POLITECNICO DI TORINO

Department of Management and Production Engineering

Master of Science in Engineering and Management

Master Thesis

Risk Assessment and Lean Implementation in Real Estate Development Projects

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Abstract

Real estate development projects are risky due to many characteristics such as the unique end-product, complex processes, and large number of stakeholders.
One of the most significant and increasing concerns with real estate projects is that they are behind schedule, over budget and show unsatisfactory performance in terms time, cost, and quality and also customer and stakeholders satisfaction.
However, the complexity and the constant changes in these projects lead real estate development and construction companies to find inadequate monitoring of the ongoing process in order to ensure that the project finishes on time. They must find a way to look ahead by predicting the possible activities that may delay the project and alarm the stakeholders about them.

Project Risk Management is the process of identifying, analyzing, assessing, processing, monitoring, and revising project risk. The objective is to decrease consequences and probability of negative events and increase consequences and likelihood of positive events. There are different, highly similar theories for risk management.
In addition, over the past several decades, the construction industry has succeeded in improving quality and productivity, using the concepts of lean thinking.
The thesis explores the relevance of lean concepts in risk management and how these two concepts can improve the success rate of projects.
The objective of this thesis is to help project managers and decision makers understand and mitigate the wide risks of real estate development projects by developing and implementing strategies of risk management and lean construction, before they turn detrimental to the firm.
In order to identify the risks and assess their impact on the project scope, an application of risk management and lean problem-solving tools is chosen as the methodology as well as highlighting the wastes caused by the critical risks to eliminate before they occur.
A real estate development project in Brazil has been considered as a case study for this research. Following the PMI standards, risk management is applied, starting with a risk initiation plan which defines the main scope and objectives of the project. This step is followed by the risk identification process in which all possible risks are identified using various techniques and registered in the risk register. Then, a risk breakdown structure (RBS) and a qualitative risk analysis and quantitative risk analysis is applied. All risk data and the project's Gantt chart have been imported into RISKYPROJECT Professional to apply Monte Carlo simulation. When critical risks are defined from the assessment, Five-Why technique is applied to them for developing the most sufficient action plans.

Finally, the analysis of lean thinking principles integration is done through the risk control process by determining wastes that are critical risk sources and suggest most practical lean techniques.

To successfully deliver housing units to clients, it is recommended that developers continuously identify and analyze possible risks and the wastes which could cause to cope with the dynamic nature of the business and relevant projects.

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1. Introduction

Background

Real estate development projects are complex and unique in terms of their size, location, project organization, timeframe, and planning. Multiple stakeholders with various interests are involved. These projects require interpretation of and compliance with numerous laws and regulations, and time, cost, and quality targets have to meet. Therefore, real estate projects incur critical risks comparing to other manufacturing industries. The real estate development industry copes with additional risks due to the unique features of construction activities such as complicated processes, long planning and construction periods, dynamic organizations, financial intensity, and challenging environment.

However, Despite the high-risk factors, the real estate development industry lags behind other industries in terms of risk identification, evaluation, mitigation, and control complexity and application. “Developers are frequently criticized for not appropriately understanding and analyzing risk.” (REED, 2008).

According to the Project Management Institute, project risk management is one of the nine most important aspects of project commissioning. This demonstrates that risk management and project success are inextricably linked. While RM is recognized as being the most difficult aspect of construction management, its application is promoted in all projects in order to avoid negative consequences.

However, many professionals are still unaware of the significance of risk management in the project delivery process (Smith et al., 2006). Although there is an awareness of risks and their consequences, some organizations do not approach them with established Risk Management methods.

It should be important to note that risk management is not a tool to guarantee success, but rather a tool which helps to increase the probability of success. Risk management is a concept that is more proactive than reactive.

When it comes to risk management, it seems relevant to start with the definition of risk:

“An uncertain event or condition that, if it occurs, has a favorable or negative impact on the project’s objectives”. (PMBOK,2017) The key threats influencing real estate project objectives are tight project schedules, design variations, excessive approval procedures in administrative government departments, and high performance or quality expectations (Zou et al., 2006). Various risk management methods and techniques are used to effectively control these risks. By understanding the definition of risk, requires a risk management system that is defined as followed:

Structured method for identifying, assessing, mitigating, and monitoring/ controlling unplanned events that may impact a project.

However, projects with lengthy, complicated supply chains involving many participants and subject to multiple, extensive process design modifications, on the other hand, cannot be managed conventionally, and complex flow management has failed horribly. (Ballard and Howell, 1994). Thus, the industry is influenced by delays and often has suffered cost and time overruns.

Generally, a very high-level non-value-added activities that are creating risks in projects exist in the construction industry. Several studies from various countries have confirmed that, these activities considered as wastes in construction industry represent a relatively large percentage of project cost. The significant number of wastes in the construction have depleted overall performance and productivity of the industry, and substantial measures must be taken to rectify the current situation (Aziz and Hafez, 2013). The inadequacies of existing project management tools, as well as the project teams' inability to apply robust and radical techniques to solve the industry's challenges, have been attributed to such wastes. According to Johnston and Brennan (1996), Koskela (2000), Koskela and Howell (2001), Ballard and Howell (1994), the conventional approaches to construction or project management have inadequacies in resolving the problems in the industry.

Nonetheless, lean manufacturing principles and techniques set the foundation for reducing or eliminating waste in the industry. Lean construction has changed the conventional view workflow reliability, which is considered as the determinant of construction work and has embraced the concept of flow and value generation. Essentially, the aim of lean construction is to reduce the wastes in workflow that the conventional methods are inadequate to eliminate. In general, Lean construction tools are intended to improve delivery systems and processes by reducing waste, boosting productivity, improving health and safety, and meeting client demands. (Hannis-Ansah et al., 2016). In essence, it will enhance delivery processes and value-added systems through the removal of wastes; transportation, overproduction, inappropriate processing, lead time, inventories, rework, and unnecessary movements in construction processes and hence, improve project and financial performance of the industry (Hannis-Ansah et al., 2016). Therefore, several lean tools have been proposed to tackle the difficulties related with waste in construction projects.

Risk management and lean management have been introduced to authorities and decision-makers in a variety of managerial areas for many years. However, a combinatorial technique of these two is recently being developed, in which lean principles and guidelines are combined with risk management planning. In order to overcome the associated risks in the lean era, obtaining additional knowledge of lean tools for having a more precise and sufficient risk assessment can be considered as an alternative. This is one way to become a pro-active planner in risk mitigation for those companies willing to grasp Lean advantages (SAS Institute Inc., 2009).

Lean Philosophy encourages waste reduction and elimination in the processes may also be argued. It is not necessary to note that it can also apply to risk management processes. In these cases, the non-value adding activities of processes are pointed to be reduced /eliminated. When it comes to various sectors like construction, where the focus might be on time scope, lean policies have different priorities. Despite the fact that risk management and lean management approaches are two widely known, popular solutions for decision makers - particularly those in the strategic management responsibility area- the prospects of integrating the two strategies remain vague.

The results of risk management with a lean philosophy as guidelines in establishing their risk management system throughout their organizations should be of significant interest to different sectors. Benefits resulted from integration of lean and risk management would be a motivation for organizations to implement this new strategy in the future.

On the whole, Risks which exist in real estate development have impacts and developers need to manage risks and minimize their impact on project objectives and their business as a whole. It's critical to understand what risks exist in real estate development projects and how they affect project objectives.

The motive of this research is to identify the major risk factors existing in real estate development projects with the help of lean problem-solving tools and examine the impact of risk factors on project scopes and to study where and how lean can be implemented for successful results. By controlling risks, the management can be assured that processes can be improved, and customers pull value from the activities.

Aim and Objectives

Aim

The aim of this research is to help decision makers and managers in real estate development companies such as Planet Smart in the decision-making process by investigating the risk management process in such projects with a focus on lean thinking and lean tools.

Objectives

The objective of this research is to provide the real estate development companies such as Planet Smart with a methodology to identify the risks causes of delay by focusing on lean root causes analysis, prioritizing the risks, and understanding their severity, and therefore anticipate schedule and forecast any potential delays that are caused by those risks that are assign to project schedule. Then wastes which may be cause by those risks are identified risks and lean thinking is applied to provide a response action to them and control risk before it occurs.

This specifically study aims to achieve the following objectives:

1. To Identify risks affecting real estate project performance with the help of lean problem-solving approach.
2. To rank the risk factors according to their impact and probability on project scopes.
3. To assess the strength of the correlation between risks and tasks in real estate development projects.
4. To provide best response plan to the critical risks with the help of lean 5why technique.
5. To suggest lean integrated as a tool to control real estate risks by identification of wastes those risks will caused.

Research Questions

Research questions are formulated as follow.

1. What are the different risk factors related to real estate development projects?
2. Which risk factors have a greater impact on residential real estate development project Schedule?
3. What is the root cause of each factor based on lean approach?
4. How could these factors be minimized and what is the best action plan with help of lean thinking?
5. How and what kind of wastes that critical risks could create?
6. Which lean tools and techniques will be helpful to control these wastes?

Limitations

The research focuses on the real estate development industry based on theories of risk management and lean thinking described in the literature. The research was complemented by a study of a real estate project in Brazil in cooperation with some of the stakeholders involved. Due to the limited research time of the thesis and the current phase of the case study project, the lean tools for controlling wastes could not be applied. The most important challenge of the research was the uniqueness of the methodology that made the literature so limited.

Outline of the Thesis

The research starts with a literature overview in order to provide the theoretical context about the Risk Management and its process. Further, a description of Lean philosophy and what tools & techniques are provided is studied. Subsequently, results from risk assessment and also reports of analysis with software are presented to show how risks affected project tasks and understand the importance of each risk and tasks. Next the selected lean tools are applied on the most significant risks to provide the best response to them and the probable wastes that they may cause are identified to suggest the best lean tools in order to controlling them. In the discussion, the results from the software and diagrams are analyzed. Finally, the recommendations are prepared in the conclusion section. In Figure 1, a more demonstrative picture of this research structure can be found.

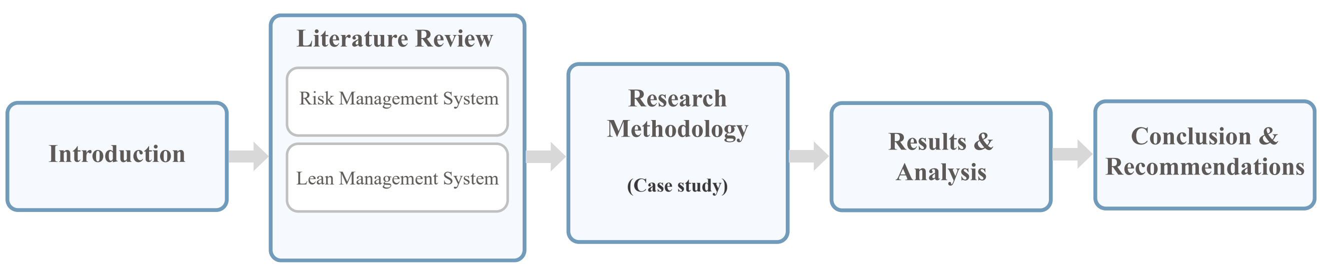


Figure 1 Research Structure

2. Risk Management

Project Risk Management

A project is a temporary, time-limited and unique piece of work, in which multiple activities typically must be done in order to achieve specified objectives. To carry out those activities, multiple stakeholders from different organizations, based in different locations, typically cooperate. Every project, whether it is simple or complex, small, or large, faces different uncertainties throughout its course. This uncertainty is crucial in determining the probability of success or failure of a project and is known as project risk. Hillson (2002) states that risk is mainly related to negative events occurring in a project, while the Association for Project Management (APM) and Project Management Institute (PMI) describe risk when they have positive and sometimes negative impacts on a project.

"Project risk can be defined as an uncertain event or condition that, if it occurs, has a positive or a negative effect on at least one project objective, such as time, cost, scope, or quality." (PMI 2017)
"Project risk is an uncertain event or set of circumstances which, should it occur, will have an effect on achievement of one or more objectives." (APM 2012)

According to these two definitions, it can be noted that project risk is an uncertain phenomenon that can affect the outcome of a project. Therefore, to ensure that project risks induce minimal negative outcomes, project risk management is essential, especially for large or complex projects.

Royer stated:
"According to experience, risk management must be a critical concern to project managers, as unmanaged or unmitigated risks are one of the major causes of project failure."

Therefore, without a proper risk management plan, there is a high chance that any project, especially large and complex projects, will encounter many uncertainties and ultimately fail. The main objective of the RM project is to identify the risks associated and take preventive and remedial measures to prevent or minimize negative impacts. Project risk can evolve in many different forms, depending on the specific sector.
Many explanations and definitions of risk and risk management have been developed recently, and it is therefore difficult to choose a definition which is always correct. Each author provides their own perception of what risk means and how to manage it. The description depends on the profession, the project and the type of business. In general, risk management is a very broad subject and therefore definitions of risk can vary and be difficult to apply in all industries. For

the purpose of this thesis, a definition of risk and risk management will be chosen in order to better understand these concepts in the construction industry.

Risk Definition

Risk and uncertainty are the two most commonly used concepts in the literature on the field of RM. Although these terms are closely related, some authors distinguish them. Additionally, practitioners working with risk have difficulty in defining and distinguishing between these two. Risk and uncertainty definitions are frequently adapted to the needs of a particular project. To make it more systematic, a bibliographic study was carried out. The findings of this research have led to several definitions of risk and uncertainty. These have been aggregated and are presented in Table 1.

Table 1 Definitions of risk and uncertainty

Author	Risk definition	Uncertainty definition
Winch (2002)	A stage where there is a lack of information, but by looking at past experience, it is easier to predict the future. Events where the outcome is known and expected.	Uncertainty is a part of the information required in order to take a decision. The required information consists of the amount of available information and uncertainty. The level of uncertainty will decrease the further a project is proceeding throughout the lifecycle.
Cleden (2009)	Risk is the statement of what may arise from that lack of knowledge. Risks are gaps in knowledge which we think constitute a threat to the project.	Uncertainty is the intangible measure of what we don't know. Uncertainty is what is left behind when all the risks have been identified. Uncertainty is gaps in our knowledge we may not even be aware of.
Smith et al. (2006)	Risks occur where there is some knowledge about the event.	There might be not enough information about the occurrence of an event, but we know that it might occur.
Webb (2003)	Risk is a situation in which he possesses some objectives information about what the outcome might be. Risk exposure can be valued either positively or negatively.	Uncertainty is a situation with an outcome about which a person has no knowledge.
Darnall and Preston (2010)	Risk is a possibility of loss or injury.	
Cooper et al. (2005)	Risk is exposure to the consequences of uncertainty.	

Regarding real estate development, definitions and discussions about risk and uncertainty are presented in a number of academic sources - most notably, Byrne / Cadman (1984), Hargitay / Yu (1993), Pellat (1972), Whipple (1988). Hargitay / Yu (1993) presents a spectrum from certainty to total uncertainty, illustrated in Figure 2. Hargitay / Yu implies that if all future outcomes could be identified and the probability of occurrence could be estimated, hereafter there would be no uncertainty. This perspective can be misleading because even thought it was possible to identify all future events or outcomes and assess their relative likelihood of occurrence, uncertainty would remain as it is not possible to determine which event or future outcomes will occur. The future is therefore always uncertain and if the future is certain there is no risk.

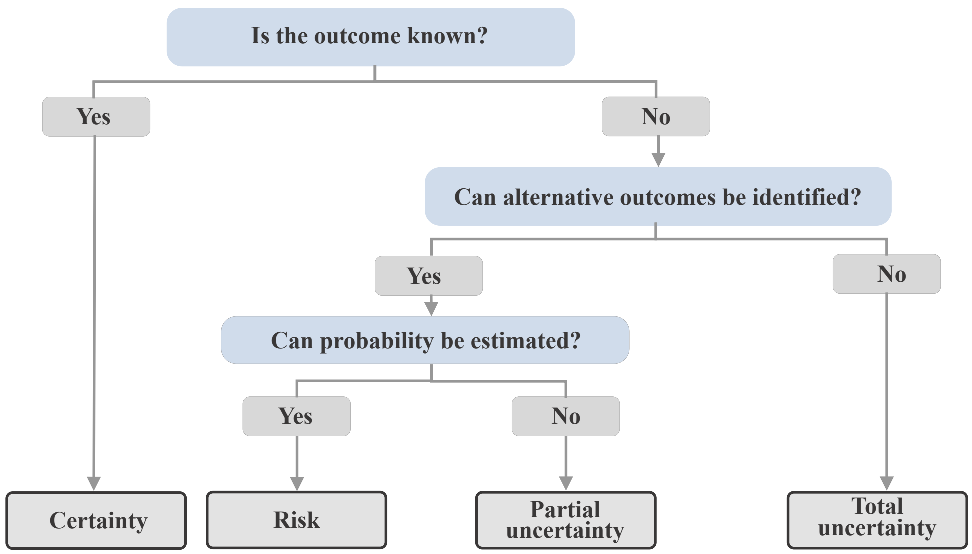


Figure 2 The spectrum of uncertainty (FISHER/ ROBSON, 2006)

In the following chapters, the focus is on risk itself and how it should be managed. Uncertainty is not a tangible term and thus will not be further demonstrated in the research.

Risks in Construction Projects

Risk is defined as the possible occurrence of negative or adverse effects exclusively resulting in damage or loss (Valeriano, 2001). Perry and Hayes (1985) define risk as an uncertain event or condition that, if it occurs, has a positive or negative impact on the project's objective. Jafar (2001) defines risk as the exposure to loss, gain, or the probability of occurrence of loss/gain multiplied by its respective magnitude. Kartam (2001) defines risk as the probability that some uncertain, unpredictable and even undesirable events will change the probabilistic outlook of a given investment.

Risks are apparent at all stages of the lifecycle of a construction project: appraisal, design, construction and operation. The relative effects, impacts, and opportunity to avoid, transfer, or retain these uncertainties will change throughout the project. Therefore, the review and assessment of risks must be carried out at all stages of the project so that they can be managed constantly (Perry and Hayes, 1985).

Developing a construction project involve enormous risks. This is due to the uniqueness of each project, the uncertainties introduced by the project stakeholders, statutory or regulatory protocols and other intrinsic and extrinsic constraints. During the development of the construction project development, risks could constrain the achievement of key project objectives – time, cost and quality targets. Failure to achieve the objectives set for the project has considerable impact on all stakeholders in the project.

For client, this could mean added costs and higher upfront costs compared to the original deal and a lower return on investment. To the end-users, increased costs or poor quality are passed on as higher prices, rental costs, excessive operation and maintenance costs, etc. For professionals, this can cause customers to lose confidence in them. For contractors, this could mean loss of profits through penalties for non-completion, and negative word of mouth jeopardizing their chances of getting further jobs, if found faulty. To the construction industry, failure to meet set project objectives due to risk could lead to a perpetuation of the bad reputation in terms of time and cost overruns, inability to procure project finance or procuring at a higher cost due to increased risk, and the client "does not allow investments from the industry to other less risky investment sectors such as shares, bonds or foreign investments (Sidwell, 2005).

Early identification of risks ensures that team's effort is focused on critical areas, focusing the project team's attention on actions and resources where there is a major risk exposure, or where the most time and cost can be saved through streamlined project management. Managing construction project risks from the outset will contribute to an early risk response where problems are reduced as they are identified. This can be differentiated from traditional approach to project management, whereby risks are only addressed when problem arise. This is not good as it will require a lot of time and money as well as effort. Risk management is the responsibility of every stakeholder involved in a project.

Risk Management Process

Risk Management is now widely used in most projects, especially large complex real estate and construction projects. RM is an essential tool today, and its rise has been linked to the increasing complex trend of projects. To manage the increasing complexity uncertainty of projects, there are several steps to follow in the context of RM. There are many process models of RM and there is a strong consensus regarding RM approach. Among them, the most commonly accepted and used process model presented by Project Management Body of Knowledge (PMBOK) that is shown in Figure 3.

PMI (2017) has divided RM steps into RM planning, risk identification, risk qualitative analysis, risk quantitative analysis, risk response development and risk monitoring and control. During the RM planning stages, a detailed plan is produced by the project team on how to approach RM activities throughout the project. The main aim is to inform all stakeholders of the risks and to build support and commitment to a clear RM strategy. This planning step is crucial for the success of the project and if planning is done extensively and covers the relevant areas, there is less chance of the project failure. These steps should be initiated when project planning is finalized and completed before project launch.

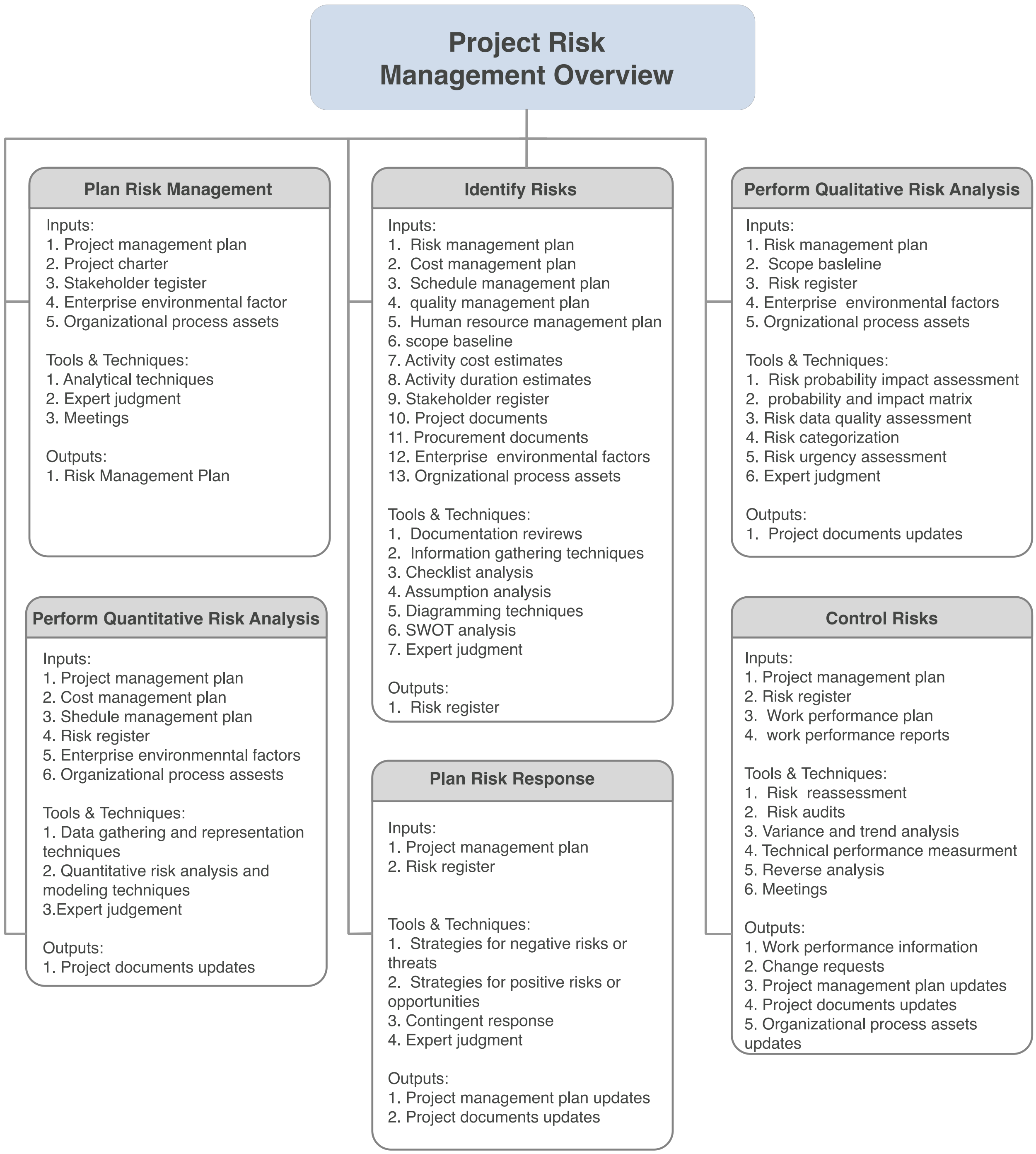


Figure 3 Project risk management steps (Adapted from: PMI, 2017).

To achieve the most desirable RM planning knowing the tools and techniques of each step is crucial. The flow chart of project risk management steps and their related tools is shown in Figure 4:

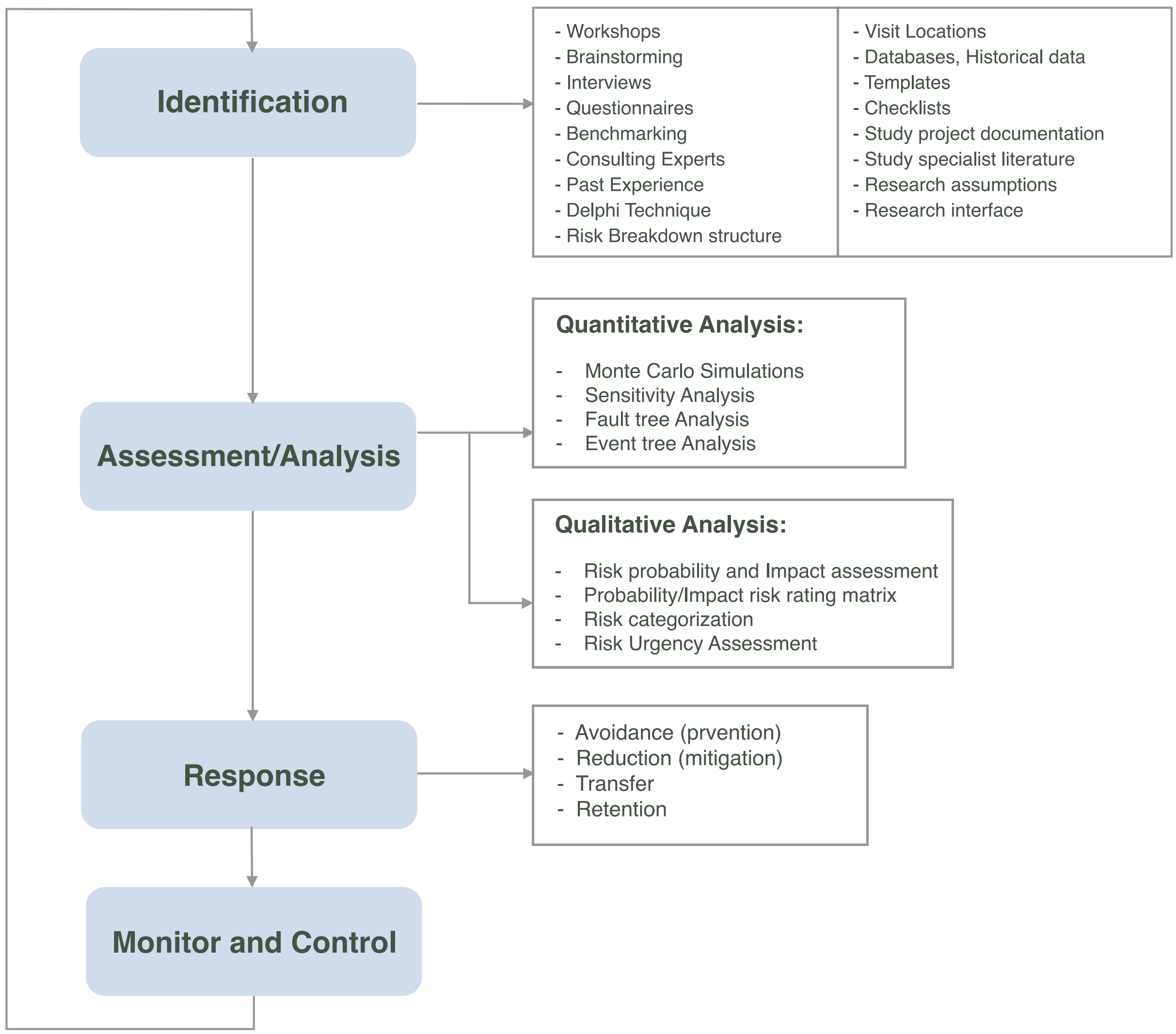


Figure 4 Project Risk Management Process Flow and related tools Diagram

Risk Management Planning

Developing a risk management plan is the most valuable activity of project risk management, as it establishes all the activities the project management team must handle to manage risk and uncertainties of the project. It functions as a guide providing procedures, tools, techniques, and documentation templates for the project management team to use when managing projects.

The risk management plan includes the project's information and risk management objectives, guides on identifying, assessing, response planning, and monitoring and controlling risks, assigning of risk owners and to whom they are responsible to communicate modifications to their own risk behavior and risk management documents (risk allocation structures, risk registers and templates).

The risk register is the main output of the risk management plan. It collects all the information on the identified risks, the qualitative and quantitative evaluation, risk response and status of the risks during the monitoring and control. Risk management is an iterative and continuous process, and the risk register should be updated regularly to identify new risks and monitor other possible risks that may occur. These reviews can take place during risk control activities.

Risk Identification

Winch (2002) claims that the first step in RMP is often informal and can be executed in various ways, depending on the organization and the project team. This means that the identification of risks is mainly based on past experiences which should be used in future projects. To find the potential risks, it is necessary to make an allocation. It can be decided and arranged by the organization. In this case, no method is better than another, since the sole purpose of which is to identify the possible risks in a project. Risks and other threats can be difficult to eliminate, but once they are identified, action and control are easier. If the causes of risk are identified and allocated before problems arise, risk management will be more effective (PMI, 2017).

RM not only solve problems in advance, but also prepares for potential issues that may arise unexpectedly. Dealing with potential threats is not only a way to minimize losses in a project, but also a way to turn risks into opportunities, which can lead to economical profitability, environmental benefits and other advantages (Winch, 2002).

The purpose of risk identification is to obtain a list of potential risks that need to be managed in a project (PMI, 2017). To find out all the potential risks that can affect a particular project, different techniques can be applied.

It is important to use a method that the project team is most familiar with, and that the project will benefit from. The aim is to highlight the potential problems, so that the team project is aware of them. Authors describe many creative alternative methods. To systematize this process, all the methods that can be found in the literature have been collected in Table 2. (Smith et al. 2006; Lester, 2007; PMI, 2017)

Table 2 Risk identification techniques

Information gathering methods	Workshops
	Brainstorming
	Interviews
	Questionnaires
	Benchmarking
	Consulting experts
	Past experience
	Delphi technique
	Risk breakdown structure
	Visit locations
Documentation	Databases, historical data from similar projects
	Templates
	Checklists
	Study project documentation (plan, files etc.)
	Study specialist literature
Research	Stakeholder analysis
	Research assumptions
	Research interfaces

Lists of potential problems are created on different bases and are tailored to each given project. In the literature, one can find examples of risks that can be used to generate such aggregates. The possible risks that can be found in the literature are combined in Table below. (Smith et al. 2006; Potts, 2008; Lester, 2007; Bing et al., 2005; Webb, 2003; Darnall and Preston, 2010; Edwards, 1995; Jeynes, 2002)

Table 3 Risk categories divided into groups

Risk Categories	
Groups:	**Risks:**
Monetary	Financial
	Economical
	Investment
Political	Legal
	Political
Environmental	Environmental
	Natural, physical
Technical	Technical
Project	Contractual, client
	Project objectives
	Planning, scheduling
	Construction
	Design
	Quality
	Operational
	Organizational
Human	Labor, stakeholder
	Human factors
	Cultural
Market	Market
Safety	Safety
	Security, crime
Materials	Resources

Assessment/Analysis

Risk analysis is the next stage in the RMP where date collected on potential risks is analyzed. Risk analysis can be described as short-listing risks with the highest impact on the project, among all the threats mentioned in the identification phase (Cooper et al. 2005). Although some researchers distinguish between the terms risk assessment and risk analysis and describe them as two separate processes, for the purpose of this research, this part of RMP will be consistent with the model provided by Smith et al. (2006) and described as one process.

In the analysis of the identified risks, two types of methods – qualitative and quantitative – have been developed. Qualitative methods are most applicable when risks can be placed somewhere on a descriptive scale from high to low. In addition, quantitative methods are used to determine the probability and impact of the identified risks and are based on numerical estimations (Winch, 2002). Companies tend to use a qualitative approach because it is more convenient to describe the risks rather than quantifying them (Lichtenstein, 1996). In addition, there is also semi-quantitative analysis, which combines numerical values from quantitative analysis and qualitative method of describing risk factors (Cooper et al. 2005). However, this approach will not be discussed further in this study.

Within the quantitative and qualitative analysis, several methods can be found which use different assumptions and it could be problematic to choose an appropriate risk assessment model for a specific project. The methods should be selected depending on the type of risk, the scope of the project and the specific requirements and criteria of the method. Regardless of the method used, the assessment's desired outcome should be reliable (Lichtenstein, 1996). Perry (1986) mentions that the selection of the right technique often depends on past experience and expertise, and today it also depends on the available computer software.

Lichtenstein (1996) explains a number of factors that can influence the selection of the most appropriate methods in the risk assessment for the correct purpose. Each organization must determine which of these factors is most relevant to them and adapt the assessment appropriately. In a survey conducted by Lichtenstein (1996), many factors were discovered, and the most important ones are listed below.

- Cost of using the method, both the employment cost and the method itself
- Adaptability, the need of adapting to the organization’s requirement
- Complexity, how limited and simple the method is
- Completeness, the method needs to be feasible
- Usability, the method should be understandable to use
- Validity, the results should be valid
- Credibility

A brief description of various risk analysis methods that are used in the construction industry is explained as followed (Azari, 2010):

Qualitative methods

Qualitative risk assessment methods are based on descriptive scales and are used to describe the likelihood and impact of a risk. These relatively simple techniques are applied when quick assessment is needed (Cooper et al. 2005) in small and medium scale projects (Heldman, 2005). Moreover, this method is often used in case where numerical data is inadequate, limited or unavailable and where resources of time and money are limited (Radu, 2009). The main goal is to prioritize potential threats to identify those that have the most impact on the project (Cooper et al. 2005). By focusing on these threats, improve the project's overall performance (PMI, 2017). The complexity of scales (Cooper et al. 2005) and definitions (PMI, 2017) used in this survey reflect the size of the project and its objectives. During the phases of the project lifecycle, risks may change, and therefore a continuous risk assessment helps to establish actual risk status (Cooper et al. 2005). In order to provide credible analysis, the accuracy of the data is needed where the Limitations of qualitative methods lie in. For the risk analysis to be useful to the project team, the accuracy, quality, reliability, and integrity of the information as well as an understanding of the risks are essential. Qualitative methods are linked to the quantitative methods, and in some cases form their foundation. PMI (2017) classifies four qualitative methods for risk assessment: Risk probability and impact assessment, Probability/impact risk rating matrix, Risk Categorization and Risk Urgency Assessment. These methods are briefly discussed below.

Risk probability and impact assessment

By applying a method known as risk probability and impact assessment, the likelihood of a particular risk occurring is evaluated. In addition, risk impact on project objectives is assessed base on its positive effects on opportunities, as well as negative effects due to threats. For the purposes of this assessment, probability and impact should be defined and tailored to a particular project (PMI, 2017). This means that clear definitions of scale should be provided, and its scope depends on the project's nature, criteria and objectives (Cooper et al. 2005). PMI (2004) identifies exemplary range of probability ranging from 'very unlikely' to 'almost certain', however, the corresponding numerical assessment is admissible. The impact scale changes from 'very low' to 'very high'. Moreover, assessing impact of project factors like time, cost or quality requires further definitions of each degree in scale to be drawn up, as shown in Figure 5. Each risk listed in the identification phase is evaluated according to the probability and the impact of its occurrence (PMI, 2017).

Defined Conditions for Impact Scales of a Risk on Major Project Objectives
(Examples are shown for negative impacts only)

Project Objective	Relative or numerical scales are shown				
	Very low /.05	Low /.10	Moderate /.20	High /.40	Very high /.80
Cost	Insignificant cost increase	<10% cost increase	10-20% cost increase	20-40% cost increase	>40% cost lincrease
Time	Insignificant time increase	<5% time increase	5-10% time increase	10-20% time iIncrease	>20% time increase
Scope	Scope decrease barely noticeable	Minor areas of scope affected	Major areas of scope affected	Scope reduction unacceptable to sponsor	Project end item is effectively useless
Quality	Quality degradation barely noticeable	Only very demanding applications are affected	Quality reduction requires sponsor approval	Quality reduction unacceptable to sponsor	Project end item is effectively useless

This table presents examples of risk impact definitions for four different project objectives. They should be tailored in the Risk Management Planning process to the individual project and to the organization's risk thresholds. Impact definitions can be developed for opportunities in a similar way.

Figure 5 Definition of Impact Scales for Four Project Objectives (PMI, 2017)

Risk impact assessment studies the potential effects on a project objective such as time, cost, scope, or quality. Risk probability assessment investigates the likelihood of a particular risk occurring. The probability level of each risk and its impact on each objective is evaluated in an interview or during a meeting. Explanatory details, including justifying assumptions for the assigned levels, are also recorded. Risk probabilities and impacts are graded as said by the definitions given in the risk management plan. Sometimes, risks with clearly low probability ratings and impact will not be rated but will be included on a watch-list for future monitoring (Ritter, 2008).

Probability/impact risk rating matrix

Probability and impact, which were assessed in the previous step, are used as the basis for the quantitative analysis and risk response which will be explained further in the research. For this reason, assessment results are prioritized by using various calculation methods that can be found in the study (PMI, 2017). Westland (2006) calculates the priority score by averaging the probability and impact. The priority score range, the rating and color are assigned to indicate the importance of each risk (Westland, 2006). In order to set priorities, the impact is multiplied by the probability. The compiled results are presented in the matrix of Figure 6 (PMI, 2017). Such combination of such factors indicates which risks are of low, moderate or high priority. Regardless of the methods chosen for calculations, such a combination of data shows priority of previously identified risks by using corresponding colors or a numerical system and helps to assign appropriate responses to risk. For instance, threats with high impact and likelihood are identified as high-risk and may need immediate response, while low priority score threats can be monitored by action being taken only if, or when, needed (PMI, 2017).

Probability and Impact Matrix

Probability	Threats					Opportunities				
0.90	0.05	0.09	0.18	0.36	0.72	0.72	0.36	0.18	0.09	0.05
0.70	0.04	0.07	0.14	0.28	0.56	0.56	0.28	0.14	0.07	0.04
0.50	0.03	0.05	0.10	0.20	0.40	0.40	0.20	0.10	0.05	0.03
0.30	0.02	0.03	0.06	0.12	0.24	0.24	0.12	0.06	0.03	0.02
0.10	0.01	0.01	0.02	0.04	0.08	0.08	0.04	0.02	0.01	0.01
	0.05	0.10	0.20	0.40	0.80	0.80	0.40	0.20	0.10	0.05

Impact (ratio scale) on an objective (e.g., cost, time, scope or quality)

Each risk is rated on its probability of occurring and impact on an objective if it does occur. The organization's thresholds for low, moderate or high risks are shown in the matrix and determine whether the risk is scored as high, moderate or low for that objective.

Figure 6 Probability and Impact Matrix (PMI, 2017)

Risk categorization, and Risk Urgency Assessment

Two methods mentioned by PMI (2017) are not as commonly used as probability and impact. Risk classification is a way to systematize project threats according to, for instance, their sources, in order to identify the areas of the project most exposed to those risks. The tools that can be used in this method are the Work Break down Structure (WBS) or Risk Breakdown Structure (RBS), and their role is to develop an effective risk response (PMI, 2017). WBS breaks down large operations into small manageable units and creates interconnected hierarchical series of independent activities (Maylor, 2005). RBS categorizes risks and shows their dependencies (Dallas, 2006). The role of the second approach, Risk Urgency Assessment, is to prioritize risks according to how quick is the response they require.

The lists with risks prioritized by applying qualitative methods, can be used to bring attention to significant project issues and problems. Problems classified as medium level risks can be subject of a quantitative analysis to better control them. The threats that are assessed as low impact can be placed on a watch list and be monitored. This will allow the project team to focus on more important issues. Risk categorization helps to uncover weak links in the project organization where more attention should be directed (PMI, 2017).

Quantitative methods

Risks are evaluated quantitatively if the probability of an event can be measured on the basis of relevant information about comparable historical events or on information gathered in some manner or based on personal experience. Many quantitative risk analysis techniques are widely used. Well-known examples are simple assessment, probabilistic analysis, sensitivity analysis, decision-making trees, and Monte Carlo simulation.

Simple Assessment

This method entails the use of arithmetic to analyse significant risks independently in order to determine their combined potential effect. The expected impact of each significant risk is calculated separately; these are finally added together to get the total impact, which is then used for contingency planning. The method is best suited to projects that are small and simple in nature. It may also be used to determine the potential impact of a risk by calculating the chance that it will occur and its full consequence if it occurs.

Probabilistic Analysis

This is a mathematical approach that allows risk measurement exposure for each individual risk or for the entire project (Powell, 1996). First, for each event, optimistic, most likely, and pessimistic cost and time estimates are assigned. For example, an optimistic estimation of the construction price of a block of flats could be 500 / m, the most probable construction cost is 750 / m, and a pessimistic estimation of the price is 1000 / m. Then, the likelihood for each assessment is established subjectively. Another example is to suppose the probability of the optimistic assessment is 0.3, the probability for the most likely assessment 0.6, and the probability for the negative assessment 0.1. the sum of all probabilities must be equal to 1. By multiplying the projected construction costs with the associated probabilities and adding up the products together, gives rise to exposure, that is the predicted value (EV). In the above case, EV = 500 * 0.3 +750 * 0.6 + 1000 * 0.1 = 700 / m. The EV ranges from the optimistic assessment by a value of 200 / m, from the most likely assessment by a value of 50 / m, and the pessimistic assessment by a value of 350 / m. This indicates that the pessimistic assessment is the most likely scenario, which is the foundation of the contingency plan. Probabilistic analysis is easy to use and very understandable, but contextual judgment base it on the expertise and understanding of the risk analyst making it.

Sensitivity analysis

Sensitivity analysis is used to calculate the potential undesirable impacts associated with each risk in the project (Flanagan & Jewel, 2008). The effects of risk and other uncertainties on the project are determined by varying the parameters that affect the exposure value and measuring the effect on the final outcome. The change in the parameters' percentage is divided by the resultant percentage change to find the sensitivity factor. Then, a graph is plotted for each modified variable to identify the most sensitive or critical variables.

The advantage of this approach is that it facilitates in-depth decision-making by presenting complex information in a user-friendly manner. This method also makes it possible to compare the strengths of the project as well as its specific uncertainties. Last but not least, the relevance of each variable is identified promptly, which facilitates the reduction or mitigation of uncertainties. On the other hand, this method is unable to assess several variables simultaneously. In addition, the sensitivity graph does not reflect the probability of an even occurring. This can be overcome by using probability contours, though as these rely on the subjective prediction of the estimator, they may be unreliable (Jordan, 2013). Sensitivity analysis is useful because it determines which parameter(s) are most effective on final risk exposure, since analyzing one parameter in isolation will not provide meaningful information about the situations where the parameters will vary.

Decision trees

Decision tree analysis are commonly used when certain risks have a remarkably high impact on the two main project objectives: time and cost (Heldman, 2005). There are two types of decisions trees: Fault tree analysis (FTA) and Event tree analysis (ETA).

The FTA method of analysis is used to determine the probability of the risk and is used to identify risks that may contribute to or cause an even to fail (Cooper et al. 2005). The goal is to uncover the underlying causes that led to the event. It is often drawn like a sketch of a tree. The branches are the causes to the problem, and the starting point of the tree is the problem itself. Each branch has its own sequence of events and possible outcomes. The problem may depend on a number of interrelated causes, or simply random causes (Cooper et al. 2005). By having multiple branches, the tree provides an opportunity to choose which branch to follow and base decisions on. (Heldman, 2005).

Fault tree analysis (FTA) and a similar analysis called event tree analysis (ETA), are simple methods that can be used as a structured model to determine causes and effects of a single event, but with different approaches (White, 1995).

As explained, ETA is very similar to the FTA, but what differentiates the methods is the outcome. ETA is also drawn as a tree but in the opposite approach to FTA. According to White (1995), failure generally does not come from a single cause. Rather it is described as a sequence of causes and consequences that can result in major damage to the project. The tree consists of branches which represent the possible consequences after the main event that this method analyzes. Each branch focuses on a specific type of causes individually, which is why creating a risk assessment is so important (White, 1995).

In both FTA and ETA, cause-effect skills are required including the possibility to understand how failure might occur and to observe the possible modes of failure arisen from the situation respectively. Therefore, it is preferable to have a risk management analyst in the project team (White, 1995).

Scenario technique - Monte Carlo simulation

The Monte Carlo method is based on statistics used in a simulation to assess the risks. The simulation is used for forecasting, estimations and risk analysis by generating different scenarios (Mun, 2006). For instance, the information collected for the simulation is historical data from previous projects. The data represent schedule and cost variables for each small activity in a project, and may contain pessimistic, most probable and optimistic scenarios (Heldman, 2005). The simulation can be presented as a basket containing golf balls, as Mun (2006) explains the process. Data (the golf balls) are mixed and one of them is selected each time the simulation is done. The chosen unit is an outcome which is recorded, and the ball is returned to the basket. The simulation is then repeated numerous times and all outcomes are recorded. After performing the required number of simulations, the average value is taken from all the results, which will form the risk forecast (Mun, 2006). The result of this method is the probability of a risk occurring, usually expressed as a percentage (Darnall & Preston, 2010). Although there are a lot of measurements, this method involves the use of a computer.

Although risk management is a human-centered method, to optimize planning and avoid replication of procedures, especially in complex and large programs, it is best to follow similar risk management tools. If the project is programmed and driven from the start using existing software, the success of the projects can be easily monitored, and the strengths and limitations of the project can be tracked and identified in the software.

One of the most common software used is RiskyProject, an innovative risk assessment software for automated risk analysis. Most projects have several unknown parameters: task duration, start and completion dates, cost and resource uncertainty, efficiency uncertainty, protection, infrastructure, and others. RiskyProject analyzes project timelines for threats and uncertainties. It measures ability to complete tasks within a specific time and budget, ranks risks, and delivers findings in a legible and comprehensive way. (RiskProject Professional 2019 User Guide).

RiskyProject also helps you to perform project risk management:

- Identify project risks
- Rank risks
- Identify mitigation and response plans
- Manage risk properties, including descriptions, probabilities and impacts, costs associated with risks, mitigation strategies, and all other information about risks
- Facilitate risk reviews, opening, and closing risks, conversion of risks to issues and lessons learned
- Save risk history. (RiskyProject Professional User Guide 2019)

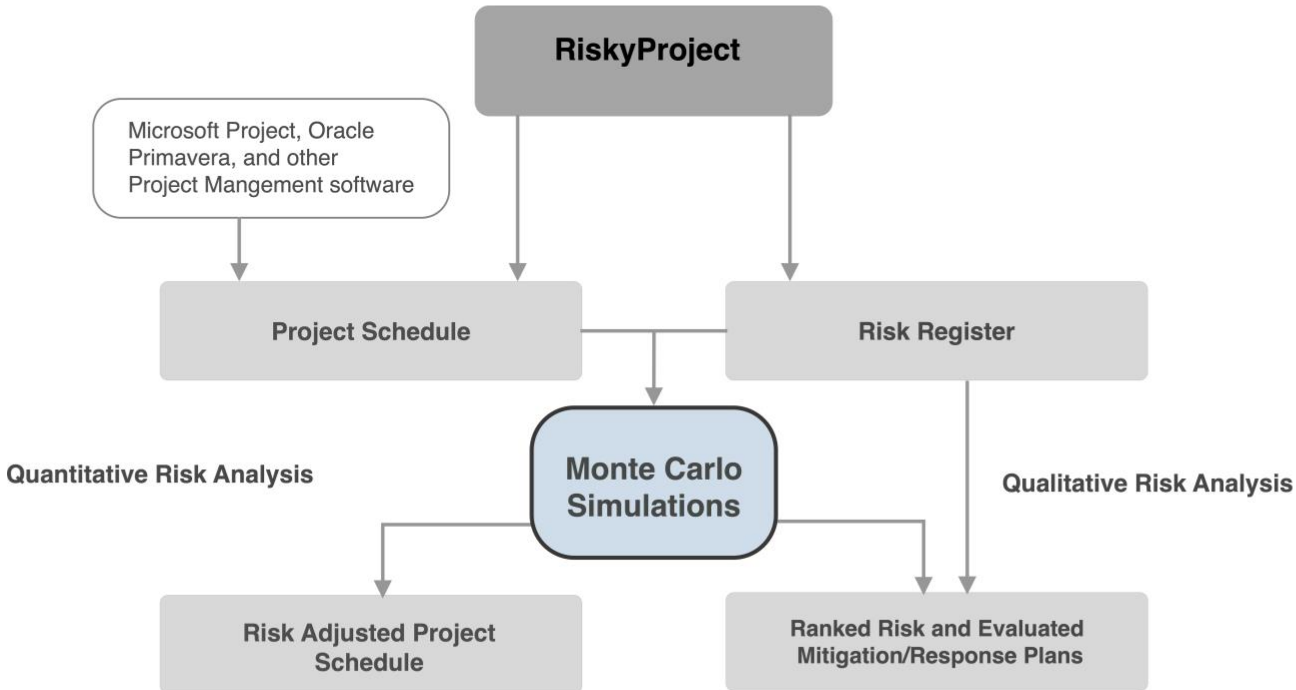


Figure 7 How the RiskyProject software works (User Guide 2019)

It could also be relevant to look at the differences between quantitative and qualitative risk analysis in detail to have a better understanding of necessity of using both for a complex project:

Table 4 Comparison of Qualitative and Quantitative Risk Analysis

Qualitative Risk Analysis	Quantitative Risk Analysis
It considers all the risks identified in the identify risk process.	It only considers the risks which we mark for further analysis in the Perform Qualitative Risk Analysis Process. These are the risks that will have a significant impact on the project objectives.
It does not analyze the risks mathematically to identify the probability and likelihood. Instead, it uses stakeholders' inputs (expert judgment) to judge the likelihood and impact	Perform Quantitative Risk Analysis uses the probability distributions to characterize the risk's probability and impact. It also uses the project model (e.g., Schedule, cost estimate), mathematical and simulation tools to calculate the probability and impact.
In this, we assess individual risks by assigning a numeric ranking of probability and impact; usually; the rank of 0 to 1 is used where 1 demonstrates high.	It predicts likely project outcomes in terms of money or time based on combined effects of risks. It also estimates the likelihood of meeting targets. And communicates contingency needed to achieve the desired level of comfort.
We apply to Perform Qualitative Risk Analysis process in almost all the projects.	We don't use this process in simple and moderately complex projects. We may not find its use in software projects

Risk response

This next step of the RMP outlines the actions to be taken towards identified risks and threats. The response strategy and approach chosen depends on the type of risk involved (Winch, 2002). Other requirements are that the risk needs a supervisor to monitor the development of the response, which will be agreed by the actors involved in this risk management process (PMI, 2017).

Winch (2002) claims that when the impact of the risk is lower, the risk can be managed better. The most common risk response strategies are avoidance, reduction, transfer, and retention (Potts, 2008). In addition to these types of responses, Winch (2002) describes that it is sometimes difficult to make decisions based on few information. This can be avoided by waiting for the appropriate information to be available in order to deal with the risk. This course of action is known as “delaying decisions”, but this approach is not appropriate in all situations, especially when dealing with critical risks. These points need to be handled earlier in the process.

Avoidance/prevention

If the risk is classified as bringing negative consequences to the entire project, it is important to review the project's objectives. In other words, if the risk has a significant impact on the project, the best solution is to avoid it by modifying the scope of the project or, at worst, canceling it. There are many potential risks that a project may face that can affect its success (Potts, 2008). This indicates the importance of Risk Management at an early stage of a project instead of dealing with damage after the risk has arisen (PMI, 2017).

Avoidance means that by considering alternatives in the project, many risks can be eliminated. If the project requires major changes to avoid risks, Darnall and Preston (2010) suggest applying known and well-developed strategies instead of new strategies, even if the new strategies seem to be cost-effective. This way, risks can be avoided, and work can proceed smoothly as the strategy is less stressful for the user.

Cooper et al. (2005) list some activities that can help to avoid potential risk:

- More detailed planning
- Alternative approaches
- Protection and safety systems
- Operation reviews
- Regular inspections
- Training and skills enhancement
- Permits to work
- Procedural changes
- Preventive maintenance

Reduction/mitigation

Through an overview of the entire project, it is easy to identify the problems causing damage. To reduce the level of risk, the area of exposure should be changed (Potts, 2008). This could be a method of minimizing the potential risks by mitigating their likelihood (Thomas, 2009). One way to reduce project risk is to add expenditures that can provide long-term benefits. Some projects invest in guarantees or hire experts to manage high-risk activities. These experts may find solutions that the project team has not considered (Darnall and Preston, 2010).

According to Cooper et al. (2005), mitigation strategies include:

- Contingency planning
- Quality assurance
- Separation or correlation of activities and resources
- Contract terms and conditions
- Crisis management and disaster recovery plans

It is also possible to share the reduced risks with parties who have the most appropriate resources and knowledge about the consequences (Thomas, 2009). By cooperating with other parties, sharing can also be another alternative. In this way, one project team can take advantage of another's resources and experience. It is a way to share responsibilities concerning risks in the project (Darnall and Preston, 2010).

Transfer

If the risk can be managed by another participant with greater capability or capacity, the best option is to transfer it. Potts (2008) states that risk should be transferred to those who know how to manage it. Depending on the risk's character, the participant that the risks can be transferred to are, for example, the client, contractor, subcontractor, designer etc.

As a result, this could lead to Risk premium, which has higher costs and additional work (Potts, 2008). It must be recognized that the risk is not eliminated, it is only transferred to the party that is most competent and able in managing it (PMI, 2017). When the risks are outside the project management's control, for example in political issues or labor strikes, shifting risks and the negative impacts they bring could also be an option (Darnall and Preston, 2010). The situation may also consist of catastrophes that are rare and unpredictable in a certain environment. (Winch, 2002) Such risks that are beyond the management's control should be transferred through insurance policies.

Retention

When risk cannot be transferred or avoided, the best solution is to retain the risk. In this case, the risk must be controlled to minimize the impact of its occurrence (Potts, 2008). When other solutions are not economical, retention is also an option (Thomas, 2009).

Monitoring & Control

This final step of the RMP is vital because all the information on the identified risks is collected and monitored (Winch, 2002). Continuous monitoring of the RMP makes it possible to detect new risks, keep track of identified risks and eliminate past risks from the project and the risk assessment (PMI, 2017). PMI (2017) also indicates that the monitoring and control assumptions are to supervise the state of risks and take corrective actions if necessary.

Tools and techniques used to risk monitor and control may be (PMI, 2017):

- Risk reassessment – identification of new potential risks. This is a constantly repeated process throughout the whole project.
- Monitoring of the overall project status – are there any changes in the project that can affect and cause new possible risks?
- Status meetings – discussions with risks owner, share experience and helping to manage the risks.
- Risk register updates

By managing the entire RMP, the process can be evaluated. This is a method of creating a risk register in which all risks and their management can be allocated to facilitate future projects (PMI, 2017). This is also a way to improve the project work because both advantages and disadvantages will be discussed.

3. Lean Management

Lean Background

The Toyota Production System (TPS) was created by Taiichi Ohno, a Toyota Motor Corporation engineer, and is the inspiration for lean manufacturing. Toyota's sales fell in the late 1940s and early 1950s, prompting the company to investigate the automobile industry in other countries. According to Womack, et al. (1990), it all began when Eiji Toyoda and Taiichi Ohno went to the United States in the 1950s to investigate the world's largest and most efficient manufacturing plant, Ford's mass production factory in Detroit. Toyota's purpose in studying Ford's plants was to learn and enhance their own manufacturing so that they could become more competitive in the automobile industry. During their time in the United States, Ohno discovered that Toyota lacked the resources and industrial ability to mass produce in the same way that Ford did. Instead, they must develop a method that is efficient and produces low volumes. Furthermore, Ohno was impressed by the construction of grocery stores in the United States. The customer expects the store has what he or she wants, and when the consumer takes it, the inventory is replenished in stores utilizing Kanban. Ohno returned to Toyota with this concept and later developed the Just in Time philosophy based on it (Womack et, al., 1990). When Ohno came back to Japan, he set out to apply innovative methods for improving manufacturing operations. His suggestions, though, were beneficial. Until Kiichiro Toyoda resigned and Ohno began to experiment with new ideas, those methods were not fully implemented (Womack, et al., 1990).
With the passage of time, Toyota was able to dramatically increase manufacturing volumes, but it also faced a significant crisis when its new brand was rejected in the American market. The cars were rejected for a variety of reasons, including a lack of safety, a lack of engine power, and a large mass of cars. This setback rekindled a motivation to enhance quality in order to survive. Following that, Toyota's management agreed to implement Ohno's Total Quality Control (TQC) method (Womack et, al., 1990). The new system worked well, and Toyota was capable of achieving quality and productivity at the same time. This innovative system became a key factor in Toyota's global market share growth. They devised a new manner of producing, which we now call lean production, based on their many learning experiences.

Poor project performance in construction and real estate development industry is not an unprecedented situation as these industries involve numerous parties, lengthy process, and various stages. Efficiency levels inside the real estate industry have reliably slacked behind other sectors of the economy, particularly manufacturing industry. The distinction between good and poor project performance was defined by the time, cost, and quality objectives. However, in reality, the construction industry has a luckless reputation of delivering projects that are unpredictable in terms of delivery on time, within budget and to the pre-specified quality, whilst concurrently attempting to ensure a zero-accident rate. There are many factors which will affect the project performance as the process is getting complex with the combination of various parties' actions, many stages of work and carrying a long period till the completion. The poor performance of the construction sector was due to a gateway waste of not measuring and/or applying incorrect, inadequate, or insufficient evaluation criteria.

A growing number of construction and real estate companies are taking steps to improve the performance of their projects by decreasing all types of risks and wastes that arise during the construction process. Most construction executives are aware that the business is vulnerable to wasted spending, delays, and project inefficiency. The construction business has been criticized for a variety of reasons, the most common of which being poor performance. Not just the final product, but also the methods, the people, the materials, and so on, are all being chastised for a lack of quality in building. Because the real estate development industry has a significant and direct impact on many other industries, both in terms of purchasing inputs from other industries and in terms of providing products to almost all other industries, eliminating or reducing waste could result in significant cost savings for society. Many projects management approaches have emerged to improve performance such as value-engineering, partnering, design-build, etc.

Increased productivity has resulted in considerable performance improvements in the manufacturing industry over the previous two decades. The application of the new production philosophy, commonly known as "lean production," which allows continuous improvement in the production process by removing various sorts of waste, is a crucial component in this achievement.

In the 1940s, lean construction methodology developed as Lauri Koskela made the transition from the development of new production management from manufacturing to construction industry. The potential impact of lean manufacturing philosophy on construction efficiency has been thoroughly documented. Lean techniques are relevant not only in manufacturing, but also in other industries such as service-oriented industry and service environment. Wastes and non-value adding activities exist in every system. There are elements that are considered 'waste' whether you are producing a product, processing a material, or providing a service. In any system, and in any industry, the techniques for analyzing systems, identifying, and reducing waste and focusing on the customer are related and applicable.
Basically, lean construction aims to reduce the waste caused by unpredictable workflow, where waste is defined in Ohno seven categories: defects, overproduction, waiting, transporting,

movement, inappropriate processing, and inventory that will be explained in the following. Implementation of lean principles to the construction industry does improved operational performance. Besides that, their study also reveals that there is a correlation between lean principles, operational performance, and risk management.

Lean Principles

The concept of lean production was founded on the original Toyota Production System, which aimed to produce exactly what the customer wanted, when they wanted it, with the minimum of waste possible. Lean is all about designing and implementing the best process possible the first time. The removal of waste activities and processes that consume resources but produce no value is critical to this. The main objective is to go closer and closer to providing a product that customers desire by understanding the process, identifying waste, and reducing it one step at a time.

In brief, lean focuses on value rather than cost, and it aims to eliminate non-value-adding processes while improving those that do. Adopters of the lean construction system have refined and extended it, as well as outlined the essential lean thinking principles.

The followings are the brief five top principles of lean thinking:

- **Value** – Precisely specify value from the perspective of the final customer;
- **Value Stream** – Clearly identify the process that delivers what the customer values (the value stream) and eliminate all non-value-adding steps;
- **Flow** – Make the product flow or organize the production in a continuous flow;
- **Customer Pull** –Customer pull means do not make anything until it is needed, then make it faster.
- **Perfection** – Reach perfection by continuous improvement and deliver on order a product meeting customer requirement with nothing in inventory.

Perhaps the most important motive to perfection is transparency, The fact that everyone—subcontractors, first-tier suppliers, system integrators (often referred to as assemblers), distributors, customers, and employees—can see everything in a lean system makes it easy to uncover better methods to produce value. Moreover, there is almost instant and highly positive feedback for employees making improvement, an important aspect of lean work and a great motivator to keep trying to improve. (Womack & Jones, 2003)

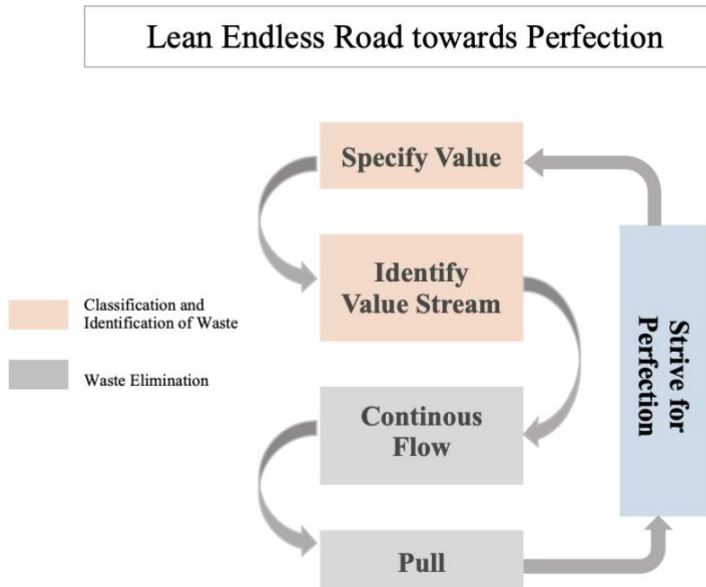


Figure 8 Cycle of Lean Principles

Lean Construction

The application of lean thinking to the construction industry is the emerging idea of lean construction. Over the last few decades, there has been an increasing interest in lean construction among international academicians. Researchers in this field try to investigate the extent to how well the Japanese model of lean production can be applied to the construction industry. From the study of lean construction background, lean construction is resulted from the adaptation and implementation of the Japanese manufacturing principles within the construction practices, which lean construction consider construction like a production process but a special one.

The concept of lean production is introduced to the construction industry resulting its success in the manufacturing industry. Subsequently, the terminology of lean construction is created.

Lean construction is still new concept to many construction industries in the world. Essential features of lean construction include a clear set of objectives for the delivery process, pointing to maximizing performance for the customer at the project level, concurrent design of product and process, and the application of production control during the life of the product from design to delivery.

Over concurrent design of both the constructed facilities and the construction process that delivers the facilities, and through the consequent control of each stage in the construction process, lean construction points to maximize the customer's satisfaction. In addition, lean construction is a continuous process of removing waste, focusing on the entire value stream, and striving for perfection in project performance. Lean also consider and focus on the impact of one activity on the next. Briefly, lean construction features include many fundamental aspects of a lean philosophy. lean philosophy needs a continuous improvement effort that is concentrated on a value stream defined in terms of the needs of the customer. Improvement is achieved in part by eliminating waste from the process.

Various beneficial results have been obtained worldwide in many areas of the construction industry by applying lean manufacturing concepts, such as greater value, lower costs, and increased customer satisfaction. For example, Ballard (1994) achieved increased productivity by 30% by matching labors to backlog workflows and protecting direct production from upstream variation and uncertainty. There are three features to distinguish the lean construction practice from a conventional construction management, namely:

a) lean construction emphases on reducing wastes that may exist in any format in the construction process, such as inspection, transportation, waiting, and motion.

b) lean construction objects to reduce variability and irregularity so that material and information can flow in the system without interruptions; and

c) construction material is expected to be on site only when it is needed. The goal of Lean construction is to manage and improve the construction's projects processes in order to deliver profitably what the customer needs.

Lean construction can be implemented in a variety of ways since it is a philosophy. However, focusing on the improvement of the entire process is the only way that lean principles can be applied completely and efficiently in construction. This means that all parties must be committed, involved, and collaborative in order to overcome obstacles that may arise as a result of traditional contractual structures. To increase performance, many project management methodologies have arisen, such as value engineering, partnering, design-build, and so on. Lean combines concepts from these approaches with principles drawn to develop a production management system that creates a new approach to project management. Lean construction may also unclog clogs in the project process by focusing on the workflow. As a result, construction operations such as planning, engineering, designing, constructing, producing, and delivery materials are better coordinated to deliver the project owner the most value.

Waste in Construction

Lean is all about creating and executing the right process and having the right first time. The crucial part of this is the elimination of waste – activities and processes that use resources but produce no value. Taiichi Ohno, during his work at Toyota, defined two types of activities: value-adding activities and non-value-adding activities. Activities that do not provide any additional value are a waste, and, therefore, should be removed. Hines and Rich (1997) divide production activities into three categories: value-adding, non-value-adding, and non-value-adding but required. These activities were defined by Hines and Rich (1997) as follows: **a)** non-value-adding activities are pure wastes that followed by unnecessary actions and should be totally eliminated; **b)** necessary but non-value-adding activities are operations that may be wasteful but are required by present operating procedures. Partial modifications to standard operating procedures are required to eliminate them; and c) value-adding activities comprise the conversion or processing of raw materials or semi-finished goods to the end product.

In recent years, numerous research initiatives throughout the world have focused on waste in the construction industry. Most studies, on the other hand, prefer to focus on material waste, which is only one of the resources used in the process of construction. Despite this, waste in construction is connected to a variety of activities such as overproduction, waiting time, inventory, faults, movement, processing, transportation, and replacement, in addition to the number of waste materials on-site.

Waste was defined by Serpell and Alarcon (1998) as any construction process/activity that incurs cost but does not directly or indirectly bring value to construction projects. Meanwhile, Tersine (2004) defined waste as unwanted, takes up time, money, and/or resources, and adds no value to the product. Anything that does not add value to the customer's experience is also considered a waste. In general, the term "waste" refers to the use of resources that do not contribute to the end product's value. This is in stark contrast to the construction industry's perspective of waste, in which waste is alluded to as material waste and no attempt is made to categorize building operations as value-adding or non-value-adding.

In the scope of lean production, there are seven main types of wastes recognized: overproduction, inventories, defective goods production, motion with no value to the product, extra process, waiting and transportation. Delay times, quality costs, safety lack, excess inventory, rework, long distances, unnecessary transportation trips, setup, moving, inspecting, handling, expediting, prioritizing, queue time, management methods or improper choice or requirements, and poor constructability are all examples of waste in construction and manufacturing.

One of the most effective methods to enhance a company's profitability is to eliminate waste. By eliminating unnecessary waste, profit may be raised while costs are lowered, resulting in a positive compounding effect on the performance.
In order to eliminate waste, it is necessary to first recognize what waste is and where it is located. While construction and factory productions differ substantially, the typical wastes generated in both contexts are very comparable. There is a system for reducing or eliminating each waste's impact on a business, therefore increasing the overall quality and performance. Construction processes may be classified as either adding value to the creation of products or services or adding waste. The recognition of which stages in the process provide value and which do not is the first step in the lean thinking process. After these two categories have been recognized, the action may be carried out by enhancing the former and removing the latter.
The seven hazardous wastes listed further below originated in Japan, where waste is referred to as "Muda." The Toyota Production System, commonly known as Lean Manufacturing, is based on “the seven wastes,” a method that was created by Taiichi Ohno, Toyota's Chief Engineer, in order to appropriately define “Muda.”
Overproduction, defect, material movement, processing and inventory are the first five wastes, whereas the final two are wastes associated with human labor: waiting, and motion.

- **Waste of Overproduction** (Unnecessary work) occurs when a quantity is produced in excess or earlier than is required. This is frequently caused by quality issues; a company anticipates losing a certain number of units during the manufacturing process; therefore, it manufactures extra to ensure that the client order is fulfilled. Overproduction of mortar that cannot be used on time is an example of this type of waste. This might result in a waste of supplies, man-hours, or equipment. The overproduction issue can be tackled by using error-proofing methods (Pokayoke) and by understanding the machine process capabilities of the production equipment.

- **Waste of Rejects** (Defect/Unsatisfactory work) results when the final or intermediate product does not follow quality requirements. This is the most basic type of waste produced by the construction industry, and it occurs when components or goods manufactured do not satisfy the specifications. Defects may require rework or the addition of extra materials to the building process (indirect waste), excessive plastering thickness, for example. The cost of producing a defective product is the same as the cost of producing a prize product. Aside from the apparent losses, rejects have a number of extra expenses that make them a particularly significant waste category to remove. Defects can arise for a variety of causes, including inadequate design and specification, a lack of planning and control, poor qualification of the teamwork, a lack of integration between design and production, and so on. New procedures to handle defects have to be implemented and verified. In order to salvage some value for the otherwise scrap product, new waste management techniques must be implemented. He goes on to say that if all non-value-added operations in a typical manufacturing business are documented, it's not surprising to learn that 99% of them are non-value-added.

- **Waste in Transportation (**Material movement/Conveyance) is concerned with the internal movement of materials on site where poor workplace layout or a lack of process flow creates many stops and starts in a production cycle. Construction site layouts can often be the fundamental cause of excess transportation. This type of waste can also be caused by excessive handling, the use of insufficient equipment, or poor pathways condition. Every movement should have a purpose since any item moved incurs a cost. Interruptions to workflow can substantially add to your transportation costs. These defects are waste of man-hours, waste of energy, waste of space on-site, and the possibility of material waste during transportation. Appropriate re-planning of machines inside a plant from a functional to a cellular layout has been shown to minimize not just transportation waste but also Work in Progress (WIP) and waiting time. This may also be applied to the construction sector, where a well-planned site layout can help to avoid unnecessary material transportation.

- **Waste of Processing** (Overprocessing) is connected to the nature of the processing (conversion) activity, in which material movement waste kinks in building process flows and adds no value to the product or service from the customer's perspective. This is most often due to an issue with the work's quality. Rework on surface finishes is the most visible example of overprocessing. In order to detect and remove the sources of quality problems, techniques such as "5 whys", Statistical Process Control (SPC), and mistake-proofing (Pokayoke) are available. Changes in construction technology can also help to reduce waste.

- **Waste of Inventory** is related to excessive or unnecessary inventories which lead to material waste (by deterioration, losses due to inadequate stock conditions on site, robbery, vandalism), and monetary losses due to the capital that is tied up. Excess inventory is regarded as waste since there is no value added by stocking inventory. In addition, inventory takes up space, ties down capital, incurs storage (and security and insurance) costs and raises the risk of damage during storage as well as the risk of obsolescence. In order to fulfill an order, businesses always order more than is necessary. He went on to say that this might be related to quality issues in the process of production or the commonly held misconception that purchasing bigger numbers saves money. It might also be due to a lack of resource planning or ambiguity in quantity prediction.

- **Waste of Waiting** (Delays) is referred to idle time produced by a lack of synchronization and leveling of material flows, as well as the pace of work by separate groups or equipments. The waste of waiting happens while products are neither moving nor being processed. Idle time can be created while waiting for raw supplies, quality assurance results, engineering, maintenance, and equipment scheduling, among other things, all of which are waste. By connecting the processes so that one feeds directly into the next, waiting waste can be drastically eliminated.

- **Waste if Movement** (Motion) is related to ergonomics and is seen in all instances of bending, stretching, walking, lifting, and reaching. The movement of this waste is concerned with the excessive or inefficient movements made by employees throughout their work, which might be caused by insufficient equipment, ineffective work techniques, or a poorly organized work environment. Traveling too far inside a work site to complete given tasks is a loss of time and effort, as well as a risk of accidents, injuries, and the expenditures that come with them. Poor housekeeping, lack of organization, inefficient machinery layout, and inconsistent or ineffective labor practices are all targets of elimination for Lean Thinking. As a result, with the correct layout of a workspace, employees' needless mobility may be reduced, resulting in cost savings. With the assistance of plant workers, jobs with excessive movements should be examined and modified for improvement.

Following Ohno's seven wastes, a number of scholars have proposed an eighth waste category. **Making-do** is one of the wastes in the construction process. Making-do refers to a circumstance in which a task is begun without all of its standard inputs, or when a job's execution is continued despite the loss of at least one standard input. Even if the inputs are negative in making-do waste, the processing begins before the input arrives. Womack and Jones (2003) have also added the eighth waste, which is the design of goods and services that do not meet the end users' needs. Moreover, Burton and Boeder (2003) have introduced the eighth type of waste: **Waste of human potential** - since the failure to properly use people's abilities is linked to human potential waste. Burton and Boeder (2003) think that once individuals have been taught to recognize waste, they can reduce it. Burglary, vandalism, severe weather, accidents, and so forth are examples of other wastes.

Other types of waste are generally included in one of the seven categories, or they are a cause of the waste rather than a waste in and of themselves, therefore the focus of this study will be on Ohno's seven wastes.

For example, "waste in human potential" is more of a cause of other sorts of waste, such as processing waste or defect waste caused by people's lack of skill. Aside from that, the seven wastes introduced by Taiichi Ohno are links between the root causes (human behaviours) and the loss of profit.

Managing construction process waste using lean techniques

Toyota is arguably most recognized for its highly efficient manufacturing method, termed "lean manufacturing" in the 1980s by an MIT study. The lean techniques from the manufacturing industry are successfully used in other industries throughout the world and are currently used in general construction projects throughout the United States. The most efficient method of production (lean techniques) was not born from a sudden brainstorming; rather, it evolved into its present state over decades of sustained, high level of continuous improvement activity.

Lean techniques are a broad term that encompasses a variety of tools, strategies, and technologies. In fact, at all stages of the project, lean approaches give ongoing guidance and support. Lean approaches, for example, increase collaboration between project participants and develop a culture of continuous improvement during the building stage. In addition, projects that utilize lean techniques can be completed in less time and with fewer costs than typically required. However direct application of lean techniques from the manufacturing industry (like Kanban, Poka yoke concepts, etc.) would not be very successful because the environments of high-volume manufacturing and constructions are quite different.

Hence, careful consideration of the tools and why they work, then adapting the appropriate tools to construction environments may result in significant breakthrough in operational efficiency. Thus, it is important to carefully select the lean techniques/tools to be inserted into the proposed construction waste management framework.

Lean Construction Tools

There is no doubt that lean construction is the way forward for construction industries around the world. About 57% of productive time waste are said to exist in the construction industry and this calls for research and the use of robust and radical techniques to solve the problems the industry faces. The traditional techniques to construction project management fall short of meeting the industry's needs. Lean production management and procedures, on the other hand, lay the groundwork for waste minimization or absolute elimination in construction projects. One of the most effective approaches for reducing delays in construction projects is through lean tools adoption. Even though the construction industry is still evolving, there is a neglect of the benefits of lean tools adoption in the industry. Meanwhile, other industries have been reaping the benefits of using lean tools. Likewise, other construction sectors have shown that lean tools are efficient in controlling delays.

Most construction projects are affected by high delays and low productivity, and the only viable solution is to embrace the lean approach, which will be much more effective if all players in the industry used lean tools. Lean construction tools, in general, are designed to enhance delivery systems and processes by reducing waste, boosting productivity, improving health and safety, and meeting client demand. In effect, it will enhance project and financial performance by removing wastes such as transportation, overproduction, improper processing, lead time, inventory, rework, and needless motions in construction operations. Several lean tools have been proposed by a few academics to tackle the difficulties related to waste in construction projects. Among them include Rahman et al. (2012), Aziz and Hafez (2013), Muhammad et al. (2013), Ballard and Howell (1994), Burton and Boeder (2003), Hines and Rich (1997) and Evbuomwan and Anumba (1998), Johnston and Brennan (1996), Koskela (2000), Marhani et al. (2013), Bashford et al. (2005), Sacks et al. (2010), Sarhan and Fox (2013), among others. Muhammad et al. (2013) emphasized nine tools for the construction sector emphatically. In addition, as an introductory guide to lean implementation, Rahman et al. (2012) offered 27 tools for construction practitioners.

- 5S: Seiri, Seiso, Seiton, Seiketsu, and Shitsuke are the five S's (meaning Sort, Straighten, Shine, Standardize, and Sustain). This is a method for removing waste from the workplace using visual controls.

- Concurrent Engineering: This technique entails multidisciplinary teams performing several activities at the same time in order to optimize product engineering cycles for efficiency, quality, and functionality.

- Check Sheet: Also known as Defect Concentration Diagram. This is a well-structured form for gathering and evaluating information. It's a general tool that can be used for a range of tasks, such as observing and collecting data on the frequency of patterns of issues, occurrences, faults, and causes, among other things.

- Construction Process Analysis: This approach makes process charts and top-view flow charts tangible, and it is widely used in process analysis methodologies. These diagrams and charts use standardized symbols in order to efficiently represent process flow and allow for easy identification of regions in the process where issues may arise. Operation, Storage, Transportation, Volume Inspection, Delay, and Quality Inspection are the six symbols on the charts. Every advancement or stage of a construction process is recorded in the process diagram. It also keeps track of the flow of information within units, sections, and departments.

- Six Sigma: is a set of tools and procedures for increasing quality by identifying and eliminating faults and reducing process variability. Six Sigma is capable of achieving a defect-free process quality of 99.99966 percent.

- Pareto Analysis: This is a bar graph that is used for analyzing data about the frequency of the causes or problems in processes. It visually depicts which situation are more important.

- Check Points and Control Points: are systems for regulating and determining the degrees of improvement in the actions of managers at various levels of the organisation.

- FMEA (Failure Mode and Effects Analysis): is a step-by-step method for possible problems identification in product or service design, production, and other areas. The failures are then rated in order of the severity of their effects so that action may be taken to eradicate them, starting with the highest-ranked ones.

- Continuous Flow: This means to constantly provide or process and produce through a progressive system of uninterrupted steps in the process.

- FIFO line (First In, First Out): This is an approach for handling work request in order of flow from first to the last.

- Jidoka/Automation: The purpose of Jidoka is to design machines to partially automate the manufacturing process and operations in order to separate people from machines so that operators carry out other task(s) while the machines are running.

- Kanban (Pull System): is a Japanese word that roughly translates to "billboard or signboard." It is an information control method that manages resource movement or flow so that components and supplies may be purchased and supplied as needed.

- Kaizen: This is Japanese business philosophy for continuous improvement. This is an approach that seeks to improve quality and efficiency through the elimination of waste from the value stream.

- The Last Planner: The last planner is a person or group of people with the task to control the production unit. They are responsible for necessitating control of workflow, verify supply stream, design, and installation in all the production units.

- Heijunka (Level Scheduling): This is a method of equally distributing product for client orders by analyzing mean demand and integrating it into a production plan that takes volume and mix into account.

- Poka-Yoke (Error Proofing): This is a mechanism design to detect and prevent errors in processes with the aim of achieving zero defects.

- First Run Studies: Experimenting with a process with the objective of determining the optimal methods, tactics, and sequencing, among other things, of carrying it out. First run studies are completed a few weeks ahead of the process's scheduled execution to allow for the acquisition of various or additional requirements and resources. This is a term used in the construction industry to describe the process of restructuring essential tasks. This is part of a continual improvement effort that includes efficiency studies and work practices evaluation, as well as redesigning and simplifying the many activities. The approaches entail demonstrating the process through pictures, video files, or graphics.

- Time and Motion Study: A method of assessing industrial or other operational efficiency based on the amount of time it takes to complete an activity or produce a product.

- Bottleneck Analysis This is the identification of the part of the process that put a limitation on the overall productivity in order to improve the performance of that part.

- Total Productive Maintenance (TPM): This is a holistic maintenance approach for equipment in order to maximize the operational time of the equipment.

- Visual Management: This is an information communication approach that uses visual signals to enhance process efficiency and clarity.

- Synchronize/Line Balancing To reduce excess capacity and bottlenecks, this entails leveling workload across all operations in a value stream.

- Work Structuring: This is used for the development of process design and operation in alignment with the supply chain structure, allocation of resources, product design, and assembly design efforts with the objective of making work process more reliable and quicker while delivering quality to the client.

- Multi-Process Handling: This involves assigning operators tasks in multiple processes in an oriented layout of a product flow.

- 5 Whys: This is a quality management tool for problem-solving and it tries to find the root cause of an issue. It stipulates that worker should be asking why five times repeatedly until they identify the underlying root, or the nature of the issue and its solution becomes clear. The procedure tries to fix a system by eliminating the root cause to avoid its recurrence.

- Fail Safe for Quality: This relies on the generation of ideas which alert for potential defects. This is almost the same as Poka-Yoke techniques, but it can be extended to safety. However, the concentration in safety is on potential hazards rather than potential defects, and it is identified with the risk assessment technique. It requires action plan that avoids bad outcomes.

- Daily Huddle Meetings: This is a technique for communicating and interacting with the project team on a regular basis in order to ensure worker participation. Job satisfaction (sense of growth, self-esteem,) will rise as a result of project awareness and problem-solving contributions, as well as some training provided by various instruments.

- Preventive Maintenance: This is regular maintenance performed on equipment to reduce the probability of its failure. It is usually performed while the equipment is working to avoid unexpected breakdown.

- Quality Function Development (QFD): This refers the use of customer's voice and different organization functions and units for final engineering specification of a product.

- SMART Goals: Goals that are Specific, Measurable, Attainable, Relevant, and Time-Specific.

- PDCA (Plan, Do, Check, Act): This is an iterative approach for improvements implementation. It involves; Plan (set up a plan and expect results); Do (execute the plan); Check (verify anticipated result achieved); and Act (evaluate; do it again).

- Setup Reduction: This is a changeover technique use to speedily change tools and fixtures in order for multiple products to be run on the same machine.

- Work Standardization Manufacturing: documented procedures that capture best practices. This "living" documentation that is easy to change.

- Statistical Process Control: This is a quality control tool that monitors and control process in order to ensure that system output variables operate to its full potential through periodic measurement.

- Suggestion schemes: This is a formal structure that permits and encourages employees to actively offer innovative ideas for product and process ideas.

- Just-in-Time (JIT): This is a technique that focuses on reducing production flow times as well as response times from suppliers and end customers. JIT is, in any case, a way of thinking, working, and managing processes to remove waste.

- Team Preparation: This is a method of conducting training on waste, continuous flow, and work standardization training for the lean team or personnel.

- Muda Walk: Muda is a Japanese word that translates to "waste." Muda walk is a waste-detection approach that involves observing operations, how work procedures are carried out, and marking areas where adjustments are needed.

- Value Stream Mapping: A method for visually examining, documenting, and improving the flow of a process while highlighting opportunities for improvement.

- Root Cause Analysis: This method of problem-solving focuses on finding and addressing the root cause of an issue rather than relying on quick solutions that only address the symptoms.

The list of sub-principles is organized into nine main principles (customer focus, supply, continuous improvement, waste elimination, people involvement, planning and scheduling, quality, standardization, transparency), and the tools and techniques for achieving each sub-principle are shown in the figure below, it could be helpful to choose the best techniques based on the needs and scope of the project.

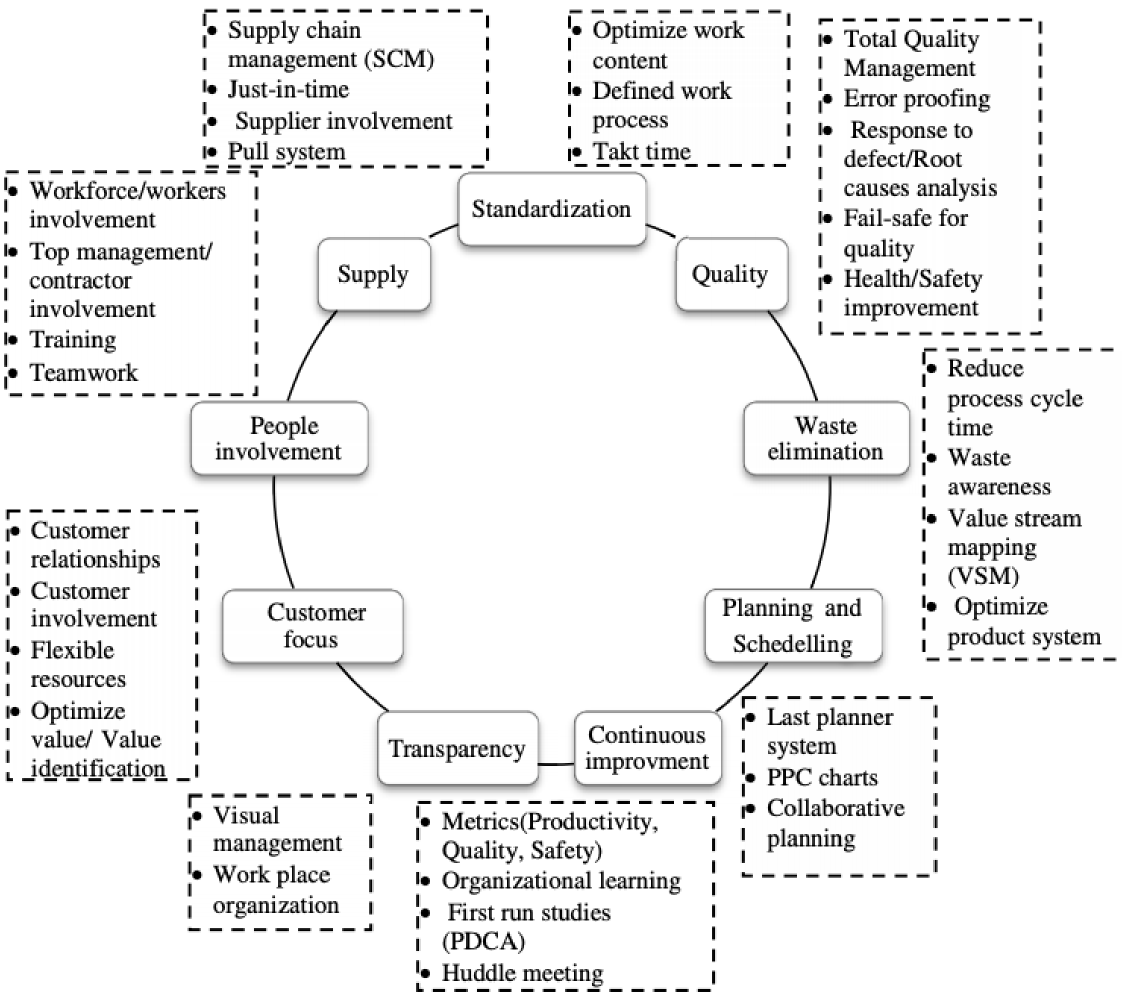


Figure 9 Conceptual model of lean construction (Bajjou, 2018)

Lean vs Risk management system

Although risk management and lean implementation are being used broadly there are a limited number of research publications linking “Lean” to “Risk”. However, from reviewing the literature of each concept it can be understood that Principles of Lean can be recast alongside those of risk management as in Figure 9. The fit between principles is clearly illustrated. The focus on "value" is shared by both Lean and risk management. The risk approach protects value, and Lean supports by focusing on delivering value to customers. The principles suggest both Lean and risk should be built as an integral part of the organisational processes and support decision making.

The major difference in this chart is the function of risk management is to explicitly address uncertainty, whereas lean explicitly addresses wasted effort through the optimisation of flow. This however is not contradictory but merely the different strategic objective of the system. Both are considered systematic and structured. Risk management is based upon the best available information and Lean improvements similarly with the review of current conditions, gathering of available data where necessary and up to date review of value in eyes of the customer. Both implementations are tailored to the organisation, take into account human and cultural factors and aim to be inclusive of the entire system (not compartmentalized or locally focused) and include all stakeholders in the processes. Both are dynamic and adaptable to change, facilitating for the organization's continuous improvement.
Both are considered systematic and structured. Risk management is based on the best available data, and Lean improvements are based on a review of existing conditions, gathering of available data as needed, and a current review of value in the eyes of the customer. Both implementations are tailored to the organisation, take into account human and cultural factors and aim to be inclusive of the entire system (not compartmentalized or locally focused) and include all stakeholders in the processes.

Risk Management Principles	Lean summary of principles
1. Creates and protects value	1. Focuses on creating customer value.
2. Is an integral part of all organisational processes,	2. Integral part of organisations processes and procedures
3. Is part of decision making,	3. Lean thinking and techniques support decision making.
4. Explicitly addresses uncertainty,	4. Addresses waste through optimisation of flow
5. Is systematic, structured and timely,	5. Has structured yet dynamic processes and methods
6. Is based on the best available information,	6. Improvements based on review of current conditions and value in eyes of customer.
7. Is tailored,	7. Implementation tailored to the organisation based on key Lean principles.
8. Takes human and cultural factors into account,	8. Involves respect for humans and an enabling culture.
9. Is transparent and inclusive,	9. Inclusive of entire system (not compartmentalised or focused on local efficiencies)
10. Is dynamic, iterative and responsive to change, and	10. Enables dynamic learning organisations of emergent change.
11. Facilitates continual improvement of organization.	

Figure 10 Principles of Risk Management besides recast principles of Lean thinking

Lean management concepts are also easily laid over the risk management strategic process (framework). In Figure 10 we have the risk management strategic process and alongside it the equivalent Lean strategic process. The Lean concepts are synonymous to those of the risk management strategic process. The Planning of the framework is synonymous with management commitment, strategy, leadership, and alignment within the organization.

The cycle itself of identify, Analyze, response, monitor continually control is a simple PDSA. This cycle came out of the quality and continuous improvement field (Deming, 1986) which are consolidated in Lean thinking. As mentioned, the five key principles of Lean (Womack & Jones, 1996) can be shown to relate to the continuous improvement cycle although possessing specific meaning to Lean thinking i.e. defining value and planning for the flow of value with as little waste as possible and the goal of perfection in view.

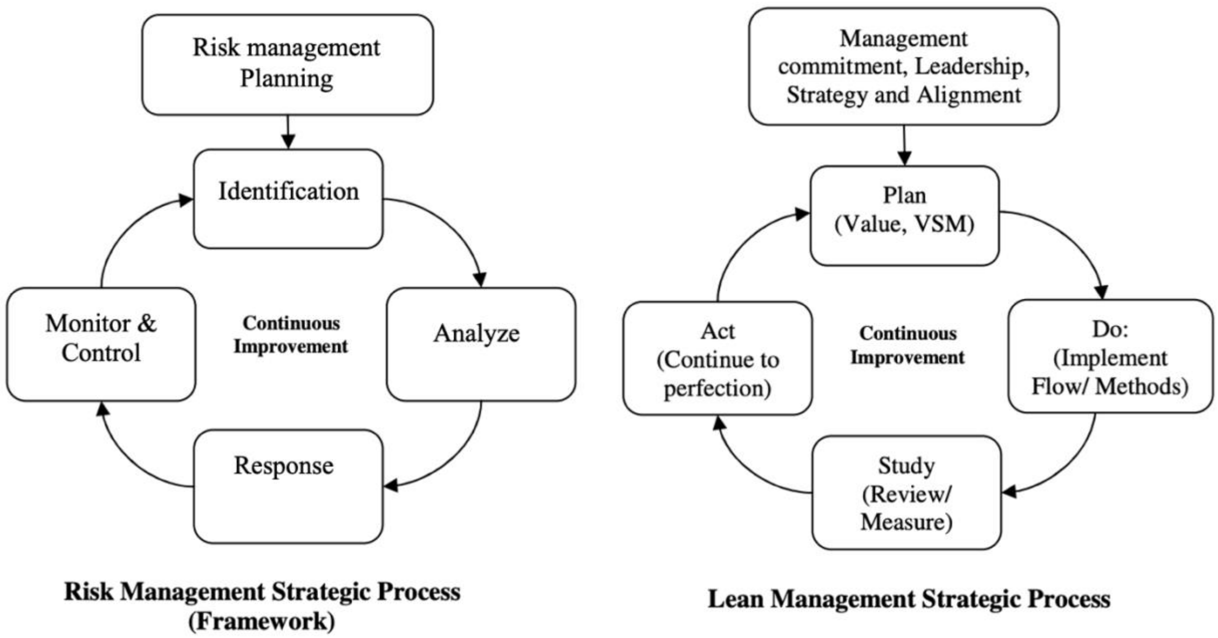


Figure 11 Risk management framework compared with Lean management.

4. Methodology

This chapter discusses how Risk Management conducted within the Lean methodology and how Lean tools and techniques can be combined with Risk Assessment to improve efficiency and success of our projects. Lean and Risk Management can easily be combined to achieve good control and monitoring, by implementing risk reducing actions.

Research Design

The aim is to help real estate development project's managers and decision makers understand and effectively mitigate the projects risks by developing and implementing strategies, before they turn damaging to the project in case of time, quality, or cost. This paper done as a case study deals with risk identification, measurement, assessment, mitigation, and control of risks present in real estate project. We also applied tools and principles of lean system in different steps of risk management process. Risk factors are then prevented from occurring which would stop the occurrence of many risk events.

The aim is to assist managers and decision makers in real estate development projects in understanding and effectively mitigating project risks by designing and executing strategies before they become detrimental to the project in terms of time, quality, or cost. This paper done as a case study deals with risk identification, measurement, assessment, mitigation, and control of risks present in real estate project. We also applied tools and principles of lean system in different steps of risk management process.

The methodology of this research divided into five steps:

1. The first part main object is to find the risks that may happen during the process of the real estate projects. For this reason, mixed of tools is used; studying the previous projects and reports were the first step to have an overview about the potential risks of these kind of projects, then with lean problem-solving tools such as ishikawa diagram the roots of the delays in real estate projects were identified the risk breakdown structure was drawn.

2. The next step for assessing the qualitative analysis of our identified risks probability impact assessment was applied to prioritizing risks according to their probability and impact. Then pareto diagram that is one of the lean tools were applied to risk rankings, it helps to separate the key risk factors from the less significant ones. It also helps to identify the main causes and risks that caused delay in our projects. Clear graphical presentation of the diagram is very useful tool to prioritize corrective actions.

3. In the third step Quantitative risk analysis is applied. It is a numerical evaluation of the overall impact of risk on project objectives like cost and schedule objectives. The results of analysis help to provide understanding of the project success likelihood and is also used to estimate contingency reserves. Quantitative risk analysis is used to determine the "effect of risks that are identified in previous step on project objectives overall". It measures the amount of cost and schedule contingencies and quantifies risk exposure. Due to this Monte Carlo simulation should run. For this case RiskyProject software is used. And the effects of risks on different scope and also correlation with the project tasks were defined.

   Monte Carlo simulation generates various impressive results in RiskyProject, such as sensitivity analysis, risk matrix and project report that aware us from the impact of risks on our project scope which was the main reason for running the simulation.

4. By the reports and data that we got from risky project we can recognize the most significant risks that are critical for our project. And we need to provide an action plan to mitigate these risks in our process. For this case we have used 5why technique that is one the most practical lean tools.
   The main goal of the technique is to recognize the root cause of a defect or problem by repeating asking "why"? Each response forms the source of the next question. The number 5 in the name comes from an anecdotal observation about how many iterations are required to resolve the problem. And by coming up with a solution for the root cause we can define how to overcome and control the root cause so we can provide a proper action plan to our most critical risks.

5. Finally, each risk factors identified could be directly linked to few lean principles which could help prevent the occurrence of it. It was evident that the risks create several wastes which can be categorized into the familiar lean wastes. Lean tools implementation is recommended since it would facilitate the mitigation plans to be more effective and bring a Kaizen (continuous improvement) approach into the system. So, we identified the wastes that each of our critical risks are creating and then suggest the best lean tools for controlling each of them during the enforcement phases.

The overview of research methodologies follows the flow path:

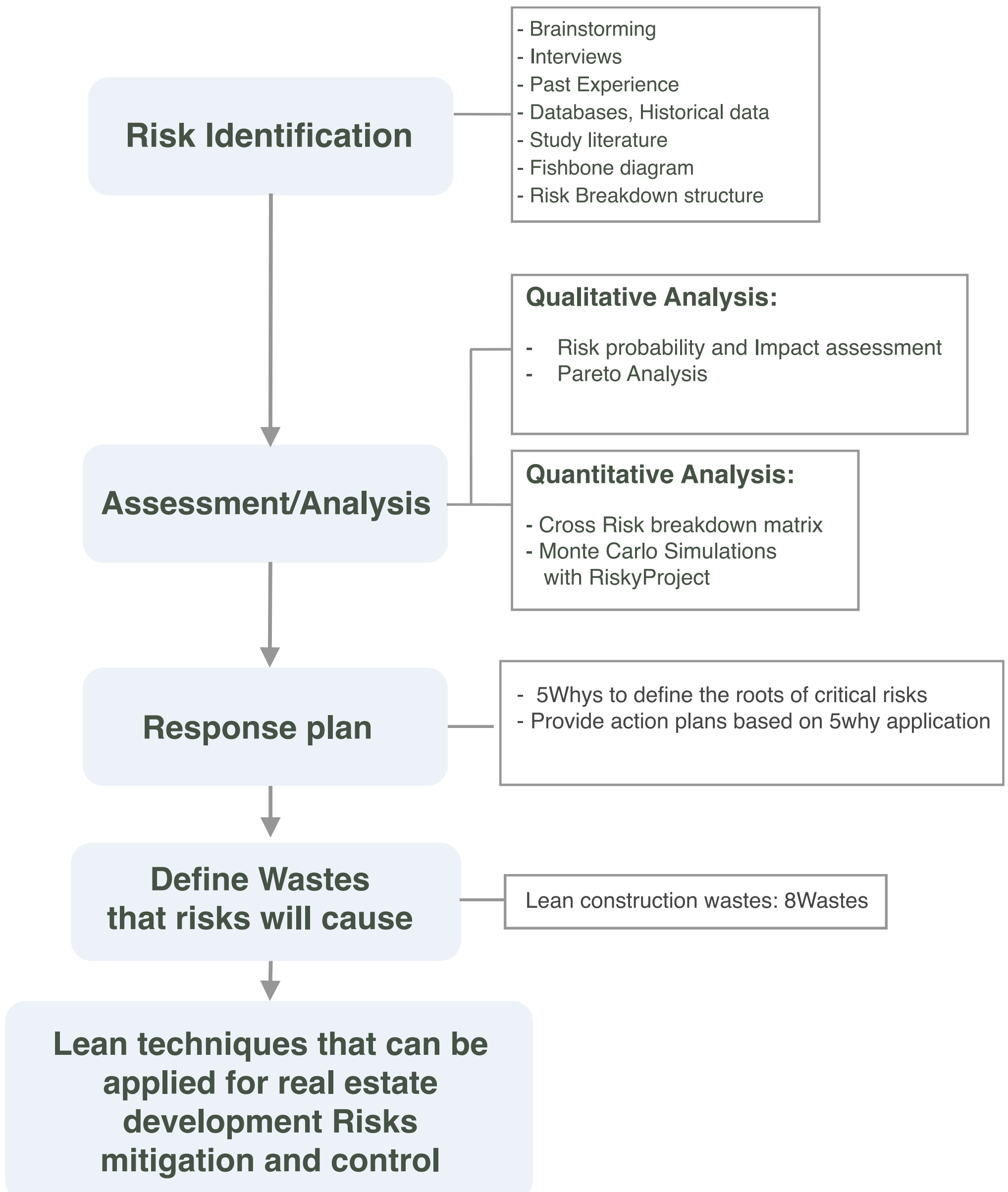


Figure 12 Methodology Flowchart

The case study was chosen as a research design in order to comprehend and assess the application of provided methodology in a project organization. A case study is a type of research design (Bryman and Bell, 2003) that is not intended to be a comprehensive examination of an organization. Its objective is to concentrate on a particular issue, feature, or unit of analysis (Noor, 2008), and it includes direct observation of that issue, feature, or unit of analysis. (Yin, 2009)

Therefore, a brief description of the case is explained and then lists all steps taken to achieve the result:

Case study

To determine how RM and lean theories are used in practice, a real estate project of residential complex was used as a case study.

Planet Smart City company designs and builds cities and neighborhoods that place people at the heart of every project. Their multi-disciplinary teams integrate architectural, digital, environmental, and social innovation solutions to deliver high-quality low-cost homes, creating lasting value. Planet tackles the global housing crisis in countries with large housing deficits and also works in partnership with developers worldwide to revitalize existing communities through smart technologies. The company has an active portfolio in Italy where it develops smart projects with key developers. Headquartered in London, Planet recently raised more than 44 million euros and is executing an ambitious growth plan which includes the launch of 8 large-scale residential projects in the next 18 months.

One of their projects that is studied as a case in this research is Natal phase 2.
It is designed to host 16,000 residents, Smart City Natal is under construction in São Gonçalo do Amarante in Rio Grande do Norte, Northeast Brazil, eight kilometers from Governador Aluízio Alves International Airport and 20 kilometers from the capital, Natal.
There will be 700 houses within the smart city, as well as residential land plots and commercial units ranging from 200 to 755 square meters in size.

The project is divided into two phase and the second phase that is our case study will be started the following year 2021.
This phase is located in 45 hectares that includes 890 lots and the plan is to construct about 150 affordable houses there. Overall duration 3 years; 2 years for infrastructures and one for houses construction and finishing.
Planet smart city acts as the owner with the capital share of its joint venture. The company is also in charge for most parts of design, also construction phases and the whole project management area.

The joint ventures are just involving in the project as investors and main parts of the construction is outsourced. The contract with the general contractor is fixed price which means they will take the risk.
Smart Planet wanted to find a way to predict upcoming activities' delays and provide recommendations to the stakeholders and general contractor to monitor the project performance better and ensure the project will be delivered on time. For this reason, Risk Management and its integration with Lean was suggested and was applied to the project. In the following each of the steps for conducting this purpose is explained:

Risk Management Plan

To prepare the risk management plan, meetings and interviews have been held with experts and key stakeholders. Data was also collected from the contract to define the following:

1- Project description: There is a full description of the project where main stakeholders are introduced, and the main objective of the project is defined.

2- Contract type and the main objectives of Planet Smart in this project: from data collected, it is a fixed price contract with contractor some parts of construction, design and management is not outsourced.

3- Objectives, the scope of the risk management:

It is not possible to identify the risks without defining the scope of project, since the risk is the uncertain event that its occurrence will affect our objectives either positively or negatively, so this is a crucial step in the risk management plan.
In our case, the objective of risk analysis is time, so any event that may delay the project tasks may be considered risk and all risks would be considered upon that objective.

Scope: The scope of risk analysis is the scope of the project, where stakeholders are the client, general contractor, Smart Planet, and join ventures.

4- Setting tools and techniques:

Tools used in each step in the process: starting from risk identification to qualitative risk assessment to risk response plan, all tools and techniques that would be used are briefly defined as follows:

- For Risk identification: checklists, interviews, and brainstorming would be used as tools.

- For risk assessment, qualitative and semi-quantitative would be applied as the result of semi-quantitative would be an input for the risk breakdown structure matrix and the pareto diagram.
- For quantitative analysis, Monte Carlo simulation would be applied using RiskyProject professional software, which would result in the sensitivity analysis.
- For response plan: five why technique would be used in this step.
- For risk control: lean integration would be applied for critical risks.

5- Setting the project-specific definitions of probability and impact (risk matrix):

As thresholds are defined, this is an important stage. Meetings with various stakeholders were held to better understand the owner's tolerance. For example, according to the owner, the impact of being delayed for more than 8 weeks is very significant, while the possibility of being delayed for more than 8 weeks is also quite high on the other side 70% to 99% for probability range is considered as very high as well, both probabilities and impact on time were given rank which ranges as VERY LOW (VLO), LOW (LO), MEDIUM (MED), HIGH(HI), VERY HIGH(VH), which would be used in qualitative risk assessment later. Again, probability and impact have been given an index from 1 to 5 to be used later semi-quantitative risk assessment. The definition of probability and impact varies from one project to another, but for this for example any impact or probability is ranked as HIGH it means it has an index of 4 and vice versa. The below table describes only the two components of risk which are impact and probability separately. To have a risk matrix the two components must be multiplied. As Risk=probability x impact.

probability and impace matrix

RANK	PROBABILITY	INDEX	impact on time
VHI	70-99%	5	>8 weeks
HI	50-70%	4	6-8 weeks
MED	30-50%	3	4-6 weeks
LO	10-30%	2	2-4 weels
VLO	0-10%	1	<2 weeks

Figure 13 Probability and Impact matrix

6- Setting the risk breakdown structure:

Setting the risk breakdown structure (RBS) has been driven from the work breakdown structure (WBS). The same concept that was used for WBS structure was applied to risk sources to get the RBS. It would be useful later as a prompt list for identifying risks and determining which project tasks are related with the most significant risk. A general RBS example is shown below:

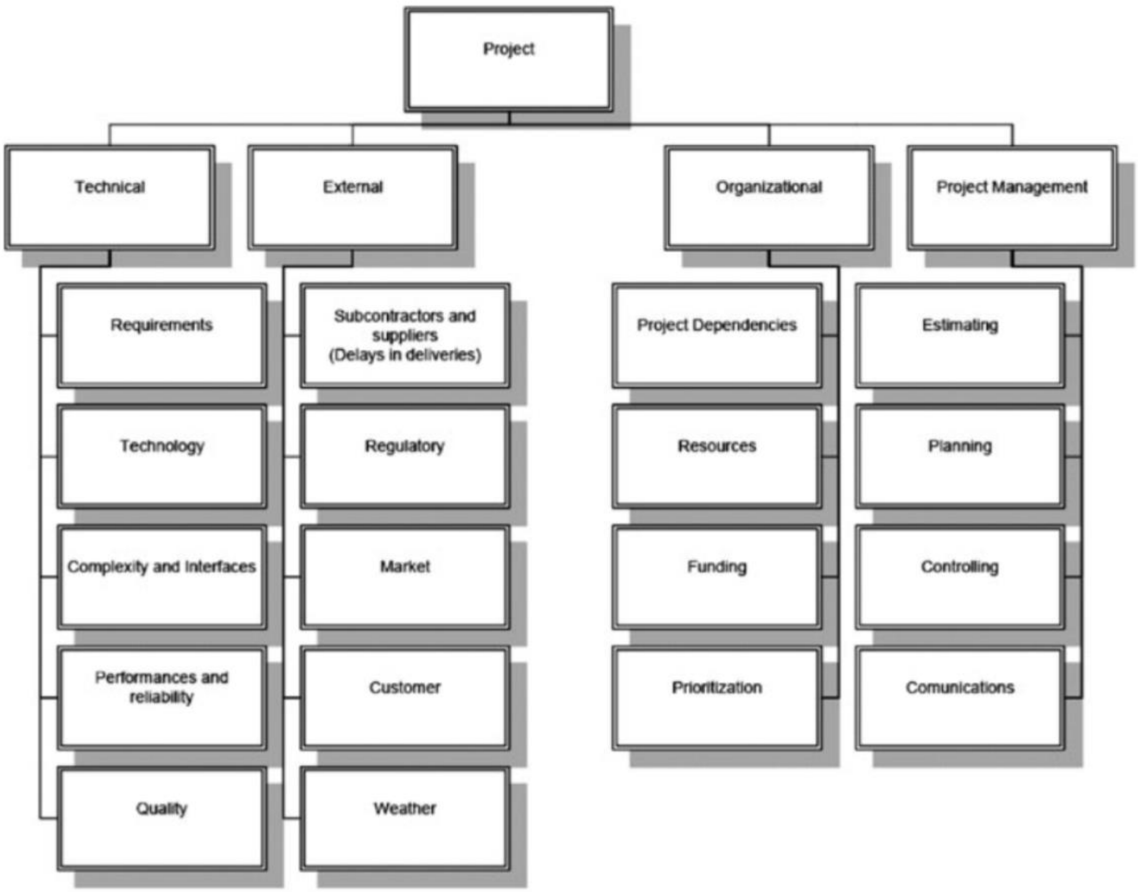


Figure 14 Example of Risk Breakdown Structure for a construction project. (Adopted from De Marco 2011)

All of the major aspects of the risk management process had been pre-defined by the end of the risk management plan, and it is possible to move on to the next stage, which is risk identification.

Risk Identification

Risk identification is the most crucial step in the process because it is impossible to manage risks without first identifying them. The outcome of this phase would determine the entire process. There were almost 500 tasks in the case study. Identifying risks for each of them seems unrealistic. As a result, a higher level of WBS was considered, and the number of tasks was reduced to 103 summary tasks, and risks identified, utilizing the fact that the construction project's tasks are repeated. A variety of techniques have been employed, including:

- Studying literature and risks that happened in the similar projects and articles

- Studying previous project reports of the company and the main risks that they have faced before.

- Interview with stakeholders and project management team: Interviews have been held with project key participants and experts to have a general idea of risk sources and extract as many possible risks. Relatively it was about taking into consideration the current situation and identify problems which might be sources for upcoming unlikely events.

- Structured Brainstorming session: Many experts confuse risks and uncertainties, as well as their sources and effects, because they perceive them all to be risks, which is not true and makes a significant difference; as a result, before beginning a brainstorming session, a presentation was given to properly explain these concepts. Brainstorming assisted in identifying the most unpredictable risks as well as their sources. Relatively it was about generating future and unpredictable risks.

- Checklists: Because Smart Planet had never used risk management in a structured manner before, there was no risk register to be used as a checklist, so generic checklists with all possible risks in the construction project industry were used to see all of the common risks that could arise regardless of the project type. Relatively, it was all about learning from the past.

- Ishikawa diagram: A root cause diagram, often known as a "fishbone" diagram, can assist in brainstorming main categories of problem causes and organizing ideas into meaningful categories. Draw four or more branches from the large arrow to show primary groups of likely causes.

Risk Assessment

Risk identification has produced a list of risks, but not all risks are the same or should not receive the same attention due to limited time and resources. Since risk=probability(P) x impact(I).

Each risk assigned to each activity has been assessed by evaluating their probability and impact. I: very high, high, medium, low, very low

Probability and Impact values:

P: very high, high, medium, low, very low

I: very high, high, medium, low, very low

Several meetings were organized to develop these evaluations, and many experts were involved in this step.

- **Risk probability and impact assessment:**

  By application of risk probability and impact assessment method, the likelihood of each specific risk to occur is evaluated. For the purpose of this assessment, probability and impact should be defined and customized to our project. This means that specific scale definitions should be put out, and the scope of the project should be determined by the project's nature, criteria, and objectives. (Cooper et al. 2005). PMI (2017) identifies exemplary range of probability from 'very unlikely' to 'almost certain', however, corresponding numerical assessment is admissible. The impact scale ranges from 'very low' to 'very high'. Moreover, assessing impact of project factors like time, cost or quality requires further definitions of each degree in scale to be drawn up. Each risk identified during the identification phase is evaluated in terms of its likelihood and impact. (PMI, 2017).

  The level of probability for each risk and its impact on each objective is evaluated during an interview or meeting. The risk probability and impacts are estimated according to the risk management plan's definitions. As a result, risk ranking will be determined by multiplying our likelihood and impact after completing this assessment.

Pareto analysis: In risk assessment, a complementary tool that does the risk prioritization could be pareto chart. Low impact risks are kept on the watch list and high priority risks are managed on a priority basis. In the same way, prioritizing root causes for 20% of the risks produces an 80% impact.

A Pareto chart describes the frequency with which certain event occurs. It's a bar graph in which each frequency (or frequency range) is displayed from left to right in descending order of data relevance. Using a Pareto chart allows us to concentrate or focus on the most important aspects. A Pareto chart should answer the following questions,
- What are the largest issues, our team is facing?
- What 20% of the sources are causing 80% of the problems?
- Where should we focus our efforts to achieve the greatest improvements?

- **Cross risk breakdown matrix:**

In this step, WBS and RBS are linked into one matrix, risks identified are imported in this matrix, and their semi-quantitative assessment, where every risk at a given cell has a score, and each work package (WP) has a score as well. Figure below explains:

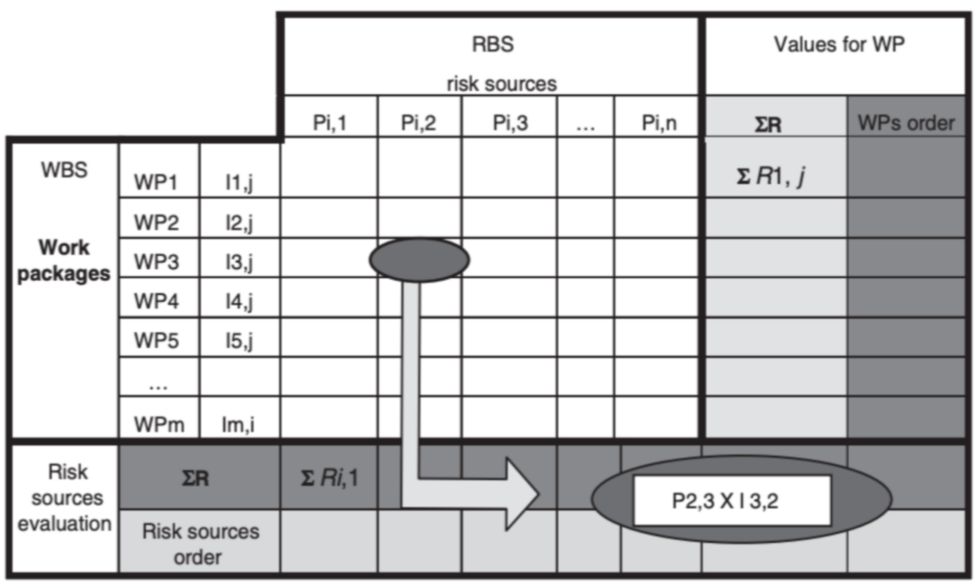


Figure 15 Risk Breakdown Matrix (RBM) with sample evaluation, (Hillson, 2005)

Considering risks for every WP, an evaluation of the criticality of each WP can be obtained by:

$$R_{WP,\ i} = \sum_{j=1}^{n} P_{i,j} * M_{i,j}$$

Where M= impact, P= probability, Rwp= risk of work package.

A similar approach can be used to analyze risk resources by considering each column separately by:

Where Risk= is the total effect of a single resource on the whole project.

- **Monte Carlo simulation:**

A few setups were required prior to running the Monte Carlo simulation. To begin, the updated Gantt chart was imported into RiskyProject, and the Risk Matrix, probability, and impact thresholds were set based on the project's requirements. Then, in the risk register, risks were created, and tasks were assigned to them.
Because there was no assumption in three points of duration values due to the lack of historical data, the task durations were kept constant. RiskyProject runs Monte Carlo simulation and generates quantitative data without the need to assume the three points of the duration because it only depends on risk data entered. So, the result of the Monte Carlo simulation obtained would depend only on risk evaluation. This feature is considered essential in the case of this project since the historical database lacked.

Monte Carlo simulation was run with 10,000 iterations, and sensitivity analysis, project dashboard and risk matrix were obtained. Figure below describes the flow the process:

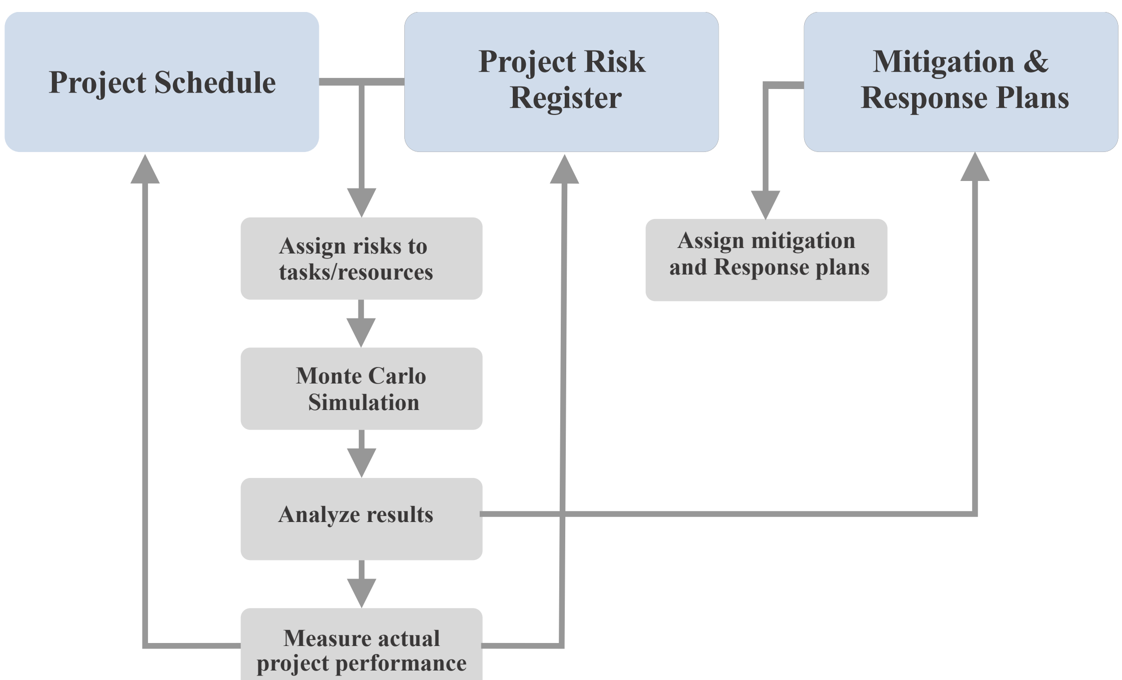


Figure 16 RiskyProject proccess flowchart

To set up RiskyProject the following steps has been followed:

- **Importing project schedule:**

  Updated Gantt chart created in Microsoft Project was imported to RiskyProject.

- **Set risk matrix:**

  in this step, all thresholds of probabilities and impacts and their relevant percentages have been customized according to the risk management plan mentioned earlier.

  As from figure in risk management plan probabilities and impact and their percentages are configured.

- **Import risks to risk register:**

  The risk register includes all identified risks that are obtained from the risk identification step. Risks were imported manually and had been created in the risk register**.**

- **Assess risks in RiskyProject:**

  Risk is assessed in a risky project by assigning them to tasks with a probability of occurrence and an impact of the given objective. Assigning risks to tasks can be done simply by dragging risks and drop them on selected tasks.

  RiskyProject is ready to run Monte Carlo simulation After setting up the risk matrix, creating and assigning risks to tasks with their probability and impact.

- **Run Monte Carlo simulation:**

  The Monte Carlo simulation is usually based on three-point estimation. The RiskyProject, on the other hand, allows us to conduct Monte Carlo simulation and provide quantitative results based only on the analysis of identified risks and the assessment of probabilities and impacts, which was the primary reason for selecting RiskyProject as simulation software. The Monte Carlo simulation's number of iterations was determined.

Response & Action plan

After running Monte Carlo simulation, the most significant risks were identified and their impact on project task duration and cost is also reported, now we need to provide response plan for these risks.

The risk response plan was implemented towards most significant risks.

The suggested method for reaching most sufficient response is 5why technique that it is implied on our most significant risks. **5-Why technique** is one of the many brainstorming methodologies of asking “why” five times repeatedly to help in identifying the root cause of a problem. When a problem is repeatedly questioned, a new solution emerges each time, which is linked to the root cause. However, the why question can be pursued until a satisfactory explanation is found.

Results Analysis and Lean Integration

In this step, lean integrated as a technique for managing enterprise-wide risks and improving project success rates is recommended. An integrated Lean - Risk management process is suggested. Our study identified the top risk factors in the real estate development project. We recommend implementing lean tools in this step because we believe it will help the mitigation plans be more effective and will introduce a Kaizen (continuous improvement) approach to the system. Each risk factor found might be related to a few lean principles that could assist prevent it from happening in the first place. It is clear that risk factors and events produce a variety of wastes that can be classified into the familiar lean wastes, and we can recommend the appropriate lean tool to control each type of waste.

5. Analysis & Results

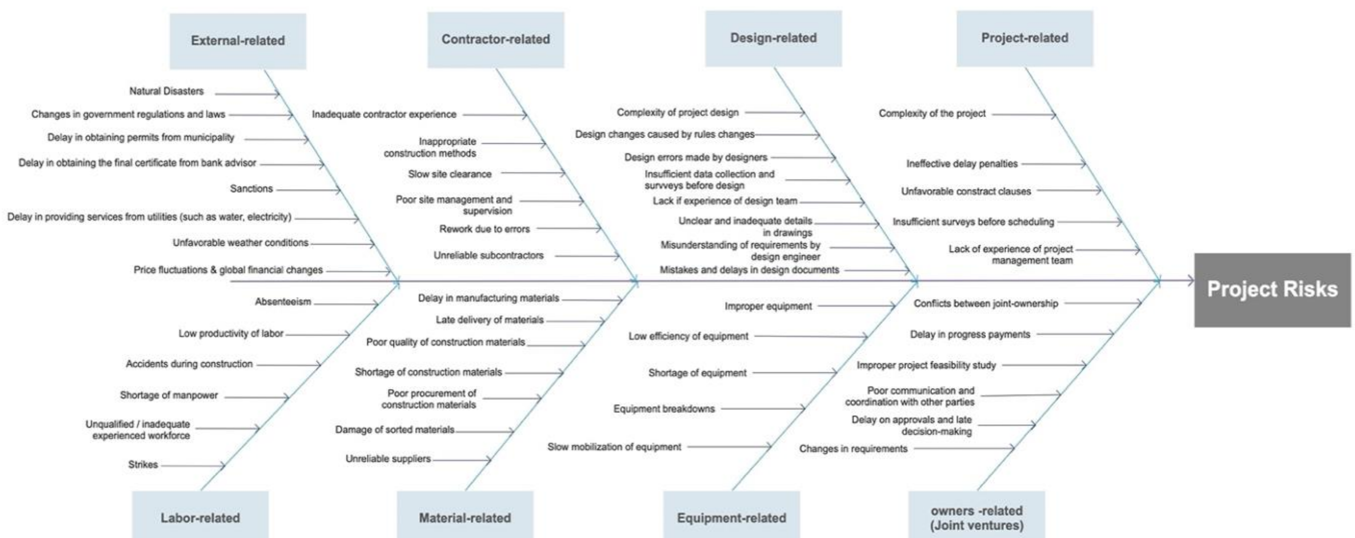
The previous chapter covered the analysis methods and the steps followed. This chapter presents, discusses, and summarizes the results of the research.

Risk identification results

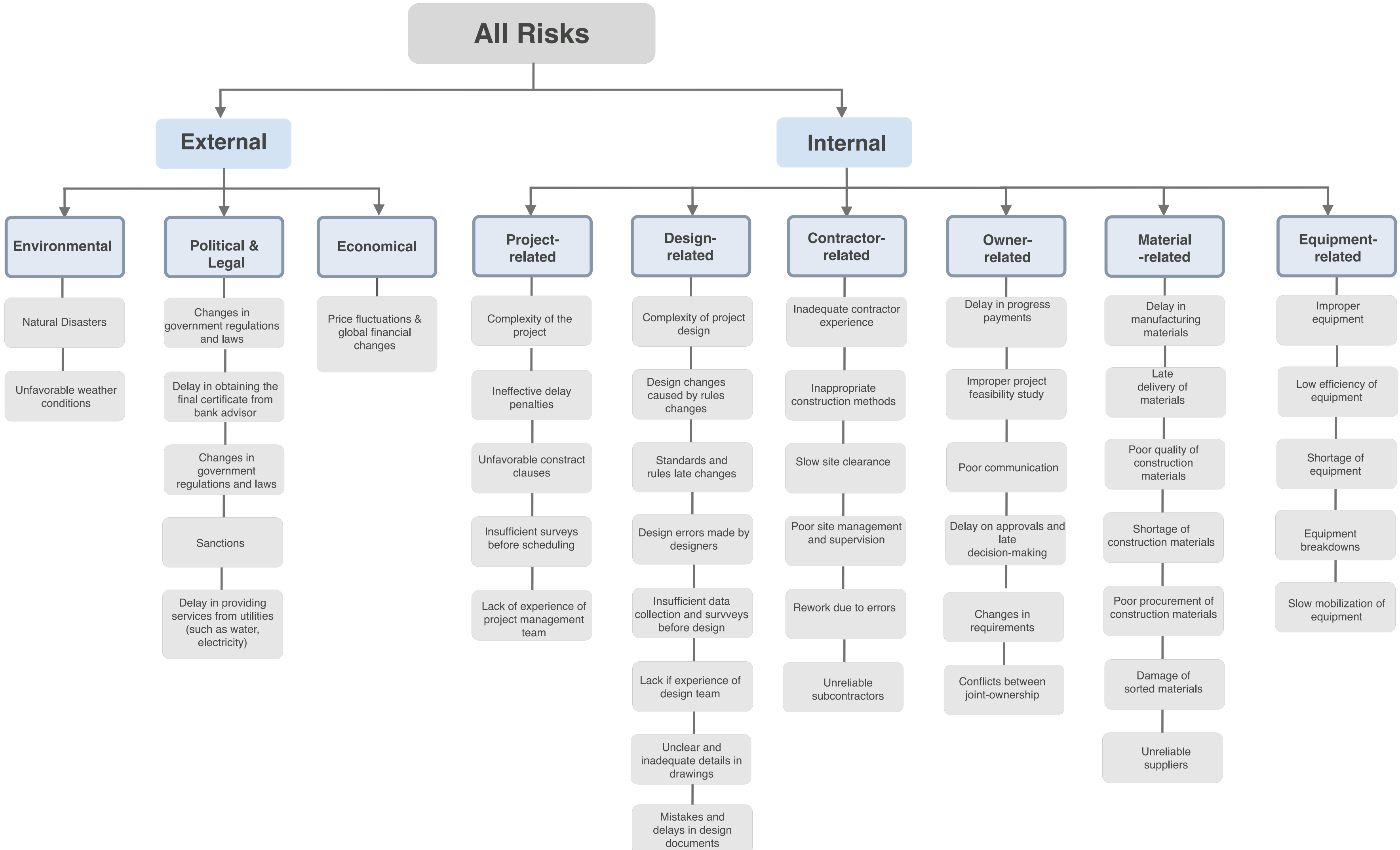
The first specific objective of this research is to identify the risk factors included in case study project of residential real estate developers. With the help of fishbone diagram eight main roots defined for causes of our risks in this sector and then 46 sub risks were identified in total. The identified risk factors are included here below. The identified risk factors are categorized into three categories namely, project-related, contractor-related, design-related, material-related, equipment-related, labor-related and owner-related.

The fishbone diagram and the RBS is shown below;

- **Risk's fishbone diagram:**



- **Risk breakdown structure:**

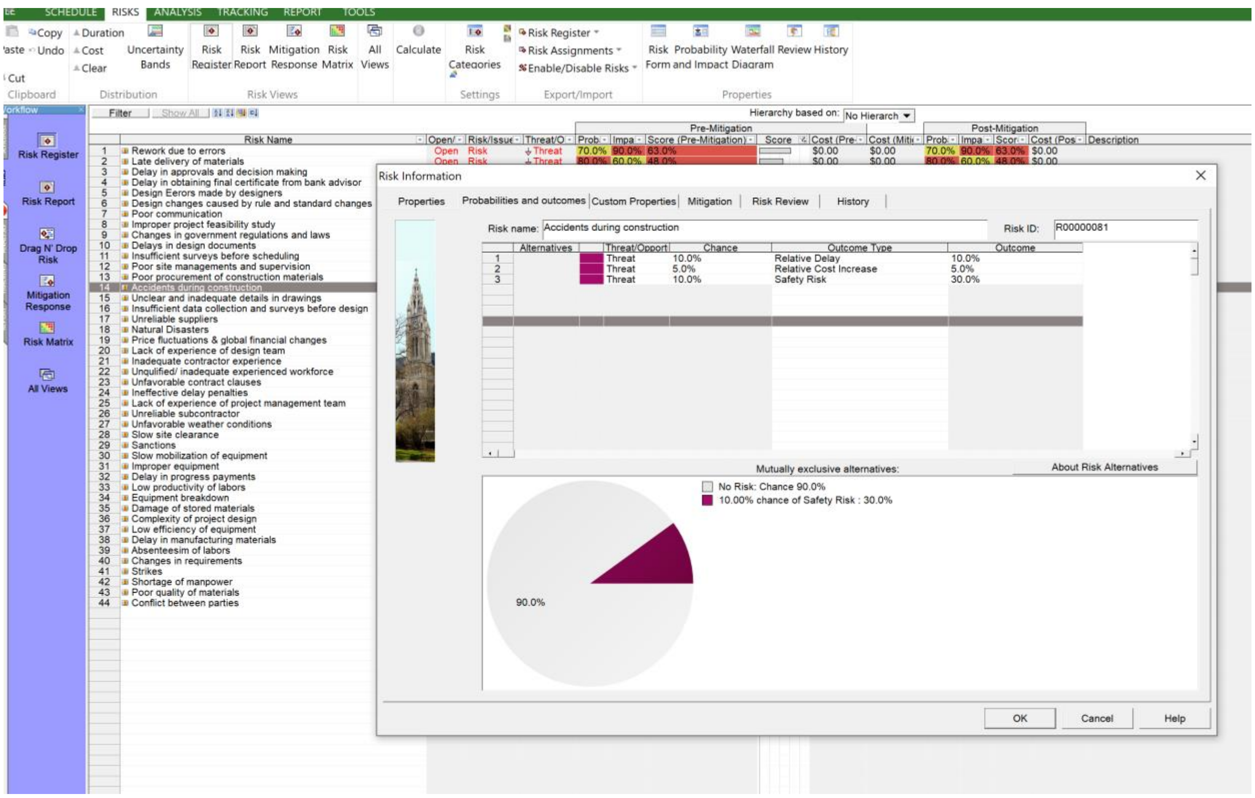


Risk Analysis results

Since we first want to do quality analysis with software, WBS of the project is not needed in this stage. We need to identify the risks and their importance and the likelihood of them. For this reason, we should use the Risks Tab after opening the software and doing steps of creating a new project and saving its name like other office software. We will go inter all of the names of the risk according to our list from the Qualitative table based on the steps of registration of risks in RiskyProject that we explained it before and with using of its tools.

Qualitative Analysis

After registration of all risks, we will continue to add the attributes of each risk, such as their all types of chances and outcomes. For example, for the risk, "Accidents during construction," we have around three different outcomes, and we should add them one by one. We will do it for all the risks.



After finishing entering data of all risks, the software will start to analysis the conditions with click on the calculation Button. You can see the result of the qualitative analysis in the next picture.

In the software calculations, the terms are quite different. To begin, we conducted a qualitative analysis of the project without reference to the tasks. As previously stated, qualitative analysis is most suited for small and uncomplicated projects, and because we are reviewing a massive project, we will not be able to get perfect results in this phase of the analysis. The colors in the next figure can be used to convey the importance and accumulating of risks.

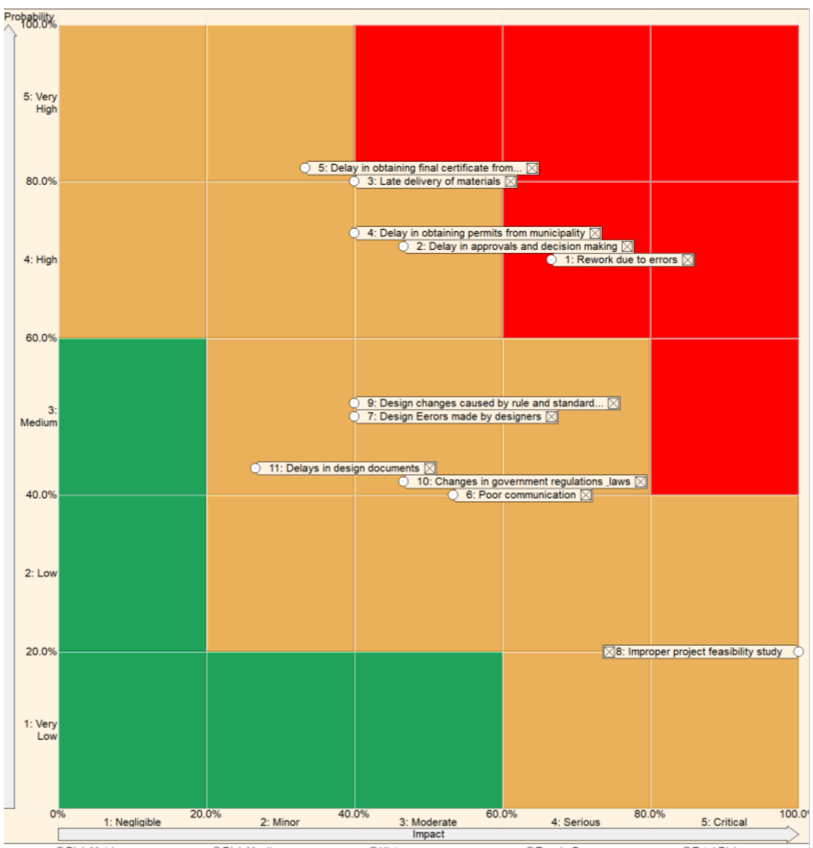
	Risk Name	Open/	Risk/Issue	Threat/O	Risk Assigned To	Prob.	Impa	Scor	Score
1	Absenteesim of labors	Open	Risk	Threat	All tasks (global)	5.0%	6.7%	0.3%	
2	Accidents during construction	Open	Risk	Threat	All tasks (global)	10.0%	30.0%	3.0%	
3	Changes in government regulations & laws	Open	Risk	Threat	All tasks (global)	40.0%	46.7%	18.7%	
4	Changes in requirements	Open	Risk	Threat	All tasks (global)	20.0%	20.0%	4.0%	
5	Complexity of project design	Open	Risk	Threat	All tasks (global)	5.0%	6.7%	0.3%	
6	Conflict between parties	Open	Risk	Threat	All tasks (global)	10.0%	10.0%	1.0%	
7	Damage of stored materials	Open	Risk	Threat	All tasks (global)	5.0%	6.7%	0.3%	
8	Delay in approvals and decision making	Open	Risk	Threat	All tasks (global)	70.0%	46.7%	32.7%	
9	Delay in manufacturing materials	Open	Risk	Threat	All tasks (global)	5.0%	10.0%	0.5%	
10	Delay in obtaining final certificate from bank a	Open	Risk	Threat	All tasks (global)	80.0%	33.3%	26.7%	
11	Delay in obtaining permits from municipality	Open	Risk	Threat	All tasks (global)	70.0%	40.0%	28.0%	
12	Delay in progress payments	Open	Risk	Threat	All tasks (global)	5.0%	26.7%	1.3%	
13	Delays in design documents	Open	Risk	Threat	All tasks (global)	40.0%	26.7%	10.7%	
14	Design changes caused by rule and standarc	Open	Risk	Threat	All tasks (global)	50.0%	40.0%	20.0%	
15	Design Eerors made by designers	Open	Risk	Threat	All tasks (global)	50.0%	40.0%	20.0%	
16	Equipment breakdown	Open	Risk	Threat	All tasks (global)	5.0%	6.7%	0.3%	
17	Improper equipment	Open	Risk	Threat	All tasks (global)	5.0%	6.7%	0.3%	
18	Improper project feasibility study	Open	Risk	Threat	All tasks (global)	20.0%	100.0%	20.0%	
19	Inadequate contractor experience	Open	Risk	Threat	All tasks (global)	5.0%	16.7%	0.8%	
20	Inappropriate construction methods	Open	Risk	Threat	All tasks (global)	5.0%	26.7%	1.3%	
21	Ineffective delay penalties	Open	Risk	Threat	All tasks (global)	10.0%	6.7%	0.7%	
22	Insufficient data collection and surveys befor	Open	Risk	Threat	All tasks (global)	15.0%	13.3%	2.0%	
23	Insufficient surveys before scheduling	Open	Risk	Threat	All tasks (global)	20.0%	20.0%	4.0%	
24	Labor Strikes	Open	Risk	Threat	All tasks (global)	5.0%	3.3%	0.2%	
25	Lack of experience of design team	Open	Risk	Threat	All tasks (global)	5.0%	20.0%	1.0%	
26	Lack of experience of project management te	Open	Risk	Threat	All tasks (global)	5.0%	20.0%	1.0%	
27	Late delivery of materials	Open	Risk	Threat	All tasks (global)	80.0%	40.0%	32.0%	
28	Low efficiency of equipment	Open	Risk	Threat	All tasks (global)	5.0%	6.7%	0.3%	
29	Low productivity of labors	Open	Risk	Threat	All tasks (global)	5.0%	6.7%	0.3%	
30	Natural Disasters	Open	Risk	Threat	All tasks (global)	5.0%	40.0%	2.0%	
31	Poor communication	Open	Risk	Threat	All tasks (global)	40.0%	53.3%	21.3%	
32	Poor procurement of construction materials	Open	Risk	Threat	All tasks (global)	30.0%	26.7%	8.0%	
33	Poor quality of materials	Open	Risk	Threat	All tasks (global)	5.0%	10.0%	0.5%	
34	Poor site managements and supervision	Open	Risk	Threat	All tasks (global)	15.0%	40.0%	6.0%	
35	Price fluctuations & global financial changes	Open	Risk	Threat	All tasks (global)	10.0%	26.7%	2.7%	
36	Rework due to errors	Open	Risk	Threat	All tasks (global)	70.0%	66.7%	46.7%	
37	Sanctions	Open	Risk	Threat	All tasks (global)	5.0%	10.0%	0.5%	
38	Shortage of manpower	Open	Risk	Threat	All tasks (global)	5.0%	3.3%	0.2%	
39	Slow mobilization of equipment	Open	Risk	Threat	All tasks (global)	15.0%	3.3%	0.5%	
40	Slow site clearance	Open	Risk	Threat	All tasks (global)	5.0%	13.3%	0.7%	
41	Unclear and inadequate details in drawings	Open	Risk	Threat	All tasks (global)	15.0%	13.3%	2.0%	
42	Unfavorable contract clauses	Open	Risk	Threat	All tasks (global)	5.0%	16.7%	0.8%	
43	Unfavorable weather conditions	Open	Risk	Threat	All tasks (global)	5.0%	13.3%	0.7%	
44	Unqulified/ inadequate experienced workforce	Open	Risk	Threat	All tasks (global)	5.0%	16.7%	0.8%	
45	Unreliable subcontractor	Open	Risk	Threat	All tasks (global)	5.0%	26.7%	1.3%	
46	Unreliable suppliers	Open	Risk	Threat	All tasks (global)	5.0%	26.7%	1.3%	

In this step we are able to see the project ranking and also risk matrix.

- Risk ranking (qualitative analysis):

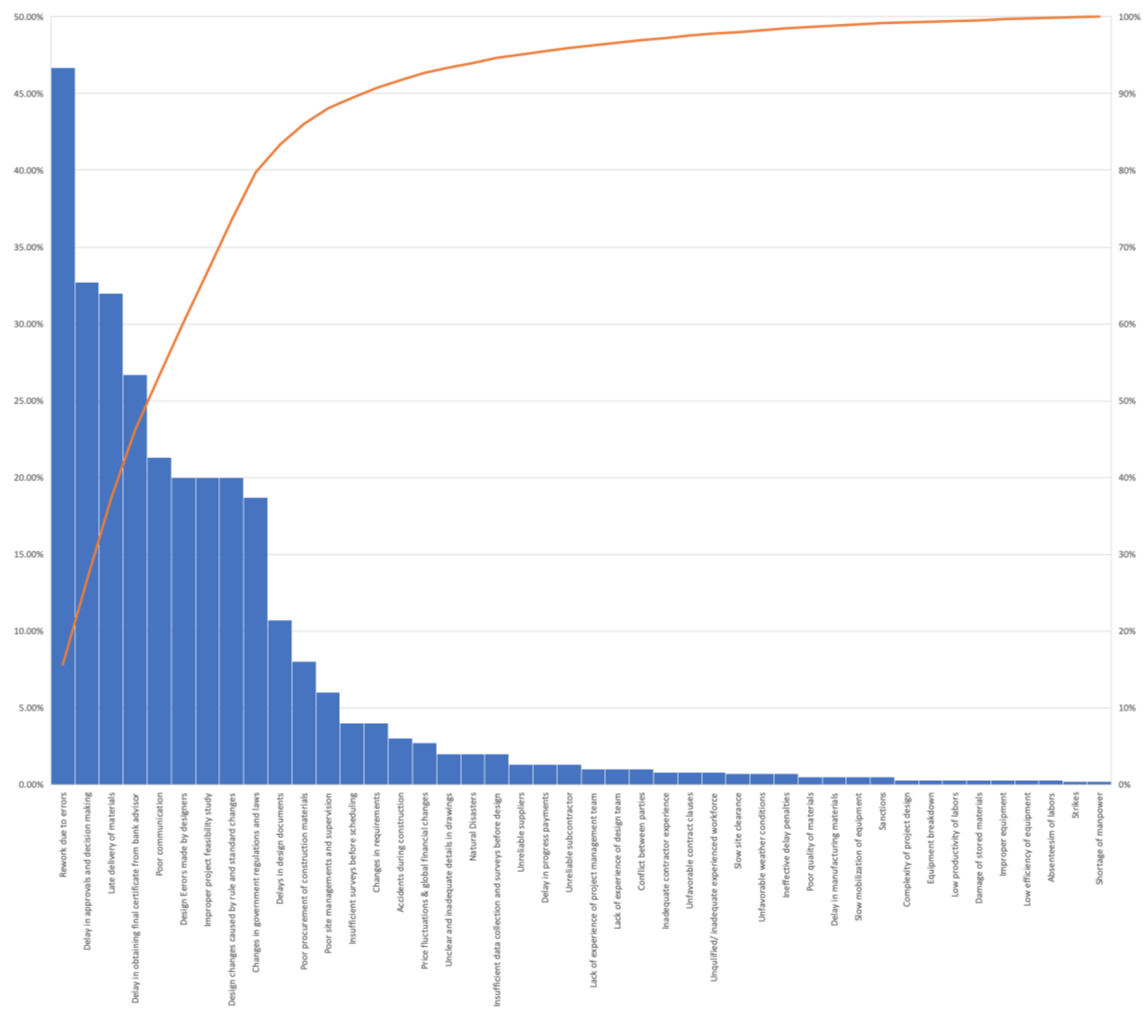
	Risk Name	Prob.	Impa	Score	Open/	Risk/Issue	Threat/O
1	Rework due to errors	70.0%	66.7%	46.7%	Open	Risk	Threat
2	Delay in approvals and decision making	70.0%	46.7%	32.7%	Open	Risk	Threat
3	Late delivery of materials	80.0%	40.0%	32.0%	Open	Risk	Threat
4	Delay in obtaining permits from municipality	70.0%	40.0%	28.0%	Open	Risk	Threat
5	Delay in obtaining final certificate from bank advisor	80.0%	33.3%	26.7%	Open	Risk	Threat
6	Poor communication	40.0%	53.3%	21.3%	Open	Risk	Threat
7	Design Eerors made by designers	50.0%	40.0%	20.0%	Open	Risk	Threat
8	Improper project feasibility study	20.0%	100.0%	20.0%	Open	Risk	Threat
9	Design changes caused by rule and standard changes	50.0%	40.0%	20.0%	Open	Risk	Threat
10	Changes in government regulations & laws	40.0%	46.7%	18.7%	Open	Risk	Threat
11	Delays in design documents	40.0%	26.7%	10.7%	Open	Risk	Threat
12	Poor procurement of construction materials	30.0%	26.7%	8.0%	Open	Risk	Threat
13	Poor site managements and supervision	15.0%	40.0%	6.0%	Open	Risk	Threat
14	Changes in requirements	20.0%	20.0%	4.0%	Open	Risk	Threat
15	Insufficient surveys before scheduling	20.0%	20.0%	4.0%	Open	Risk	Threat
16	Accidents during construction	10.0%	30.0%	3.0%	Open	Risk	Threat
17	Price fluctuations & global financial changes	10.0%	26.7%	2.7%	Open	Risk	Threat
18	Unclear and inadequate details in drawings	15.0%	13.3%	2.0%	Open	Risk	Threat
19	Insufficient data collection and surveys before design	15.0%	13.3%	2.0%	Open	Risk	Threat
20	Natural Disasters	5.0%	40.0%	2.0%	Open	Risk	Threat
21	Unreliable subcontractor	5.0%	26.7%	1.3%	Open	Risk	Threat
22	Unreliable suppliers	5.0%	26.7%	1.3%	Open	Risk	Threat
23	Delay in progress payments	5.0%	26.7%	1.3%	Open	Risk	Threat
24	Inappropriate construction methods	5.0%	26.7%	1.3%	Open	Risk	Threat
25	Lack of experience of project management team	5.0%	20.0%	1.0%	Open	Risk	Threat
26	Lack of experience of design team	5.0%	20.0%	1.0%	Open	Risk	Threat
27	Conflict between parties	10.0%	10.0%	1.0%	Open	Risk	Threat
28	Inadequate contractor experience	5.0%	16.7%	0.8%	Open	Risk	Threat
29	Unqulified/ inadequate experienced workforce	5.0%	16.7%	0.8%	Open	Risk	Threat
30	Unfavorable contract clauses	5.0%	16.7%	0.8%	Open	Risk	Threat
31	Ineffective delay penalties	10.0%	6.7%	0.7%	Open	Risk	Threat
32	Unfavorable weather conditions	5.0%	13.3%	0.7%	Open	Risk	Threat
33	Slow site clearance	5.0%	13.3%	0.7%	Open	Risk	Threat
34	Delay in manufacturing materials	5.0%	10.0%	0.5%	Open	Risk	Threat
35	Slow mobilization of equipment	15.0%	3.3%	0.5%	Open	Risk	Threat
36	Poor quality of materials	5.0%	10.0%	0.5%	Open	Risk	Threat
37	Sanctions	5.0%	10.0%	0.5%	Open	Risk	Threat
38	Complexity of project design	5.0%	6.7%	0.3%	Open	Risk	Threat
39	Equipment breakdown	5.0%	6.7%	0.3%	Open	Risk	Threat
40	Low productivity of labors	5.0%	6.7%	0.3%	Open	Risk	Threat
41	Absenteesim of labors	5.0%	6.7%	0.3%	Open	Risk	Threat
42	Low efficiency of equipment	5.0%	6.7%	0.3%	Open	Risk	Threat
43	Improper equipment	5.0%	6.7%	0.3%	Open	Risk	Threat
44	Damage of stored materials	5.0%	6.7%	0.3%	Open	Risk	Threat
45	Labor Strikes	5.0%	3.3%	0.2%	Open	Risk	Threat
46	Shortage of manpower	5.0%	3.3%	0.2%	Open	Risk	Threat

- Risk matrix (qualitative analysis):



- **Pareto diagram:**
  In this step for have better visual understanding pareto diagram is drawn. In order to draw pareto diagram we need to calculate the cumulative percentage of each risk factor. As it can be seen in the diagram about 80% of the risks are caused only by 9 of the risk factors. This diagram helps the stakeholders and managers to have a clear observation of the importance of the main and critical risk factors.

Risks	Score	Cumulative %
Rework due to errors	46.70%	16%
Delay in approvals and decision making	32.70%	27%
Late delivery of materials	32.00%	37%
Delay in obtaining final certificate from bank advisor	26.70%	46%
Poor communication	21.30%	53%
Design Eerors made by designers	20.00%	60%
Improper project feasibility study	20.00%	67%
Design changes caused by rule and standard changes	20.00%	74%
Changes in government regulations and laws	18.70%	80%
Delays in design documents	10.70%	83%
Poor procurement of construction materials	8.00%	86%
Poor site managements and supervision	6.00%	88%
Insufficient surveys before scheduling	4.00%	89%
Changes in requirements	4.00%	91%
Accidents during construction	3.00%	92%
Price fluctuations & global financial changes	2.70%	93%
Unclear and inadequate details in drawings	2.00%	93%
Natural Disasters	2.00%	94%
Insufficient data collection and surveys before design	2.00%	95%
Unreliable suppliers	1.30%	95%
Delay in progress payments	1.30%	96%
Unreliable subcontractor	1.30%	96%
Lack of experience of project management team	1.00%	96%
Lack of experience of design team	1.00%	97%
Conflict between parties	1.00%	97%
Inadequate contractor experience	0.80%	97%
Unfavorable contract clauses	0.80%	98%
Unqulified/ inadequate experienced workforce	0.80%	98%
Slow site clearance	0.70%	98%
Unfavorable weather conditions	0.70%	98%
Ineffective delay penalties	0.70%	98%
Poor quality of materials	0.50%	99%
Delay in manufacturing materials	0.50%	99%
Slow mobilization of equipment	0.50%	99%
Sanctions	0.50%	99%
Complexity of project design	0.30%	99%
Equipment breakdown	0.30%	99%
Low productivity of labors	0.30%	99%
Damage of stored materials	0.30%	100%
Improper equipment	0.30%	100%
Low efficiency of equipment	0.30%	100%
Absenteesim of labors	0.30%	100%
Strikes	0.20%	100%
Shortage of manpower	0.20%	100%

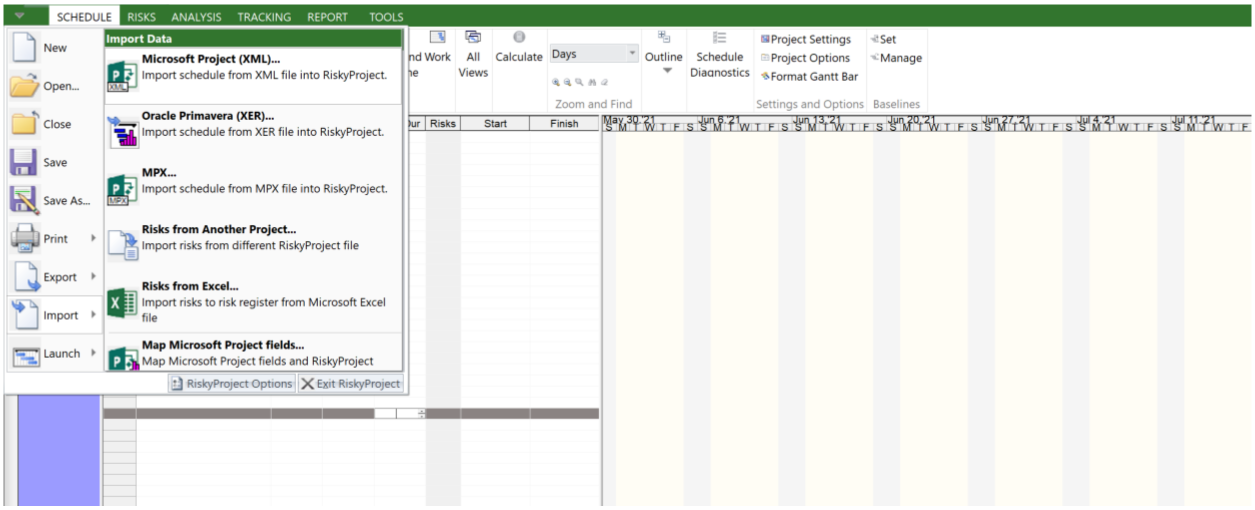


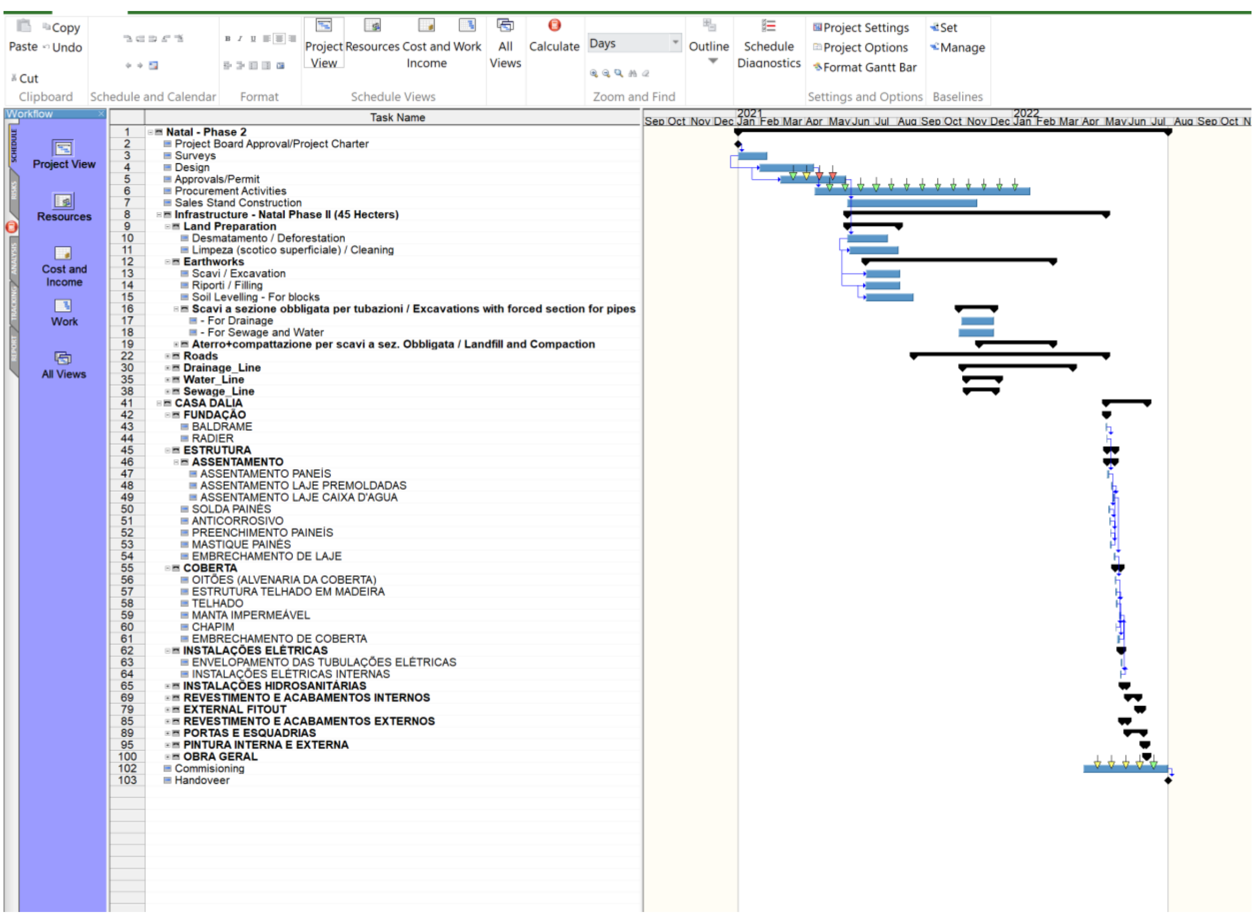
Quantitative Analysis

In this section, we start with tasks, considering cost and timing, and assign a variety of risk scenarios to different tasks based on the forecast. Then, we can see the results obtained by the software based on Monte Carlo simulation. It is clear that there is no limit to analyzing the high volume of risk situations anymore, and also, by using the different types of reports the software offers us, we can make any necessary adjustments at any time during the project. Also, we can see cost and duration changes according to previous modifications or performs of response plans.

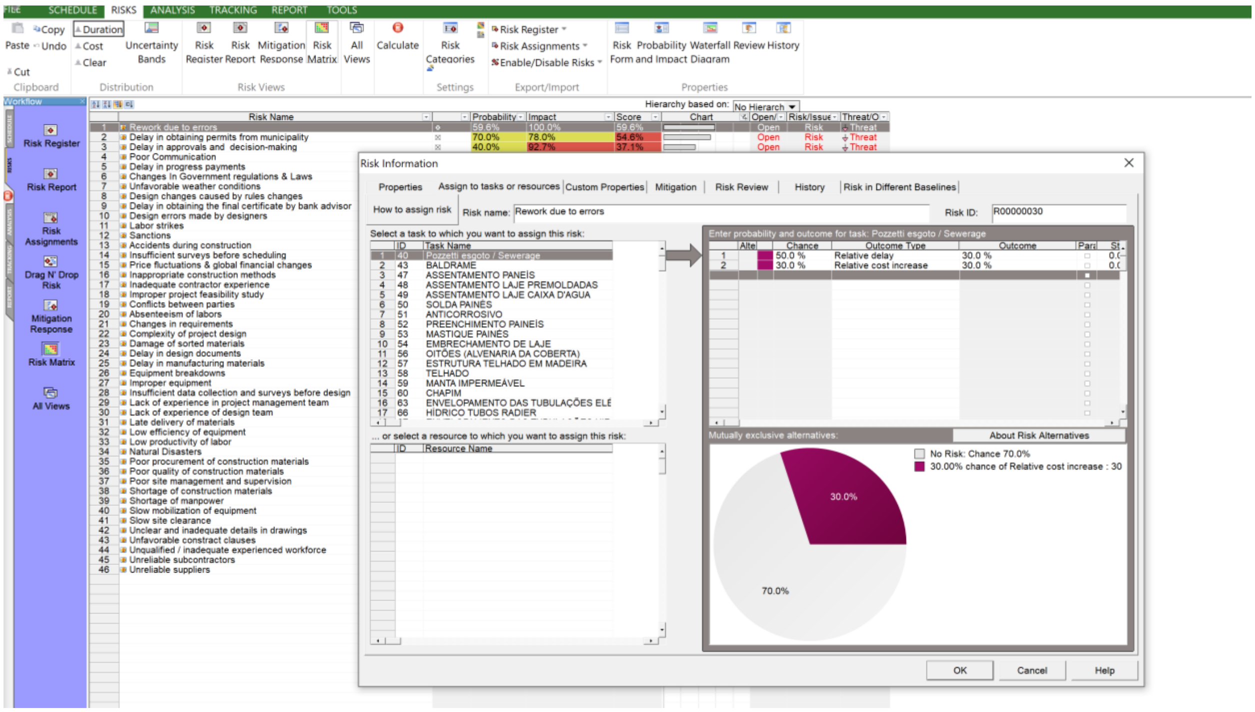
We will explain a summary of the steps that we did for this part as follow text:

In the first step, there is two ways to open the software as to be mentioned before: using the Microsoft Project (Using our prepared WBS in MS project) or working with RiskyProject directly. We used the second. As you can observe in the next figures, we could import project schedule in this way:





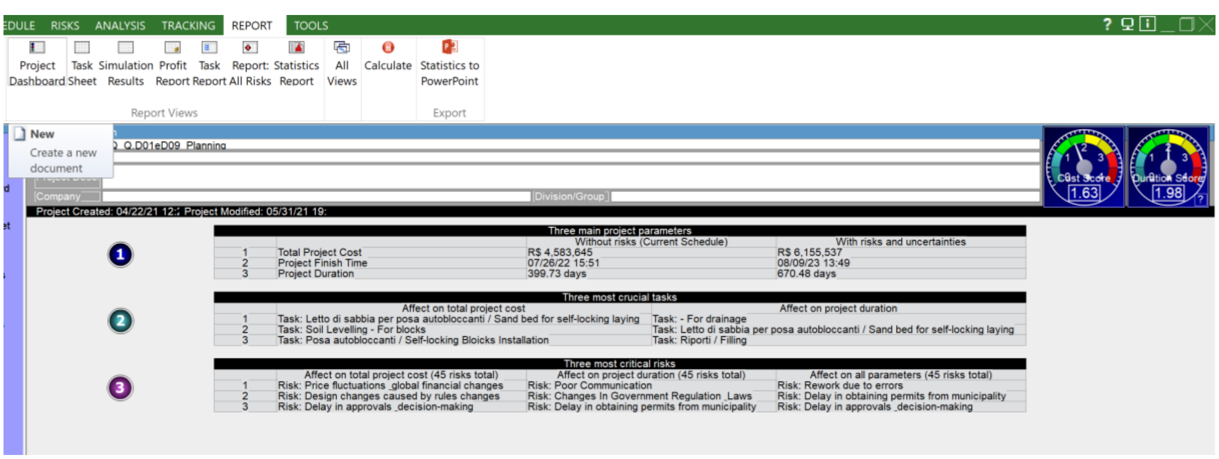
We can access our project's schedule with Schedule Tab. Then we should assign each risk to our tasks and insert their outcome probability and impact.



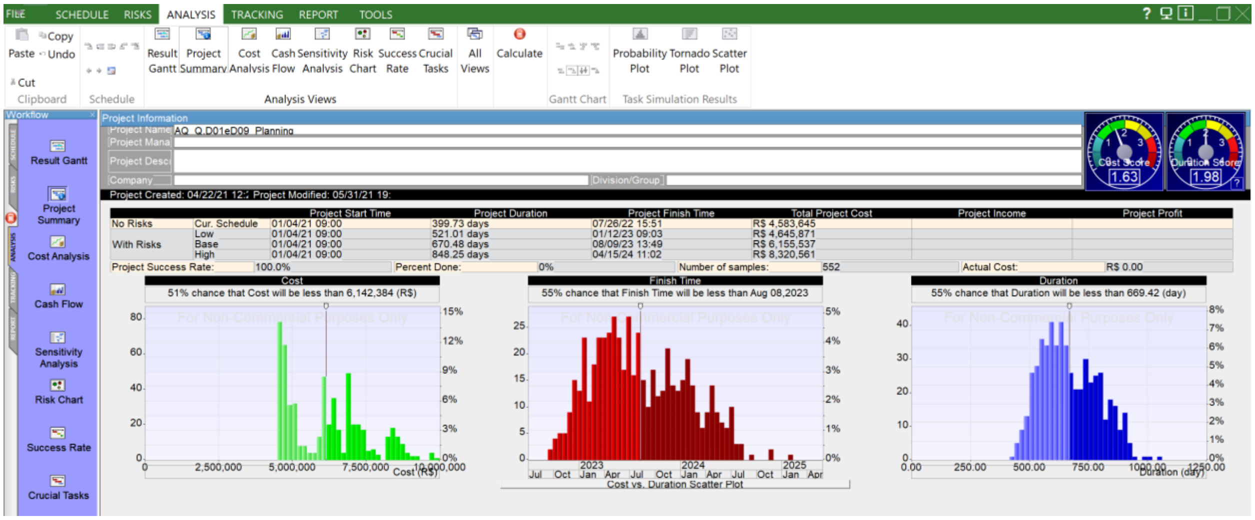
After completing importing all risk data and assigning it to each task, there's a column on the main screen that shows how many tasks have been assigned to each risk.

We can get all the results and reports we need for quantitative analysis by clicking the calculation button, just like we did for qualitative analysis. The following are some of the output reports:

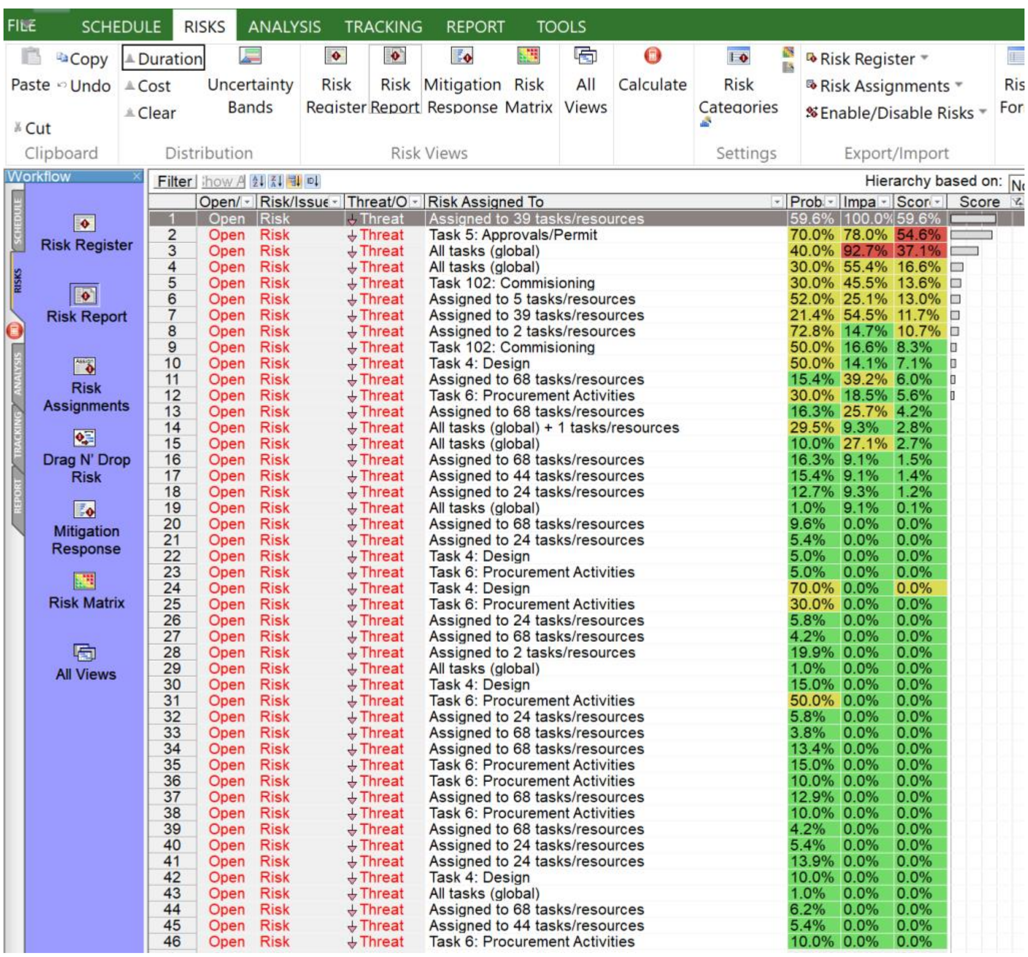
- **General Report:**



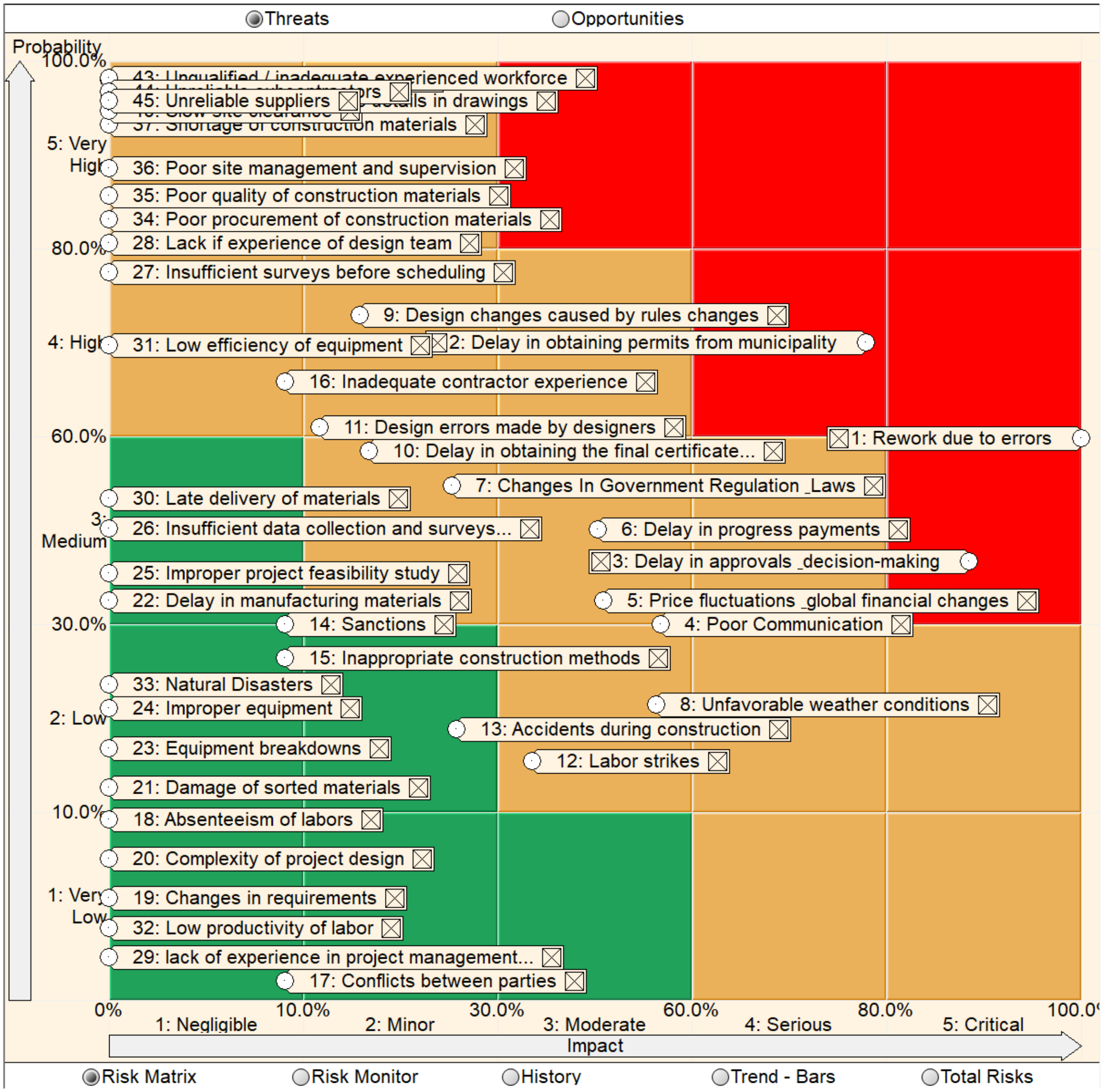
- **Project Summary:**



- **Risk Report**



- **Risk Matrix**


Threats
Opportunities
Probability
100.0%
5: Very High
80.0%
4: High
60.0%
3: Medium
30.0%
2: Low
10.0%
1: Very Low
0%
43: Unqualified / inadequate experienced workforce
45: Unreliable suppliers
37: Shortage of construction materials
36: Poor site management and supervision
35: Poor quality of construction materials
34: Poor procurement of construction materials
28: Lack if experience of design team
27: Insufficient surveys before scheduling
9: Design changes caused by rules changes
31: Low efficiency of equipment
2: Delay in obtaining permits from municipality
16: Inadequate contractor experience
11: Design errors made by designers
1: Rework due to errors
10: Delay in obtaining the final certificate...
7: Changes In Government Regulation _Laws
30: Late delivery of materials
26: Insufficient data collection and surveys...
6: Delay in progress payments
3: Delay in approvals _decision-making
25: Improper project feasibility study
22: Delay in manufacturing materials
5: Price fluctuations _global financial changes
14: Sanctions
4: Poor Communication
15: Inappropriate construction methods
33: Natural Disasters
24: Improper equipment
8: Unfavorable weather conditions
13: Accidents during construction
23: Equipment breakdowns
12: Labor strikes
21: Damage of sorted materials
18: Absenteeism of labors
20: Complexity of project design
19: Changes in requirements
32: Low productivity of labor
29: lack of experience in project management...
17: Conflicts between parties
10.0%
30.0%
60.0%
80.0%
1: Negligible
2: Minor
3: Moderate
4: Serious
5: Critical
Impact
Risk Matrix
Risk Monitor
History
Trend - Bars
Total Risks

- **Sensitivity Analysis**

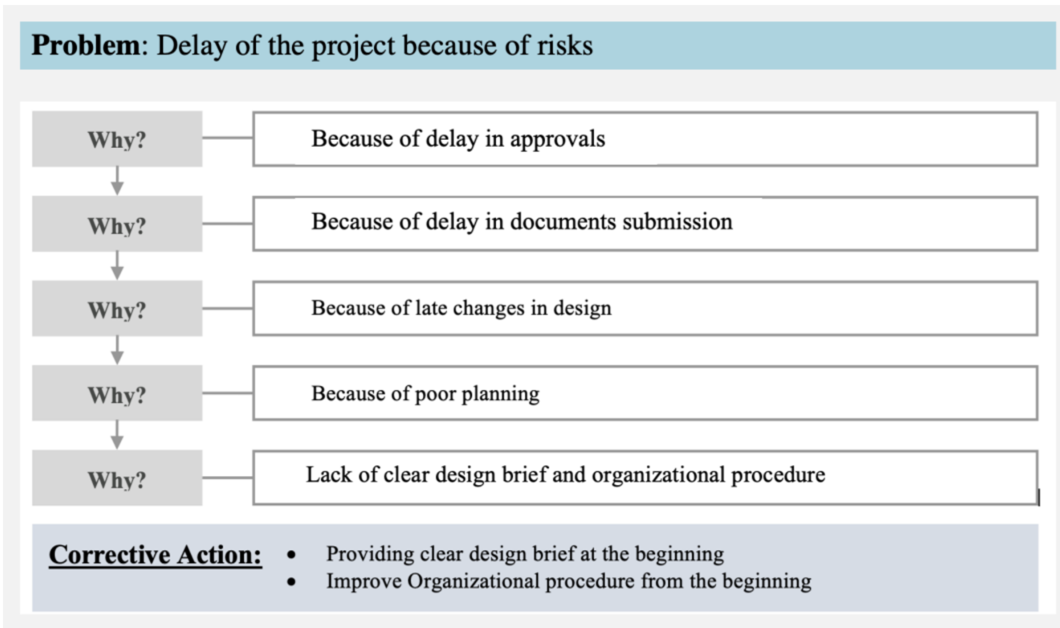
Sensitivity Analysis identifies the input parameters (task duration, start and completion times, success rate, and so on) that have the greatest impact on project outcomes (total project cost, total duration, project finish time, and success rate). Sensitivity analysis helps you identify major risks that could have a considerable impact on your project. These major risks must be prioritized.

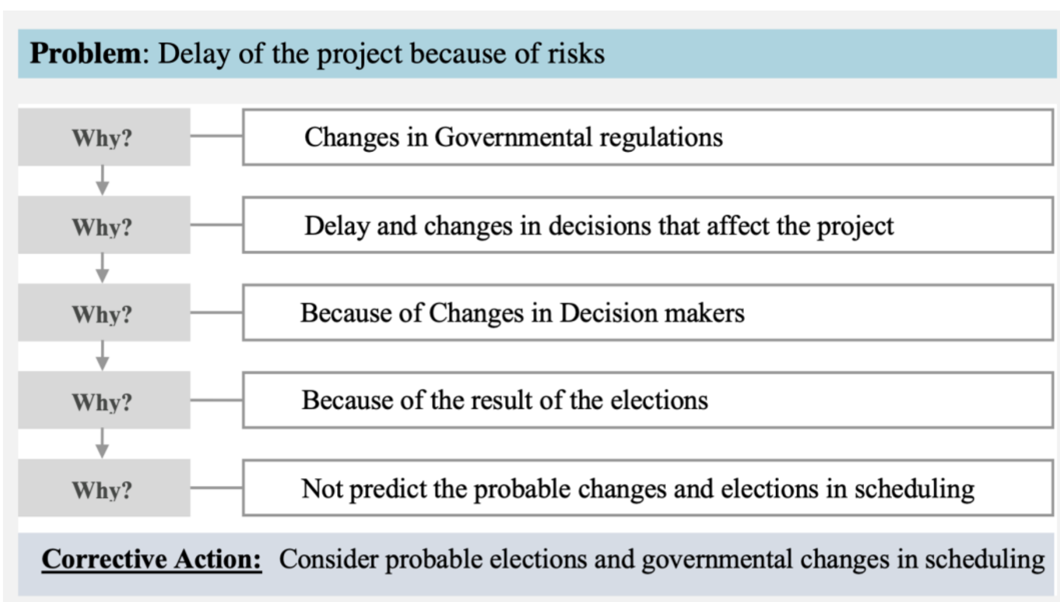
	Name	Task ID	Type	Risk Assigned To	Sensitivity Chart	Cost (Pre-M	Rankin
1	Risk: Design changes caused by rules change:		Risk	Assigned to 2 tasks/resource		R$ 0.00	0.123
2	Risk: Insufficient data collection and surveys b		Risk	Assigned to 2 tasks/resource		R$ 0.00	0.000
3	Risk: Improper equipment		Risk	Assigned to 68 tasks/resour		R$ 0.00	0.000
4	Risk: Unfavorable contract clauses		Risk	All tasks (global)		R$ 0.00	0.000
5	Risk: lack of experience in project managemen		Risk	All tasks (global)		R$ 0.00	0.000
6	Risk: Price fluctuations & global financial chan		Risk	All tasks (global)		R$ 0.00	0.371
7	Risk: Unreliable subcontractors		Risk	Assigned to 44 tasks/resour		R$ 0.00	0.000
8	Risk: Damage of sorted materials		Risk	Task 6: Procurement Activitie		R$ 0.00	0.000
9	Risk: Delay in obtaining permits from municipal		Risk	Task 5: Approvals/Permit		R$ 0.00	0.523
10	Risk: Slow mobilization of equipment		Risk	Assigned to 24 tasks/resour		R$ 0.00	0.000
11	Risk: Insufficient surveys before scheduling		Risk	All tasks (global) + 1 tasks/re		R$ 0.00	0.000
12	Risk: Delay in progress payments		Risk	Task 102: Commisioning		R$ 0.00	0.222
13	Risk: Delay in manufacturing materials		Risk	Task 6: Procurement Activitie		R$ 0.00	0.000
14	Risk: Unclear and inadequate details in drawin		Risk	Task 4: Design		R$ 0.00	0.000
15	Risk: Poor site management and supervision		Risk	Assigned to 68 tasks/resour		R$ 0.00	0.000
16	Risk: Poor procurement of construction materi		Risk	Task 6: Procurement Activitie		R$ 0.00	0.000
17	Risk: Improper project feasibility study		Risk	Assigned to 24 tasks/resour		R$ 0.00	0.000
18	Risk: Unfavorable weather conditions		Risk	Assigned to 39 tasks/resour		R$ 0.00	1.000
19	Risk: Delay in approvals & decision-making		Risk	All tasks (global)		R$ 0.00	0.616
20	Risk: Changes in requirements		Risk	Assigned to 24 tasks/resour		R$ 0.00	0.000
21	Risk: Inadequate contractor experience		Risk	Assigned to 44 tasks/resour		R$ 0.00	0.201
22	Risk: Natural Disasters		Risk	Assigned to 68 tasks/resour		R$ 0.00	0.000
23	Risk: Complexity of project design		Risk	Task 4: Design		R$ 0.00	0.000
24	Risk: Shortage of manpower		Risk	Assigned to 68 tasks/resour		R$ 0.00	0.000
25	Risk: Accidents during construction		Risk	Assigned to 68 tasks/resour		R$ 0.00	0.429
26	Risk: Equipment breakdowns		Risk	Assigned to 24 tasks/resour		R$ 0.00	0.000
27	Risk: Conflicts between parties		Risk	All tasks (global)		R$ 0.00	0.000
28	Risk: Unreliable suppliers		Risk	Task 6: Procurement Activitie		R$ 0.00	0.000
29	Risk: Changes In Government Regulation & La		Risk	Assigned to 5 tasks/resource		R$ 0.00	0.244
30	Risk: Shortage of construction materials		Risk	Task 6: Procurement Activitie		R$ 0.00	0.000
31	Risk: Design errors made by designers		Risk	Task 4: Design		R$ 0.00	0.096
32	Risk: Delay in obtaining the final certificate by		Risk	Task 102: Commisioning		R$ 0.00	0.108
33	Risk: Delay in design documents		Risk	Assigned to 2 tasks/resource		R$ 0.00	0.000
34	Risk: Rework due to errors		Risk	Assigned to 39 tasks/resour		R$ 0.00	0.837
35	Risk: Poor quality of construction materials		Risk	Task 6: Procurement Activitie		R$ 0.00	0.000
36	Risk: Absenteeism of labors		Risk	Assigned to 68 tasks/resour		R$ 0.00	0.000
37	Risk: Unqualified / inadequate experienced wo		Risk	Assigned to 68 tasks/resour		R$ 0.00	0.000
38	Risk: Low efficiency of equipment		Risk	Assigned to 24 tasks/resour		R$ 0.00	0.000
39	Risk: Slow site clearance		Risk	Assigned to 24 tasks/resour		R$ 0.00	0.000
40	Risk: Labor strikes		Risk	Assigned to 68 tasks/resour		R$ 0.00	0.259
41	Risk: Inappropriate construction methods		Risk	Assigned to 68 tasks/resour		R$ 0.00	0.000
42	Risk: Lack if experience of design team		Risk	Task 4: Design		R$ 0.00	0.000
43	Risk: Sanctions		Risk	Task 6: Procurement Activitie		R$ 0.00	0.204
44	Risk: Low productivity of labor		Risk	Assigned to 68 tasks/resour		R$ 0.00	0.000
45	Risk: Late delivery of materials		Risk	Task 6: Procurement Activitie		R$ 0.00	0.000
46	Risk: Poor Communication		Risk	All tasks (global)		R$ 0.00	0.355

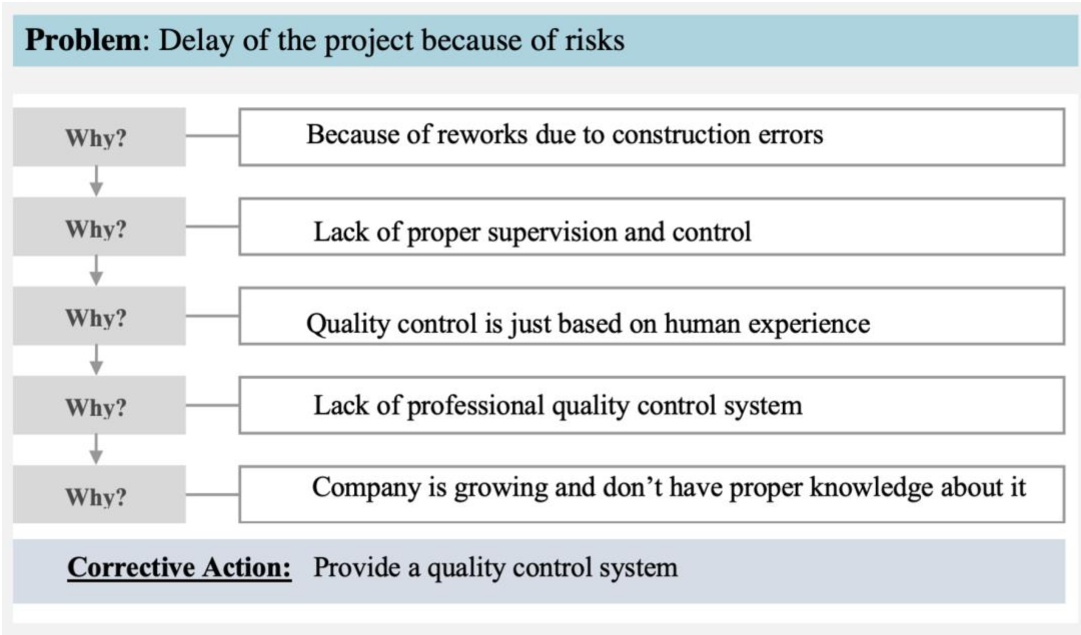
Development of the preventive actions to reduce risks

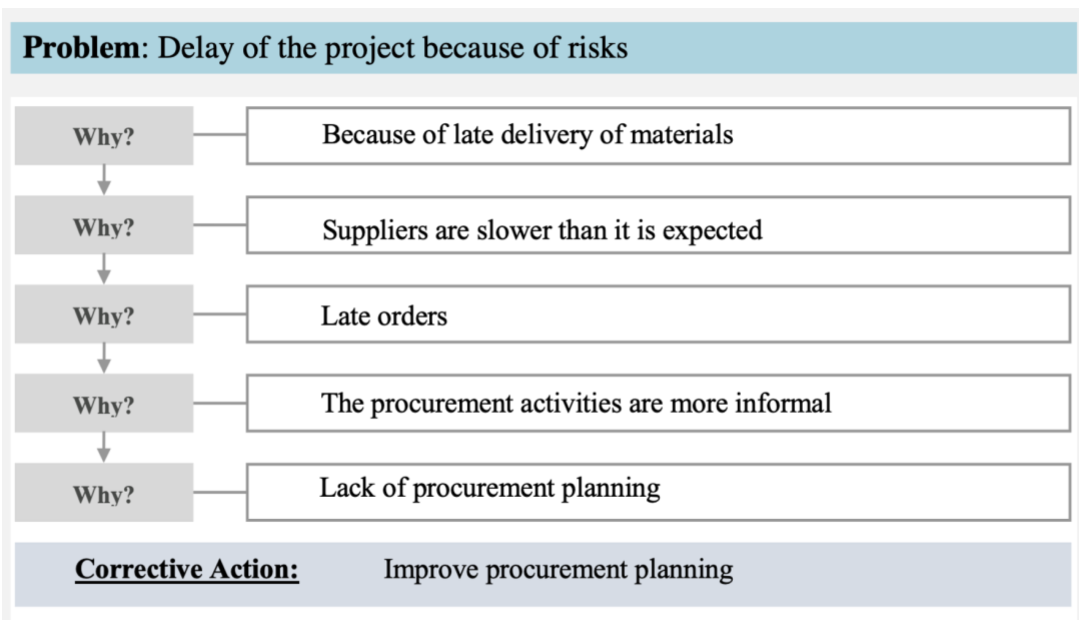
- **5Why Analysis:**

In this stage we can see the result of five why techniques for 11 most critical risks that we had in the result of our assessment. The corrective action that are suggested to prevent these risks are also defined by brainstorming sessions with experts and managers.






Problem: Delay of the project because of risks
Why?
Because of reworks due to construction errors
Why?
Lack of proper supervision and control
Why?
Quality control is just based on human experience
Why?
Lack of professional quality control system
Why?
Company is growing and don't have proper knowledge about it
Corrective Action:
Provide a quality control system


Problem: Delay of the project because of risks
Why?
Because of late delivery of materials
Why?
Suppliers are slower than it is expected
Why?
Late orders
Why?
The procurement activities are more informal
Why?
Lack of procurement planning
Corrective Action:
Improve procurement planning

Problem: Delay of the project because of risks

Why?	Because of Design changes by rules changes
Why?	Most designs are based on previous projects designs
Why?	Designers doesn't have knowledge about local rules
Why?	Designers are not local
Why?	Lack of local partnership for design phase

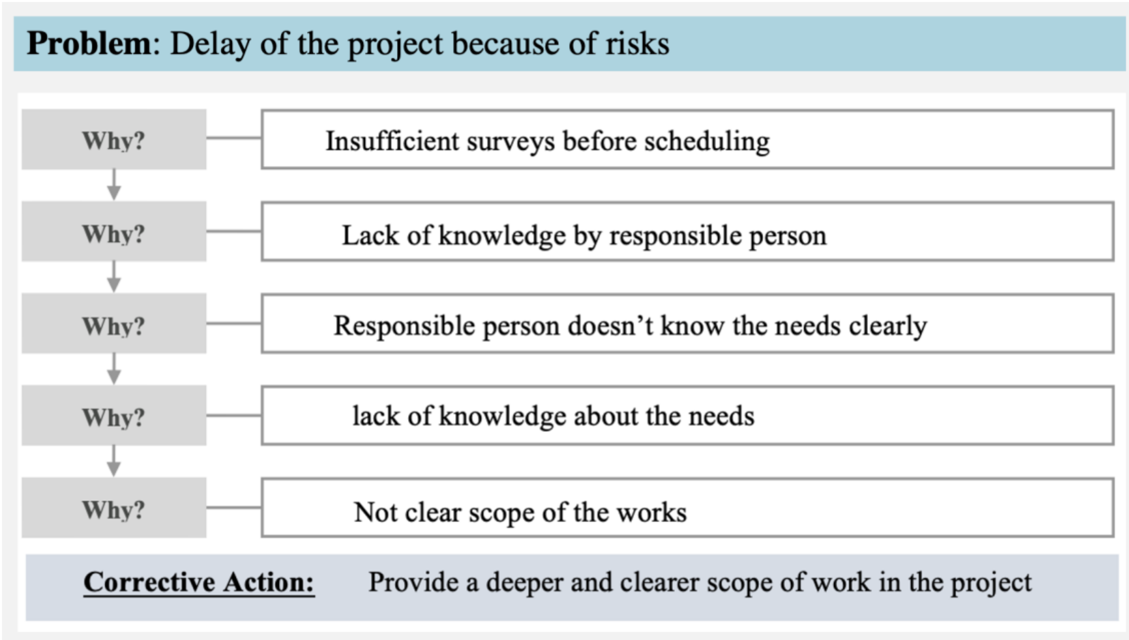
Corrective Action:

- Find local designers
- Establish local partnerships

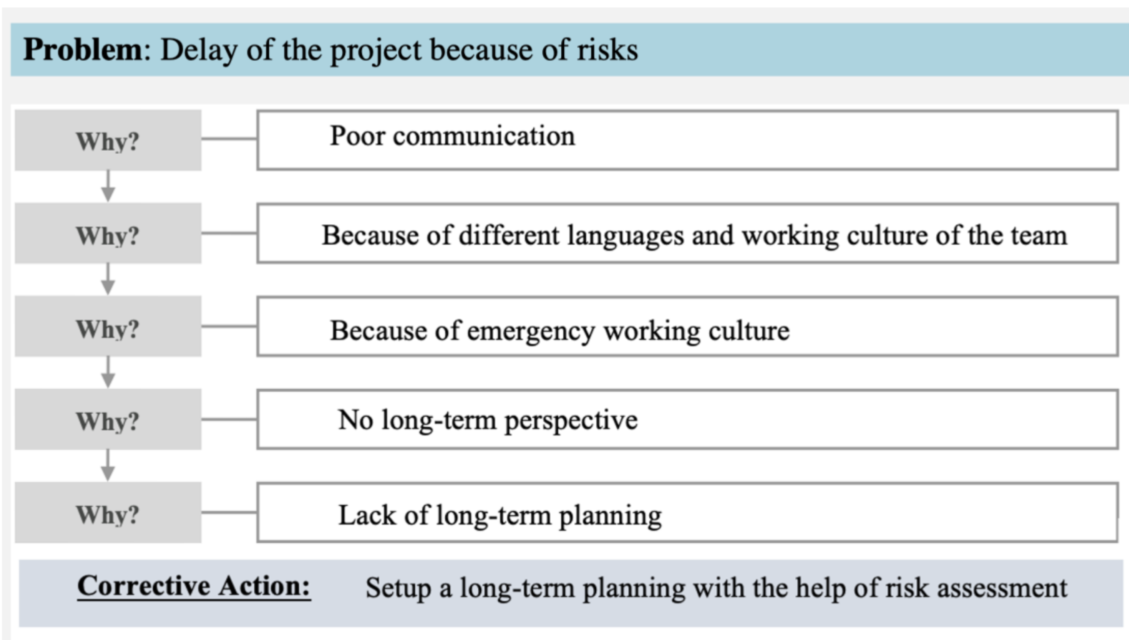
Problem: Delay of the project because of risks

Why?	Mistakes & delays in design documents
Why?	Insufficient designers
Why?	limited knowledge about location
Why?	They are not local designers
Why?	Not enough knowledge to select most proper designers

Corrective Action: Improve knowledge of decision makers and human resource team to select local designers



Problem: Delay of the project because of risks
Why?
Insufficient surveys before scheduling
Why?
Lack of knowledge by responsible person
Why?
Responsible person doesn't know the needs clearly
Why?
lack of knowledge about the needs
Why?
Not clear scope of the works
Corrective Action:
Provide a deeper and clearer scope of work in the project



Problem: Delay of the project because of risks
Why?
Poor communication
Why?
Because of different languages and working culture of the team
Why?
Because of emergency working culture
Why?
No long-term perspective
Why?
Lack of long-term planning
Corrective Action:
Setup a long-term planning with the help of risk assessment

Problem: Delay of the project because of risks

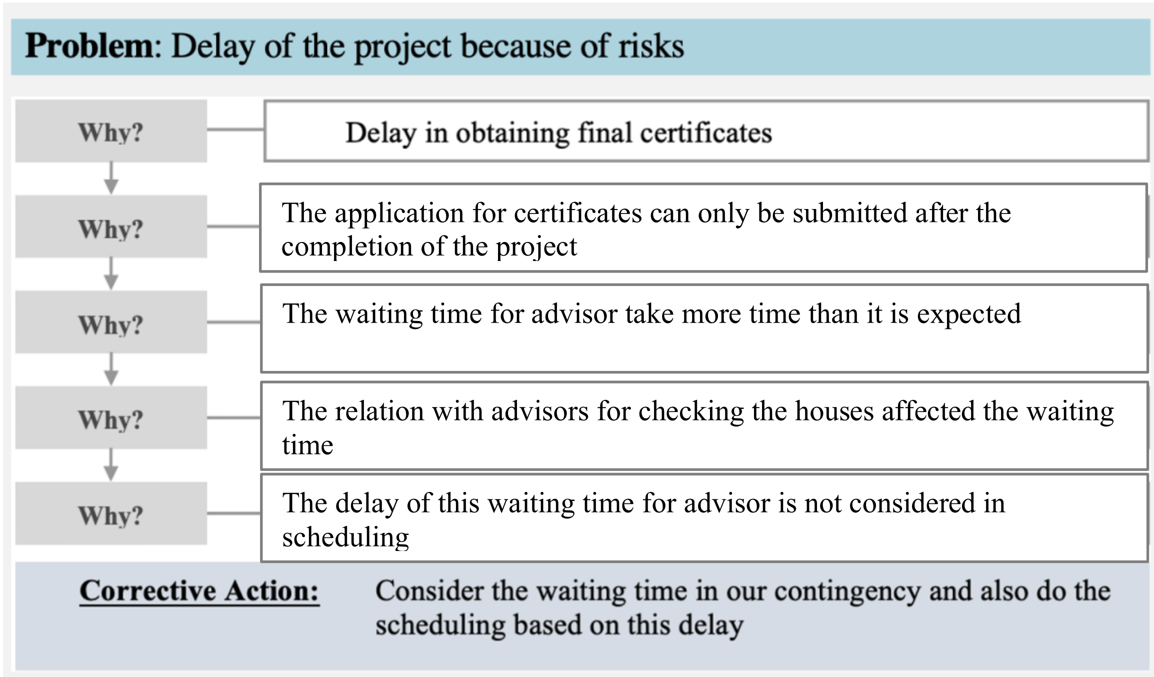
Why?	Late decision making by decision makers
Why?	They don't know the overall procedure related the project management
Why?	Lack of technical knowledge of decision makers
Why?	They are from different backgrounds
Why?	The company is quite new, and the main focus is investment

Corrective Action: More focus on communication between project management team and decision makers
Use of last planner system and huddle meetings

Problem: Delay of the project because of risks

Why?	Because of Improper project studies
Why?	More focus on financial studies than technical
Why?	Lack of knowledge about the market
Why?	Company is an investment company
Why?	Lack of resources and motivation in technical aspect

Corrective Action: Improve technical knowledge and focus on technical studies by Invest in human capital in this field



Lean Integration Results

Lean manufacturing initiatives focus on the problem identification as and when it occurs, does a root cause analysis of the problem and corrections are done at the earliest.

According to Jeffrey, K the popular lean wastes are the ones due to Waiting, over processing, over production, inventory, defects, unwanted motion, unwanted transportation.

This study is unique in that we suggest lean integrated as a tool to control Enterprise-wide risks and thereby increasing productivity and reducing delays.

As it mentioned in methodology lean tools implementation is applied to accelerate the mitigation plans to be more effective and bring a Kaizen (continuous improvement) approach into the system. Each risk that is identified in previous steps could is directly linked to few lean principles. These critical risk factors could create several wastes which can be categorized into the familiar lean wastes as shown in following.

Lean wastes created in project by each of the risk factor:

- **Rework due construction errors**
  - Defects: construction errors will cause defects in final product of construction
  - Overprocessing: errors in construction activities caused some tasks to be redone to correct the errors and obtain the standards.
  - Waiting: any error during the construction tasks will cause delay in next tasks.

- **Delay in getting permits**
  - Waiting: Infrastructure and construction activities cannot be started till permits are obtained
  - Overprocessing: if the designs are not accepted by standard and the permits provide late may some of the design part should be done again to get the permits.

- **Poor Communication**
  - Waiting: Poor communication can take several forms, such as delays in the flow of information that cause waiting waste in upcoming tasks.
  - Overprocessing: it can cause ordering an incorrect material, missing a step in the construction process, misappropriating workers that all these scenarios can result redoing and overprocessing in the project.
  - Defects: poor communication can increase level of misunderstanding and misinterpretation that they will cause defects in both design and construction process.

- **Improper project studies**
  - Overprocessing: improper project studies cause lack of knowledge and understanding about the real problems that occur during the practical phases thus many tasks should redo and also the studies should be done again.

- **Design changes by standard and rules changes**
  - Overprocessing: During or after design phase, changes in some standards or rules based on the location or other parameters may happen so redoing or changes in designs is a must in these situations.
  - Waiting: Successor tasks that should be done after design should wait and have delay to design be done based on new rules and changes.

- **Delay & Errors in design by design team**
  - Waiting: mistakes that happen by designers or delays in this phase doesn't let the successor tasks to be done or started. Getting permits and construction works should wait for design to be completed first.

- Defects: any error in design may happen defects in construction tasks and failure of the project.
- Overprocessing: errors in design can cause overprocessing in both design and construction phase. If the errors will be found immediately it causes redoing just the design phase otherwise the construction tasks that are done based on those design should be done again.

- **Changes in governmental regulations & laws**
  - Waiting: changes in regulation in governmental level in our project that government is the buyer could affect the finishing time so widely and, in each phase, could cause waste of waiting and delay in tasks.
  - Overprocessing: changing in governmental regulations may happen in the middle of the project when some of tasks or designs are already done and with these changes some alterations are also needed in these tasks. This will cause overprocessing in these phases.

- **Late Delivery of materials**
  - Waiting: It is obvious that late delivery of materials causes delay in construction tasks that is a waiting waste in our project

- **Late decision making and approvals by decision makers**
  - Waiting: when decision makers or owner of the company have delay in taking final decisions or approvals, some tasks like design or infrastructure phase can't be started so waste of waiting is inevitable.

- **Delay in obtaining final certificate by bank advisor**
  - Waiting: after finishing all the construction parts final certificate that allow the project to be sold is a must and the bank advisor who is selected by governmental bank should issue this certificate. If this certificate is issued late the final handover couldn't be done so it makes delay in finishing the project and the marketing team should wait.
  - Overprocessing: if the advisor doesn't issue the final certificate due to some issues regarding standards, the tasks or part of the houses that have issue should be redone. So overprocessing is the waste that may will be happen.

Integrating lean into risk management

Lean has to be a company strategy. Top management commitment is essential and transforming people through lean training and awareness is significant. Thus, when the wastes are defined with the help of lean principles and tools, we can control them.

Table below shows the lean tools which can be beneficial in eliminating the risks at the source.

Critical risks	Lean principles effective for risk control
1. Rework due construction errors	Poka-Yoke (Error Proofing) Check sheet FMEA Quality management system
2. Delay in getting permits	Time and motion study First Run Studies
3. Poor Communication	Last Planner system Suggestion Scheme
4. Improper project studies	First Run studies Time and motion study
5. Design changes by standard and rules changes	First run studies Last planner system
6. Delay & Errors in design	Check points and Control points Continuous flow
7. Late Delivery of materials	JIT Supply chain management
8. Changes in governmental regulations & laws	First Run Studies
9. Late decision making and approvals by decision makers	Daily Huddle meetings PDCA (Plan Do Check Act)
10. Delay in obtaining final certificate by bank advisor	SMART goals First Run studies

6. Conclusion & Recommendation

In the following, the overall conclusion and summary of the study will be provided below. The results and findings gathered throughout the study are summarized in this chapter. In addition, it will also describe suggestions for this study and recommendations for future research.

Conclusion

In the scope of this study, lean and risk management theories have been studied and analyzed to rationalize a proactive approach. A case study of Brazilian real estate development was conducted to examine the extent to which lean principles can be combined with risk management, and how lean technologies can help reduce waste caused by critical risks.

- Lean thinking and therefore the risk management process naturally coexist whether we understand the relationship or not. By understanding this correlation between risk management and lean thinking, we are able to better integrate them and upgrade our organization or company success rate.
- Both Lean and risk management should be built as an integral part of the organizational processes and support decision making. The major difference is the function of risk management is to explicitly address uncertainty, whereas lean explicitly addresses wasted effort through the optimization of flow.
- Each risk identified can be directly linked to few lean principles which could help prevent the occurrence of it. It had been evident that the risks and events create several wastes which can be categorized into the familiar lean. Thus, Lean techniques were specified as a control tool for the risks that are linked to the wastes within the project.
- Lean management strategies should be incorporated in the planning stage itself if it has to be effectively practiced in risk control and mitigation. Management support in identifying and eliminating waste to continuously improve the processes is essential so that value addition occurs in each project. If wastes identified at different processes are curtailed it would remove all the risk factors from various parts and thus ensure an effective risk management in place.
- Lean problem-solving techniques such as Ishikawa diagram, pareto analysis and 5whys could be combined with risk management tools in order to identify and assess risks more thoroughly and could help the project decision makers have a clear understanding of critical risks and their root causes.
- In this study, the risks of real estate development projects were evaluated. Initially, by reviewing the background and previous studies available, brainstorming session with stakeholders and checklists, risks associated with construction projects were identified and

classified into six categories, including external (environmental, economic, political), labor, materials, equipment, contractor, project, owner and design.

- Qualitative assessment and pareto analysis help our stakeholders to have clear overview about most critical risks and their ranking.
- The assessment of risks showed that the majority of critical risks are related to design delays and errors, delays in obtaining permits and final certificates, changes in regulation and laws, poor communication, late decision making, and late delivery of materials.
- In quantitative analysis, RiskyProject in applying the risk management process in practice, proved to be efficient, especially when it comes to base Monte Carlo simulation on experts' experience when lacking historical data, which had been one of the limitations of this research.
- 5whys is a powerful evaluation method for all non-statistical analyses which can be applied once found. It can uncover and trace back issues that were vague. In addition, it could be helpful to finally achieve the best action plan for critical risks.
- Understanding wastes in lean construction that could be caused by our critical project risks for controlling them and implementation of lean techniques, could help the decision makers achieve project success.
- The most significant wastes defined by considering critical risks in our Real estate development case study were waiting, overprocessing and defects.
- Construction Lean tools such as last planner, first run studies, error proofing, huddle meetings and JIT and etc. which are defined based on each risk were suggested to help the decision makers reduce the wastes (such as waiting, overprocessing, defects, etc.) and to control the risks before they occur.

Recommendation for Further Research

The subject of this thesis is very broad to the frame of a master's thesis. Thus, there could not be an in-depth study of all the components of the process, such as assessing each lean controlling tool. This thesis has focused on the implementation of risk identification, analysis, and evaluation, as well as lean integration in projects. Also, much attention was given to the risk management practices in the projects. As for further research, more in-depth research of lean risk management is proposed. The framework of proactive lean risk management and the way it affects the effectiveness of the process could be studied in future research.

This research was conducted as a case study of a real estate development company. The subject should be studied among a wider sampling of companies in order to obtain more reliable results. It would also be interesting to examine the lean control tools suggested in this study to assess the effectiveness of this proactive approach.

Another interesting topic could be implementing the suggested proactive risk management in projects from other sectors.

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