the characterization of the current situation, where the mapping of processes was described in detail, a Pareto analysis was conducted, and the most relevant indicators for the dissertation project were analysed, the future vision for the company was designed. In this Chapter, the design is described, which is divided into three parts: the handover and planning phase, the execution phase, and the Lessons Learned phase. While Project Management methodologies support all, the second is geared towards Lean Construction.

Considering that the Pareto analysis concluded that construction projects over 500,000€ are responsible for a large percentage of the revenue, it is proposed to divide these phases into projects above and projects below that amount, hereafter called big construction and small construction projects, respectively. The division of the projects into two types allows the teams to efficiently allocate their concentration and effort to those representing the largest share of the company's results and thus improve them. For small construction projects, the goal is to allocate the least effort and resources possible. Where there are differences in the proposed model, emphasis will be given.

The implementation of the models was carried out in a big infrastructure project. Through its monitoring, the effectiveness in achieving the main objectives of this project, the increase in Construction Net Margin and On-Time-Completion, is evaluated.

4.1 Handover and Planning Phase

For designing the future vision of the Handover and Planning Phase, a stage-gate model was designed as present in figure 21. The model is composed of the phases Handover, Re-Budgeting and Kickoff.

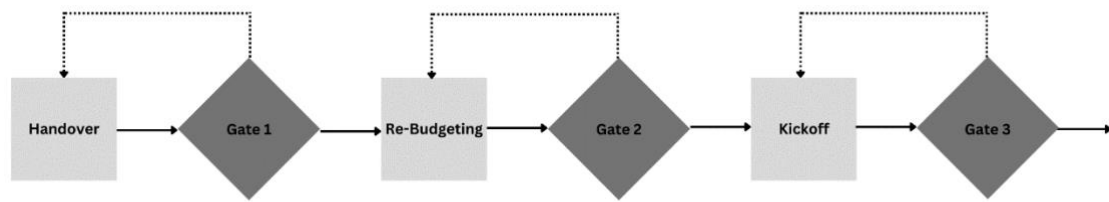


Figure 21 - Stage-gate design for Build Company

The creation of the stage-gate model aims to ensure that the passage of information up to the kick-off occurs in the most correct and standard way and that a set of assumptions have been obeyed, which impact the overall outcome of it.

The first gate is associated with the handover. For this meeting, a script was created for the meeting and the set of deliverables that ensure that information is passed most efficiently. In addition, it was defined that the construction manager had to be mandatorily present in the meeting, one of the improvement opportunities identified during the characterization phase. The other mandatory participants for the meeting were also defined: the budget analyst, the production manager, the procurement manager, the Quality, Safety, Environment (QSE) manager, the communication responsible, and the equipment manager in the case of bituminous. For small projects, equipment and communication are excluded from the mandatory attendance list.

In conjunction with the company's managing director, it was defined that the budget analyst should begin the meeting with an executive summary, in which he gives a brief presentation of the project and the execution strategy considered for the budget. Next, the budget study should be presented, including direct costs, indirect costs, site costs, structure costs, estimated margin, deadline, and important considerations. The issue that follows the budget study is related to QSE matters. At this stage, any customer requirements and considerations made in the budget are presented. This is followed by considerations of discounts made on materials and subcontracts, which are taken to gain competitiveness in the budget phase but represent an increased risk in the execution phase of the project. After the materials and subcontracts, the planning considered for the budgeting phase should be presented, which is essential for project managers to verify the feasibility of the deadlines set. Finally, critical contractual issues should be highlighted, and the construction file handed in.

Complying with the script and the deliverables described, it is possible to go through gate 1, shown in figure 21, and carry out the re-budgeting. Since this phase is one of the most decisive in the execution of the project and has the most significant impact on the indicators to be improved, an intensive work session was conducted with a multidisciplinary team, the production directors and the administration to develop a new study procedure. In this session, the commitment and dedication of the participants were fundamental.

The first step in the new procedure is to review the contract, an important step to consider possible restrictions imposed by the client. Next, the construction manager must analyse the specifications in detail, analyse the drawings, and analyse the bill of quantities. From that moment on, is able to re-budget one of the main improvement opportunities identified, which

allows for significant savings and impacts the project's margin before the project has begun. To achieve savings, the construction manager must propose new execution strategies and alternative materials. To ensure that the study and re-budgeting can be carried out, standard times to develop the re-budgeting were defined with the administration. These timings are shown in table 3.

Table 3 – Standard times to study and re-budgeting

CONSTRUCTION TYPE	SMALL PROJECTS	BIG PROJECTS
CIVIL	5	21 to 28
INFRASTRUCTURE	5	21 to 28
BITUMINOUS	1	14

After studying the project and re-budgeting, it is possible to go through gate 2, presented in figure 21, for the kick-off meeting.

Again, the script for the kickoff meeting was defined in an intensive working session. For big projects, the mandatory participants are the site manager, the foreman, the procurement manager, the QSE manager and the equipment manager for bituminous projects. Regarding the session script, which is similar to the handover script, but with respect to the re-budget, it was defined that the first topic to be addressed is the executive summary to make the project known, particularly to the foreman who was not present at the handover. Next, the re-budget should be presented, in which the budget study, planning, construction site, material and subcontracts, equipment, and QSE-related issues should be addressed. Afterwards, the risks detected should be highlighted, and the contract should be analysed. Finally, an analysis should be made of the project, in which the bill of quantities, the specifications and the descriptive memory should be presented.

For small projects, it was defined that the attendance list would be reduced to the site manager and the foreman. In addition, to allocate the slightest effort to small projects, it was defined that the meeting takes place through a conversation at the worksite, addressing the same topics in a simplified and informal way.

4.2 Execution Phase

The future vision for on-site planning management was to create an Obeya room with Lean Construction methodologies. This implementation addressed an identified pain point, the lack of communication and coordination between the various parties involved in the projects. This room, where the daily and weekly meetings will be held, is the space that intends to gather all the essential information for the construction management and the stakeholders, allowing faster and more efficient decision-making.

The implementation of the new execution model will only be applied to large projects to maximise the company's revenues with the least possible effort, as seen in the Pareto analysis

performed in the previous chapter. On the other hand, the small projects continued to be managed as status quo. Therefore, the distinction created in this phase aims to create a customised model to maximise the company's profit.

In the project's scope, three pilot projects were defined: one for infrastructures, one for bituminous and one for civil projects. The start-up of the remaining construction projects will take place outside the dissertation period. The pilot construction projects will allow the collection of information to assess the customised management model's feasibility, effectiveness, and impact. For confidentiality reasons, the name of the company and workers will be hidden from the images used in the document.

The first step of the implementation was a collaborative session to support the definition of the boards used. Although the sequence of the boards and the content was practically decided, it allowed the director's involvement. It ensured that, for example, the indicators were the most adjusted to the reality of the project. It also allowed defining the daily frequency for shorter meetings and weekly meetings with a maximum of fifteen minutes.

The daily meeting, which involves only the site director and the foreman, consists of a brief discussion in front of the four-week last planner, shown in figure 22. In this session, problems for the day are discussed and made commitments to unblock the constraints. The involvement of the foreman in a meeting room was a disruptive point in that it improved regular and open communication, which allowed problems to be identified and solved more quickly. Consequently, it increases their motivation and commitment since they were never involved and encouraged to give opinions.

The weekly session involves the site manager, foreman, production manager, safety technician and environmental technician. The meeting begins with the attendance list, a record that quickly proves everyone's involvement.

The second step is the analysis of tables related to planning (plan). The Last Planner, shown in figure 22, allows the construction manager to fill in the activities of each team and discriminate the planned performance over the four weeks. The actual performance should be updated daily, which allows the visualisation of the deviation to quickly understand if the team is complying with the plan and, if not, use the meeting to discuss possible problems and do everything feasible to achieve the goal. Furthermore, measuring and displaying data makes monitoring visible to everyone. In addition, the last planner allows teams to identify and address potential problems, making work more predictable and, therefore, more productive.

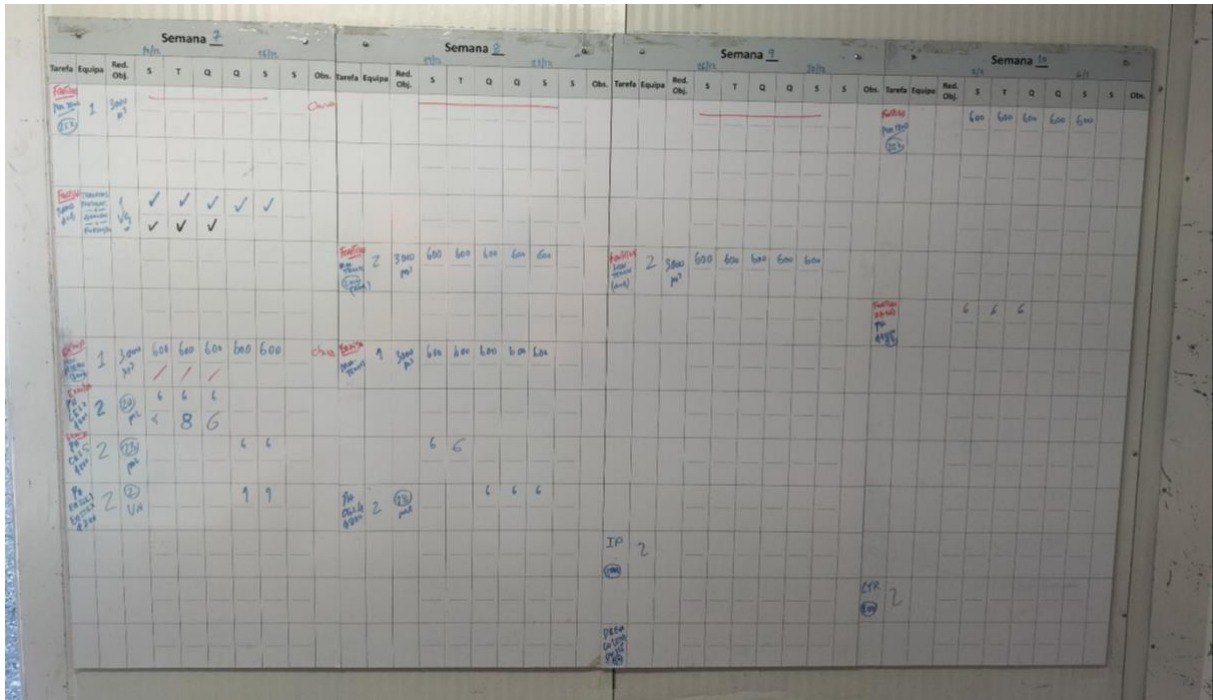


Figure 22 – Implemented Last Planner board

The Macro Planning frame, present in figure 23, serves as a support for the Last Planner. The left frame is moved to the right at the end of each week. At that moment, the planning for week $x+3$ is made and filled in with the information in the Macro Planning. In addition, the presence of this board ensures that all team members are committed to the medium-term goals, which improves team alignment and cooperation. Additionally, macro planning helps allocate the resources needed to achieve the goals, including people and equipment.

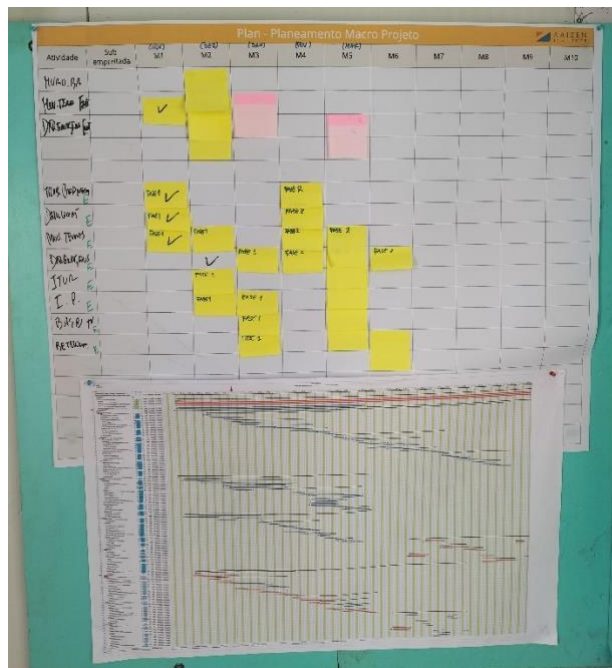


Figure 23 – Implemented Macro Planning

The next step of the meeting is to update the operational planning board (Do). As highlighted in figure 24, the areas already worked on are painted to give visibility to the current state of the work. When a person is present who usually is not involved in the site or not dedicated to the

fieldwork, he or she can be easily integrated into the discussion and involved in solution principles.

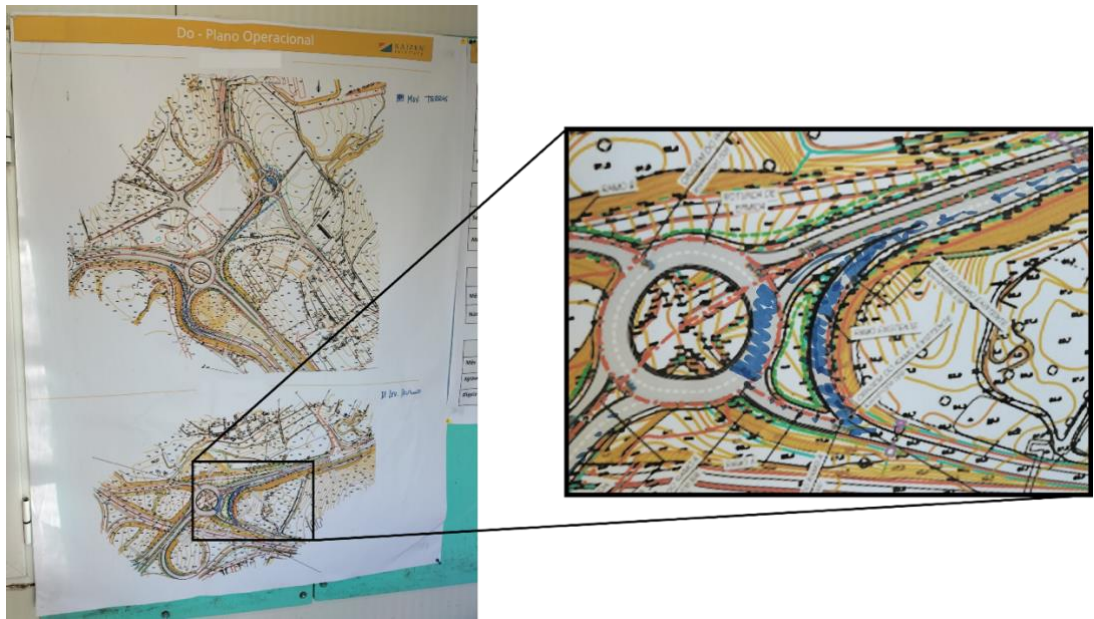


Figure 24 – Implemented Status of the Construction Graph

Next, the team analyses the indicators (Check), shown in the table in figure 25. In the pre-implementation session, it was decided that the indicators measured are the Monetary Progress, the Construction Delay, the number of non-conformances, and the number of accidents. By regularly checking and discussing the KPIs, the team is kept informed of performance and can make the necessary adjustments to stay on track to achieve the goals. Although in the beginning, the measurement was weekly, the difficulty experienced by the team in getting the data made its measurement monthly. Still, the monthly monitoring and constructive discussion represent an improvement compared to the current situation.

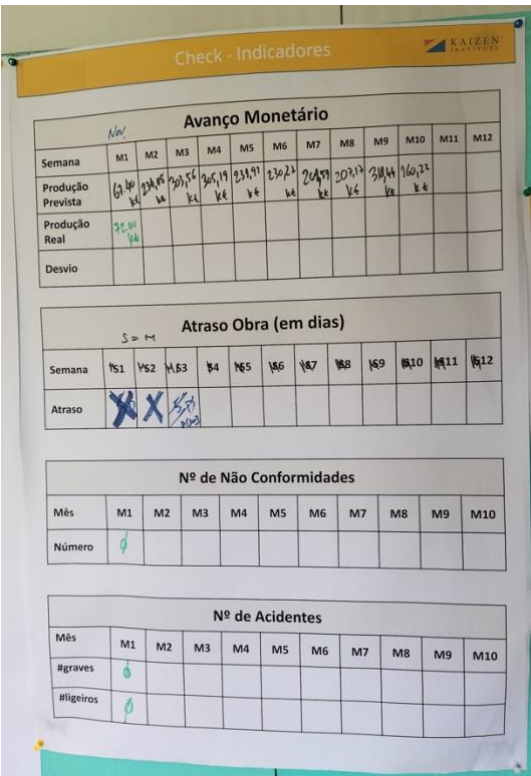


Figure 25 – Implemented measurement and Indicators control board

Subsequently, concerns that may impact the project negatively, or positive opportunities for the construction project, should be raised. These risks or opportunities are placed in a risk matrix, as represented in figure 26, which reflects probability and impact. The visibility provided by the chart allows the team to perceive the potential impact of risks and consequently prioritise their mitigation.



Figure 26 – Implemented Risk and Opportunities Assessment board

The last step is the inclusion of tasks to unblock constraints in the action plan, represented in figure 27. These actions can come from the Last Planner, the analysis of indicators or the risk matrix. Using the board allows for greater responsibility among team members since there is always one person responsible. In addition, it creates greater transparency of progress since actions can have four states: Planned, Running, Checking and Done.



Figure 27 – Implemented Actions Plan Board

In figure 28, a photograph of the weekly meeting of the Obeya room is shown.



Figure 28 - Weekly meeting of the Obeya room

In the picture, it is possible to see the beginning of the Obeya room meeting, where the actual performances of the current week are discussed. As it is possible to see, all participants are attentive to the information shared by the site director. In conclusion, the implementation of in-site planning management aimed to maximize team performance by creating a culture of engagement, quick reaction to problems, and reduced waste.

4.3 Lessons Learned Phase

To address one of the main pain points identified in the current situation characterization phase, the lack of communication and understanding between the budgeting and production team, a Lessons Learned meeting was created at the end of big construction projects and small bituminous projects over 200,000€. The remaining small projects were decided to continue without conducting lessons learned sessions together. The meeting was implemented at the end of each project to encourage the company to apply past successes and improve best practices in future projects. Additionally, it allows to avoid previously made mistakes, minimize risks and gain competitiveness in the budget phase.

The future vision designed for the Lessons Learn phase was divided into two parts. The first involves preparation, in which the site manager is expected to document, critically analyse the results, and share a posteriori with the team. As shown in figure 29 to figure 31, templates were created in a *Ms Excel* file to facilitate analysis, enhance learning, ensure uniformity, and allow any stakeholder to access the content.

The first step in the preparation is to ensure that the construction manager analyses the comparison map, shown in figure 29, in which he should analyse costs, revenues and results to perform a critical analysis of deviations. In this way, he can identify root causes, which will serve as the basis for discussion at the meeting.

Comparative Map					
Description Costs	Planned Cost	Actual Cost	Deviation	Deviation analysis	Root Causes
Direct Costs			- €		
Equipment			- €		
Labour			- €		
Materials			- €		
Bituminous Products			- €		
Subcontracting 1			- €		
Subcontracting 2			- €		
Subcontracting 3			- €		
Subcontracting 4			- €		
Subcontracting 4			- €		
Indirect Costs			- €		
Total	- €	- €	- €		

Figure 29 - Comparative Map Template in *Ms Excel*

In addition, suppliers and subcontractors should be given a performance review. This evaluation is critical to transmit to the purchasing department which relationships should be strengthened, and which materials and subcontractors did not meet the requirements. In this way, the purchasing department will be able to filter which suppliers and subcontractors to call back and which ones not to contact again. The criteria under consideration are, for example, the adherence to delivery times, the quality of the raw material, and the level of service. At the time, the company had a template for performing this analysis annually. The template was adapted for the present project and centralized in the same *Ms Excel* file.

In addition, the experience should be characterised by the customer, the inspection, and the contract. Again, this characterisation allows the commercial department to filter which clients the company is interested in working with and focus more on lead acquisition. The same goes for the commercial department, which gains more experience negotiating contracts.

Finally, the QSE director should reflect on the number of non-conformities and accidents and analyze the audit reports, to be discussed in the collaborative session of learned sessions.

The second part of the meeting is a collaborative session, where the site director presents his previous study to the commercial department, budgeting, purchasing, QSE and equipment. At the end of the meeting, the team should jointly discuss the lessons learned and materialize them in a table like the one shown in figure 30.

Lessons Learned				
Department	Description of the Situation	Well Done/Improvement Opportunity	Why? (the problem happens because....)	Possible Solutions

Figure 30 - Lessons Learned to fill in collaboratively in *Ms Excel*

For the lessons learned to become improvement actions, the support template ends with an action plan, which ensures that the actions are not forgotten and that they have a person

responsible for completing them. Figure 31 shows the actions plan created at the end of the *Ms Excel* Template.

#	Responsible	Date	Description	State
#1				
#2				
#3				
#4				
#5				
#6				
#7				
#8				
#9				
#10				

Figure 31 - Actions Plan for Lessons Learned

Despite the high relevance of the implementation of the lessons learned, the impact can be expected to be noticeable over a longer time horizon than the duration of this dissertation project.

Chapter 5

5 Results

This chapter aims to evaluate the results of the implemented solution design. Therefore, it is essential to verify the achievement of the objectives listed at the beginning of this work by measuring the KPIs and describing the effects of the implemented actions. The results that will be exposed are relative to the first Sprint of the infrastructure pilot project.

5.1 Handover, Re-budgeting and Kickoff

The handover, re-budgeting and kickoff implementation was carried out in more works other than the infrastructure project under analysis to collect more feedback. This subsection contains descriptions of the results that were visualized during the meetings and reported through conversations with the main stakeholders.

The implementation of the phase-gate process, with a clear definition of the scripts and deliverables for each phase, allowed the meeting to become standard, increasing the productivity of the sessions.

During the handover and kickoff, the meeting became more fluid, with fewer interruptions, the participants showed more interest in listening to the information to be transmitted, and the presence of the site Manager was fundamental to guarantee first-hand information.

Concerning re-budgeting, it was proven that the period of dedication is fundamental to studying the work and making a proposal for alternative solutions, which in the case of the work under analysis corresponded to a saving compared to the budget of 10%.

5.2 Execution

Before presenting the results, the adverse weather conditions experienced during the first month of construction should be considered. Figures 32 and 33 show the precipitation, highlighted in blue, during the months under analysis. Through visual analysis, it is possible to see that during November and December, there were three consecutive sunny days only three times.

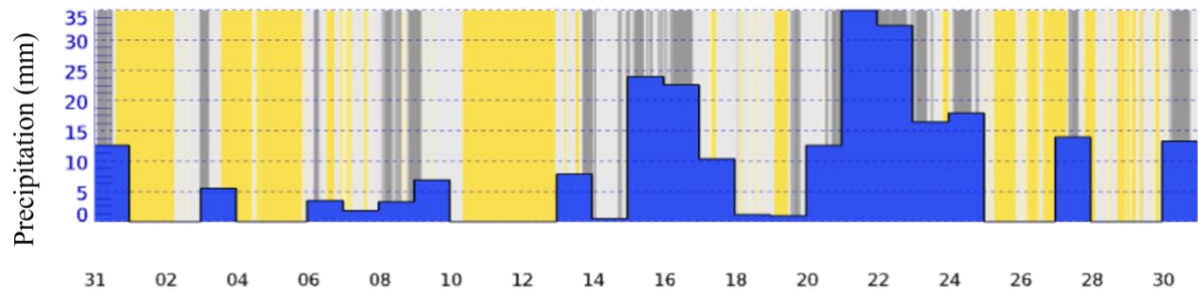


Figure 32 - Precipitation during November 2022 (Meteoblue 2022)

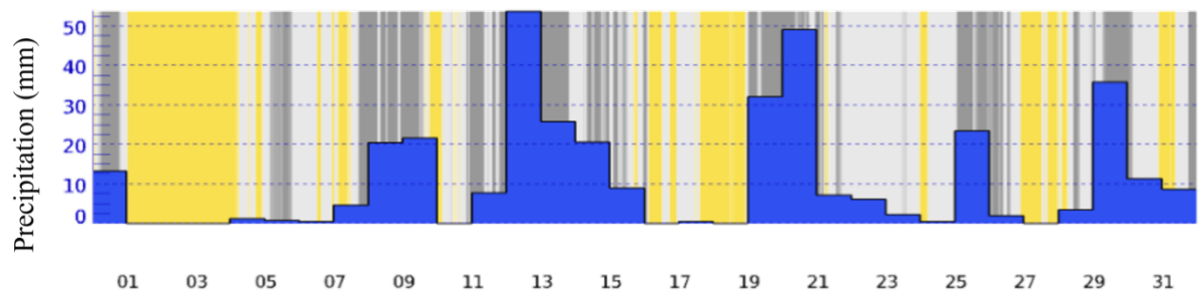


Figure 33 - Precipitation during December 2022 (Meteoblue 2022)

It is essential to consider the amount of precipitation since the earth-moving activity, strongly conditioned by precipitation, was one of the activities planned for the period under analysis. Additionally, the execution of the activity was dependent on three consecutive sunny days to guarantee the drying of the soil, which happened very few times, as mentioned above. Considering the criticality of the task, the team even considered suspending the construction project.

Despite the substantial limitation in the realization of the project related to weather conditions, which would dictate the suspension of the project, the use of the Last Planner collaboratively and dynamically allowed the team to study different alternative solutions and anticipate possible constraints. The constructive discussion in front of the board, with the involvement of everyone, including the foreman, allowed solutions to be found for productive progress equivalent to what was originally planned. Furthermore, through the action plan, it was possible to unblock work fronts that were contractually planned at different times. This way, with the involvement of all the stakeholders and all the information in the same space, it was possible to make quick decisions. With this quick decision-making, the development of the work was possible, given the short reaction time resulting from the unpredictability of the weather conditions.

As shown in figure 34 and despite the prevailing limitations, the solutions found in the Obeya room were able to match the expected monetary advance and even outperform it for the pilot project.

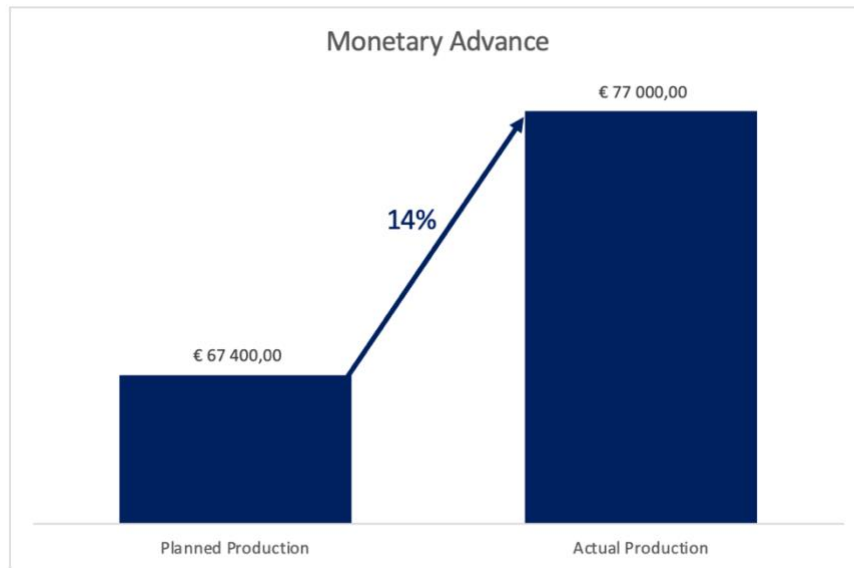


Figure 34 - Planned production versus actual production

5.3 Lessons Learned

The Lessons Learned pilot session, carried out for a construction project whose completion coincided with the start of this dissertation work, proved to be very positive as the participants were able to identify many opportunities for improvement and communicate what was well done, so it should continue to be performed in the same way.

In Appendix A, there is an extract of the recording of the session. The preparation phase was fundamental to ensure good performance and focus on the most relevant topics from the beginning. Several budgeting issues were raised during the session, as seen in Appendix A. This allowed the lack of proximity between budgeting and production to be addressed, one of the pain points identified during the current situation characterization phase. This way, the budgeting department can gather feedback and improve future tenders.

5.4 Key Performance Indicators

5.4.1 On-Time-Completion

Regarding On-Time-Completion, the Build Company's goal was to complete the projects within the planned deadlines, representing an On-Time-Completion of 100%. Nevertheless, unfortunately, through the present dissertation project, it was impossible to achieve this for the deadline of the first Milestone, corresponding to 0%.

At the end of this period, the project shows a delay of considerably five days, which despite not corresponding to the achievement of the goal, is seen as positive given the weather conditions that prevailed during it. Without the implementation of this dissertation project, the project would be suspended, which would correspond to a worse scenario and represent higher costs.

5.4.2 Construction Net Margin

For the analysis of the results of the net construction margin, it is fundamental to know the expected values for the first month of the construction project since the value under analysis does not correspond to the final margin of the work. In the strategy developed during the re-budgeting phase, planning was created that led to a 15% margin, the project's objective. Although this is the project's final objective, the margin can be different over the months, given the distribution of tasks that can lead to months in which profits are greater than costs or the opposite. The distribution of the margins expected in the construction project under analysis over the ten months is shown in Appendix B.

Table 4 presents the data relating to the re-budgeting and the project results. The expected margin for the first month is -27%.

Table 4 - Expected margin versus the actual result

	<i>Re-Budget</i>	<i>Results</i>
<i>Income</i>	€ 67 300,00	€ 77 000,00
<i>Costs</i>	€ 92 800,00	€ 98 000,00
<i>Margin [%]</i>	-27%	-21%

The net construction margin result for the first month is -21.4%, which represents an increase of 6.1%, as illustrated in figure 35. The results can be seen in detail in Appendix C.

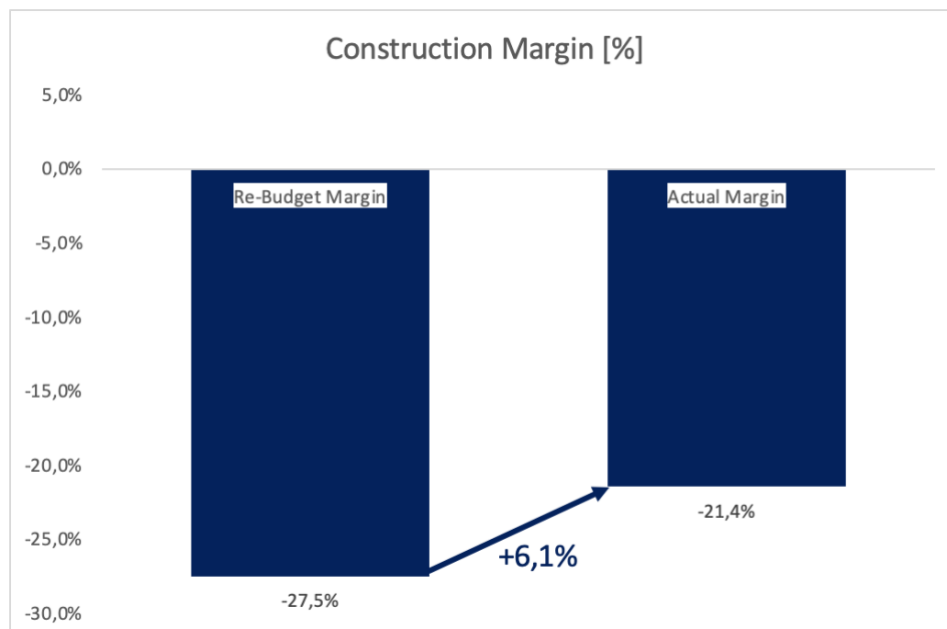


Figure 35 - Construction Margin Improvement

Although the value is negative, it is possible to conclude that the implementations have proved to be positive. Therefore, if the tendency is maintained, the objective for the final margin of the construction project will be reached.

Chapter 6

6 Conclusion and Future Work

This chapter will draw the main conclusions of the dissertation project. The objectives of the project, described at the beginning of the document, and the results obtained through the implementation of the customized model will be taken into account. Additionally, opportunities for improvement identified during the project are exposed, which may serve as future work.

6.1 Main Conclusions

This work, related to the master's thesis, was carried out in a corporate environment at the Build Company, a Kaizen Institute client. The main objectives of the construction project are to improve the net margin of construction and on-time-completion by creating a customized model for the pre-construction processes and the on-site planning model.

The main reasons that hindered the company's growth were identified from the analysis of the current situation. The characterization allowed deducing that the company does not have well-defined standardized processes, which leads to the non-execution of an engineering re-budget or very distinct meetings for the passage of information. Additionally, the on-site planning method depended on the site manager, with no monitoring of KPIs, no team involvement, and the absence of a culture oriented towards continuous improvement. All these factors result in the inability to react to planning constraints and unforeseen events. In addition to the current situation of the processes, it was proven through Pareto analysis that big construction projects, representing approximately 20% of the projects, are responsible for about 80% of the results.

The first solution adopted was creating a customized model for big construction projects and another distinct one for small projects, with a greater focus on big projects. For the activities that precede the project, a stage-gate model was created to ensure that all the information is transmitted in the best possible way. The process ensures that issues such as re-budgeting and planning are carried out and will positively impact the execution of the project. For the execution, an Obeya room was implemented, according to the Lean Construction methodology, to do on-site planning collaboratively, making it able to anticipate constraints, manage risks and introduce a spirit of continuous improvement.

Through the analysis of the results, it was possible to conclude that the implementation, with a greater focus on big works, results in visible improvements. The stage-gate model and the lessons learned made it possible to make the processes before execution more robust and consistent and to implement a culture of continuous improvement in the organisation. The Obeya room proved to be fundamental to dealing more quickly with the daily constraints, and it is concluded that it represents added value in a construction environment.

Regarding the results, it was concluded that the implemented processes positively influenced both results even though the work presented a delay of five days. Through the continuity of the initiatives implemented with this dissertation project, it is likely to recover the five days delay and continue to improve the expected margins.

6.2 Future Work

This sub-chapter proposes opportunities for improvement following the implementation of the project. The objective is to identify the initiatives that should be considered in future improvement work, whether to enhance the results obtained in the present master thesis or to attack different areas.

First, a continuous effort should be made to sustain, consolidate and evolve the implemented initiatives. As Zandy (2019) defend, the introduction of Lean Construction concepts should be done gradually. As a continuation of this project, the following improvement actions were identified:

- **KPI's Board Update:** Measuring the indicators more frequently, representing the second improvement opportunity, allows for better responsiveness. The higher frequency allows the team to be more reactive to changes, allowing them to adapt to new circumstances quicker. Additionally, it allows decisions made during Obeya room meetings to be based on more accurate and up-to-date data.
- **Production Data Update:** Release of monthly production data more quickly. Currently, the process takes more than a month, which prevents a quick reaction in case of negative results.
- **Last Planner KPIs:** The first opportunity for evolution and improvement is the insertion of the indicators Percent Plan Complete, Tasks Made Ready and Tasks Anticipated. The monitoring of the indicators aims to identify problems and continuously improve the process through corrective measures.
- **Project Buffer Indicator:** Using the project buffer graph is the last improvement opportunity identified in the evolution of the current project implementation. However, it is identified as the most complex to implement, given the prominent paradigm regarding the exclusion of security at the task level.
- **Replication of the methodology:** Apply the model of the present master thesis to all construction projects. To do this, it is essential to ensure the training of the remaining site managers.

The improvement opportunities identified during implementation, related to other issues, go through the digitization of some processes. For example, although Jan Koeleman (2019) identifies the lack of replication, fragmentation and decentralization as characteristics of the construction sector that make the digital transformation complex, the implementation of an IT

process of equipment management and Remote Assistance was identified as improvement opportunities to be considered.

Implementing an IT process for equipment management would make the process independent of people. In addition, since the construction projects performed by Build Company are often far from the construction site, it would be possible to optimize the equipment allocation to the works and consider logistical costs in its displacement. It would also give real-time visibility of the allocation of machines to all users and increase the likelihood of the equipment being available on-site when needed, increasing construction uptime.

Remote Assistance would make it possible to deal with the frequent breakdown of equipment on site, which leads to various wastes, such as material on hold and extra costs. Implementing remote Assistance would not only increase the equipment's availability time but also increase the maintenance team's productivity, which currently consists of about 20 people.

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Appendix A

Lessons Learned Results

Process/ Macro Activity	Situation description	Well Done/ Improvement Opportunity	Why? (the problem happens because...)	Possible Solutions
Orçamentação	Período de Execução de 4 / 5 meses para Site costs EW, Site costs CW, site costs QHSE	IMPROVEMENT OPPORTUNITY	Dividiu-se nos site costs 4 meses para civil e 4 meses para elétrica, mas isto não acontece visto que as duas tarefas se realizam em paralelo, visto existir edifícios e algumas atividades de civil so serem realizadas após atividades elétricas	Se a duração do projeto é 8 meses os site costs civil e site costs elétricos devem considerar os 8 meses
Orçamentação	Trabalhos Cíveis não estão discriminados nos edifícios	IMPROVEMENT OPPORTUNITY	O preço dos edifícios é apenas um e devia ser dividido entre materiais, mão de obra, etc.	A produção já realizou a quantificação de horas homem por MR no orçamento tipo. Também é importante referir que com o aumento de obras o uso de subempreiteiros vai ser mais frequente sendo necessário pesquisar preços de subempreiteiros nos próximos orçamentos
Orçamentação	Mão de Obra com um custo demasiado baixo: EW de maneira geral: 134 000€ EW REAL: 123 800 (sem gastos de transporte, alimentação e alojamento) CW fundações: 28 000€	IMPROVEMENT OPPORTUNITY	O preço para a mão de obra elétrica e civil é demasiado baixo	A produção já realizou a quantificação de horas homem por MR no orçamento tipo. Também é importante referir que com o aumento de obras o uso de subempreiteiros vai ser mais frequente sendo necessário pesquisar preços de subempreiteiros nos próximos orçamentos
Orçamentação	Equipamentos	WELL DONE	Estávamos bem defendidos com o tema do Interruptor Híbrido - ABB	
Orçamentação	Edifícios com custos extra	IMPROVEMENT OPPORTUNITY	A orçamentação não teve em consideração a documentação específica da EGP para os edifícios da SE	Considerar no orçamento todos os materiais a serem considerados por edifício de acordo ao anexo 10.
Orçamentação	Budget topografia demasiado baixo: 6500€ Gasto final: 33 000€	IMPROVEMENT OPPORTUNITY	A topografia só foi considerada durante 2 meses	Deve ser considerada topografia pelo período de obra visto ser sempre necessário até mesmo para os protocolos
Orçamentação	Gastos com COVID 19	IMPROVEMENT OPPORTUNITY	Não estava previsto gastos com COVID 19	Deve ser considerado um custo para COVID 19 nos próximos projetos
Orçamentação	Site costs QHSE	IMPROVEMENT OPPORTUNITY	A orçamentação não considera o valor correcto de cada funcionário QHSE	Visto que os QHSE são estrutura LATAM rever a média de salários dos funcionários QHSE como um custo para DPs
Orçamentação	Custos maiores com trabalhos em zonas energizadas	IMPROVEMENT OPPORTUNITY	Em construção de extensão de SE trabalhamos com subestações energizadas, sendo o processo mais demorado e custoso.	Aumentar o custo em Site costs e mão de obra quando trata-se de subestações energizadas
Orçamentação	Custos edifícios	WELL DONE	O custo de venda do edifício foi bem realizado pela comercial	
Orçamentação	Melhoramentos de solo	WELL DONE	Estávamos contratualmente defendidos para possíveis melhoramentos de solos	
Orçamentação	Pouco tempo de utilização da retroexcavadora	IMPROVEMENT OPPORTUNITY	Assumiram a construção com uma excavadora em função dos m3 de escavação e aterro	Deve ser considerado um equipamento em obra (retro) em todo o período de construção visto que as atividades de movimentos terra não são sequenciais
Engenharia	Soluções técnicas que improvisaram custos e respetivos adicionais	WELL DONE	Foi sempre optimizada a engenharia de maneira a melhorarmos custos, tempos de construção e possíveis adicionais com o cliente	

Appendix B

Expected Margin per month

PREVISÃO										
	1	2	3	4	5	6	7	8	9	10
	nov/22	dez/22	jan/23	fev/23	mar/23	abr/23	mai/23	jun/23	jul/23	ago/23
MARGEM	-25.484,51 €	28.001,34 €	38.703,72 €	40.776,48 €	17.895,92 €	9.012,27 €	-8.290,97 €	9.255,82 €	36.278,10 €	-1.104,90 €

Appendix C

Results of the construction Project

Classes de custo	Real	% Prod/Real	Proj. Projeto	Prod/Projeto	Plano do projeto
** Mão-de-Obra Própria	36.872,81-	49,71	13.154,22-	17,75	403.503,80-
** Equipamento Próprio	42.733,68-	57,61	20.596,50-	27,79	631.794,60-
** Equipamento Aluguer			53,79-	0,07	1.650,00-
** Matérias-Primas	1.601,89-	2,16	15.470,84-	20,87	474.565,58-
** Produtos Acabados	3.343,07-	4,51			
** Subempreitadas	2.100,00-	2,83	14.057,36-	18,97	431.207,44-
** Deslocações e Estadas	5,15-	0,01			
** Outros Custos	9,31-	0,01	8,12-	0,01	249,00-
** Custos Indirectos	5.939,29-	8,01	383,66-	0,52	11.768,67-
** Custos Estrutura	4.969,63-	6,70	4.935,70-	6,66	151.401,82-
** Pós Venda	370,86-	0,50	368,34-	0,50	11.298,64-
*** Custos	97.945,69-	132,05	69.028,53-	93,14	2.117.439,55-
** Revisão de Preços	2.773,03	3,74-			
** Produção	74.173,48	100,00-	74.114,31	100,00-	2.273.445,14
*** Proveitos	76.946,51	103,74-	74.114,31	100,00-	2.273.445,14
**** Margem Obra	20.999,18-	28,31	5.085,78	6,86-	156.005,59
** Trabalhos Normais	69.611,12	93,85-	73.669,32	99,40-	2.259.795,14
** Trabalhos a Mais			444,99	0,60-	13.650,00
*** Total Contrato (IN+IM)	69.611,12	93,85-	74.114,31	100,00-	2.273.445,14
*** Rever. Produção	74.173,48-	100,00	74.114,31-	100,00	2.273.445,14-