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Study of the Coherences and Dependencies between Quality and Risk Management, within the Construction Industry

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Final Dissertation

Study of the Coherences and Dependencies between Quality and Risk Management, within the Construction Industry

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Topic

It is very troublesome to work with Quality Management without touching Risk Management as well and vice versa. These fields are quite complex and one cannot understand one without also understand the other.

Abstract

Today's world is evolving faster that it has never done before (Cvijanovic & Mihailovic, 2016; Jorgenson & Vu, 2016). No field can escape from this perpetual development: from agriculture to industry and from trade to health care (Moshirian, 2008; Pop & Valeriu, 2015; Waltman, Tijssen & van Eck, 2011). Among these areas, the construction sector is subject to these changes more than ever: client's demands, project's needs, law's requirements… Everything need to be achieved faster, better and cheaper (Ngowi, Pienaar, Talukhaba & Mbachu, 2005).

Considering these increasing constraints, Projects Managers cannot successfully reach project's goals without being assisted by some tools (Ansah & Sorooshian, 2017; Bygballe, Sward & Vaagaasar, 2016). Quality Management and Risk Management are methods that have proved to be efficient in the past (Marty, 2015; Rumane, 2013). Both these systems bring numerous benefits to a project, but unfortunately, they are too often considered separately (Gallego Navarro, 2017). Nowadays' demands make Quality and Risk Management less and less efficient, but a synergy could result in more valuable outcomes (Bazin, 2017; Gallego Navarro, 2017).

Resume

The present dissertation first focused on investigating Quality and Risk Management in an attempt to briefly explain them to someone non-initiated toward Project Management. To do so, an investigation of the existing state-of-the art takes place in this report. It was found that Quality Management improves processes and strategies as to lead to better project quality and ensure satisfaction of needs, whereas Risk Management focuses on mitigating threats and increasing opportunities to enhance project's performance and avoid deviations from requirements.

The essay, then intended to find the coherences and dependencies that exist between Quality and Risk Management as to further clarify them and to propose a new approach that would merge both these tools together if more efficiency can be demonstrated. Such a task is reached by analysing the literature review and extracting relationships between the fields of study. These links are also detailed thanks to an examination of a real case study, which purpose was to confirm or to invalidate the previous theoretical findings.

The key results extracted from this study were first, a certain complementarity between the systems, in terms of interchangeability and compensation. Secondly, robust similarities among the tools were discovered, regarding their intended purpose, their methodologies and their use for construction projects, according to both participants and stages. These relationships were fortunately confirmed by the case study as well as the advantages of merging QM and RM: enhanced project performance in terms of quality and risks, but also cost, time and communication.

Key Words

Quality Management – Risk Management – Quality – Risk – Cost – Time – Safety – Communication – Regulations – Environment – Customer – Construction Projects.

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List of Abbreviations

FIDIC: Fédération Internationale des Ingénieurs-Conseils (*International Federation of Consulting Engineers* in English)

HAZOP: Hazard and Operability study

ISO: International Organization for Standardization

MADS: Méthode d'Analyse des Dysfonctionnements des Systèmes (*Method for Systems' Dysfunction Analysis* in English)

MOSAR: Méthode Organisée Systémique d'Analyse des Risques (*Systematic Organized Method for Risk Analysis* in English)

PDCA: Plan-Do-Check-Act

PMBOK: Project Management Body of Knowledge

QM: Quality Management

RM: Risk Management

RMP: Risk Management Plan

SWOT: Strengths, Weaknesses, Opportunities and Threats analysis

TQM: Total Quality Management

1. General Introduction

In a world of perfectibility and constant improvement, humans are increasingly demanding and are looking for more and more innovation and quality in the goods they produce. This affects every sector, from the car industry to the medical field and also the construction industry. A great importance is attached to performance, aperture, lifespan and physical resistance of objects. Such parameters describe well the word quality.

It is nowadays essential to offer customers high quality products in the construction world, as buildings and infrastructures are visible, voluminous and very expensive goods. People are also using these products continuously: from working in offices to living in houses, buildings are of first importance in human life. It seems thus obvious to make sure that such products properly ensure their functions, which can be viewed as quality, from different points of view: architectural, energetic and acoustic comfort, space organization, human well-being…

To make sure to provide this level of perfection and since quality can be viewed differently from one individual to another, it seems necessary to carry out methods to evaluate and reach quality: this is what it is called Quality Management. According to Siva, et al. (2016, p. 149) Quality Management is "a philosophy consisting of principles, practices and tools that includes principles or values such as customer focus, continuous improvement, and fact-based decisions".

Nowadays, due to the world's evolution and this level of exigence, people always want the best products, with the lowest price and, in the case of buildings, the sooner, the better. Taking into account the great number of requirements that need to be fulfilled, the risks not to reach the customers' desires is extremely high. Furthermore, internal parameters such as safety or profitability for the producer should also be considered.

To be able to deal with these constraints, methods are also needed to measure and to mitigate these risks: Risk Management seems to take care of these problems. This method can be described as "a positive and proactive process intended to reduce the likelihood of unsatisfactory consequences to the project in its different stages, such as design, construction and operation" (Serpell, et al., 2015, p. 202).

Considering the aforementioned definitions, it appears as an evidence that both Quality and Risk Management are linked together. Quality Management is necessary to provide high added-value goods meanwhile Risk Management makes sure to reach this goal by avoiding as much as possible unwanted troubles.

The topic of this dissertation emphasis the previous points with the following description: "It is very troublesome to work with Quality Management without touching Risk Management as well and vice versa. These fields are quite complex and one cannot understand one without also understand the other." However, what are exactly Quality and Risk Management? How to understand Quality Management, taking into account Risk Management and vice versa? The purpose of this study is to answer these questions.

Evaluating the problems from the questions above, this write up shall be chronologically presented from giving a general understanding about the Quality and Risk Management procedures and their various usages. In addition, a careful study of the links between these two fields will be investigated using both the research and a real case study. Finally, the conclusions of this report will be synthesized with short statements over viewing the findings.

2. Scope of the Dissertation

The purpose of this chapter is to define the scope/ limitations of the current study as well as its main purposes, the problems posed by the chosen topic and what is going to be done in order to solve them and let the lecturers understanding the general framework of this dissertation.

2.1. Main Objectives and Limitations

As previously mentioned, the primary objective of this dissertation is to investigate two fields taking part in the Project Management procedure, Quality and Risk Management, as to provide a general overview and to make them understandable for someone not initiated. The secondary purpose is to find and study the links between these two fields, in order to go deeper into the explanation and to provide a full understanding of one field, including the other in the explanation. Ultimately, the third goal will be to provide some interpretations, resulting from the relations between Quality and Risk Management. To reach these three aims, the investigation will be conducted mainly in the construction sector and applied on a single construction site only.

2.2. Significance of the Study

Numerous studies have been carried out in the fields of Quality and Risk Management, but separately. Although some connections between these two methods seem obvious, no serious research has been made on the key points that link Quality and Risk Management. When describing the Quality Management procedure, some facts are indirectly given on Risk Management and vice-versa. In order to properly understand these two fields, it is of great necessity to explain them while considered together. The main contribution of this report will be to easily make understandable both Quality and Risk Management in order to use these tools efficiently, together, while leading a construction project.

2.3. Interest for the Topic

Before starting to work on this dissertation, a certain amount of knowledge, necessary to properly handle this study, has already been acquired. In fact, the author has studied the Risk Management process in detail during his fourth year of studies at the ESITC Caen engineering school, France, which developed his interest in this subject and his desire to continue studying it. However, the process was not applied to the construction sector, but was more a general approach. On the opposite, Quality Management is quite new for the author, although it has been viewed, within the construction industry, during his studies with the Master, and this topic also deserved to be investigated further. That is why, it appeared as a good choice to work on the Quality and Risk Management fields due to author's knowledge, lack of knowledge and his personal interests.

2.4. Problems to be Solved

Based on the aforementioned objectives and significance, the current report will intend to answer the following question: *How can Quality Management be fully understood using Risk Management as part of the explanation and vice versa?* To fulfil such a task, it seems fair to divide this interrogation into several sub-problems which will be solved throughout the whole dissertation, as follows:

- What is Quality Management, on a general basis and within the construction sector?
- How Risk Management can be understood for general purposes and in construction?
- What are the patterns or common points that link Quality and Risks Management together?
- What conclusions can be drawn from such an interconnectivity between the two fields of study?
- Are those boundaries strictly the same for both the theoretical and the practical points of view?

2.5. Research Methodology and Document Structure

To answer the above questions, the main body of this study is divided into two parts which are going to be investigated along the study as follows:

The first one matches to an academic review, through a state-of-the-art, and includes analysis, descriptions and the latest research findings on the topic:

- First of all, clear definitions, scope, objectives and methodology of quality and Quality Management, as they are broadly used, are going to be detailed. A brief overview of this set of tools, specifically applied in the world of construction, will then be provided, as to introduce the necessary adaptations;
- As well, the same pattern will be reproduced in the case of risks and Risk Management, independently of the first topic.

The second part contains original findings on the topic, based on the author's own work, through the analysis of the state-of-the-art as well as a case study, and includes results and discussion of this investigation:

- Firstly, the data found within the literature review will be examined and the results obtained will be analysed as to investigate the theoretical relationships between Quality and Risk Management. Potential use of these links in the case of a project and their benefits are also provided;
- Secondly, a case study will be investigated and detailed, regarding a construction project, experienced by the author. Data collected at that time will be used to extract the practical boundaries between the two fields studied, and eventually, to provide connections and advantages that have not been mentioned in the papers. As well, a comparison with what was expected from the theoretical point of view will be undertaken.

Finally, some conclusions and recommendations will answer the problem by summing up the discussed points of the topic and by giving some possibilities of future works for applying Quality and Risk Management procedures when understood as a whole rather than single entities.

3. Quality Management: an Overview

In this section, a general definition of quality and the necessity to reach it are provided, as well as a brief description of the Quality Management procedure and its consequences, to give to the lecturers a better idea of the study's context. Finally, Quality Management applied in the construction sector will be briefly detailed as to show the specificities to be taken into account while implemented to such a particular field.

3.1. What is Quality?

3.1.1. General Definitions

Before going through Quality Management, it is necessary to briefly explain the sense of the word *quality*, as it possesses a vast significance. Quality does not have a single definition: depending on the point of view, the meaning is different. For customers, quality is viewed as a maximization of their satisfaction; Workers see quality as being the conformance of requirements; For financing manager, quality is a synonymous of profitability; For Government, quality must be conformed to safety of the population (Padhy, 2013).

Within the construction sector, the problem is the same: for designers and architects, quality equals building aperture and functionality. For the builders, quality is a deliverable from designers, with documents and blueprints, a service as well as a timely response during the Construction Stage. Finally, for the owner, quality is viewed as a deliverable from the designers and the builders, which represents the whole building and its various properties, uses and functions (Rumane, 2013).

However, only one definition seems to be universal: according to the International Organization for Standardization (ISO), quality is the "degree of excellence" (Padhy, 2013, p. 119) or can be defined as "the totality of characteristics of an entity that bears on its ability to satisfy stated or implied needs" (Rumane, 2013, p. 11). But it is of great importance to make a difference between quality in manufacturing industries and construction projects since the final product is completely unique.

Based on this principle and according to Janipha, Ahmad, & Ismail (2015), it is possible to describe quality as a set of various organized activities, methods or procedures whose purpose is to manage the organization of a construction project in order to reach a defined goal, by improving its performance and efficiency. Because of the complexity faced in construction management, these actions must be applied during each stage of a construction project.

3.1.2. A Need to Reach Quality

Quality does not refer only to the architectural appearance of a building or construction element, as it is often thought this way, but affects also its various performances: physical properties, lifespan, integration with other materials as well as the degree of reaching needs along the construction process. Moreover, quality does not affect only products and equipment necessary to build an infrastructure, but it affects the whole construction procedure and its management approach necessary to reach the customer's wishes according to the project scope and within a defined budget and schedule (Rumane, 2013). These three parameters are part of the so-called Construction Project Trilogy (Figure 1).

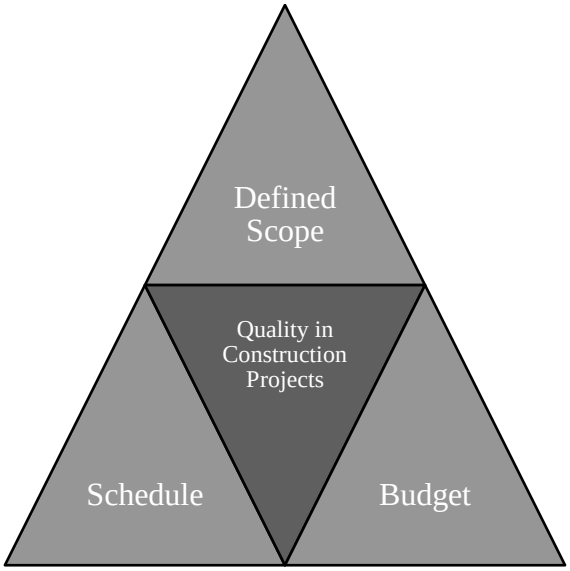

Figure 1 – The Construction Project Trilogy (Rumane, 2013)

Experience has proven that a lack of quality in construction projects led to failures and incidents. In 2007-2008, no less than 37 fatal accidents were caused by poor quality materials on construction projects; in 2009, 306 deaths were due to 257 incidents implying quality and safety failures. Among these events, 49 buildings collapsed because of improper materials and process concerns (Chen & Luo, 2014).

As a consequence, it seems obvious that there is a need to improve quality. This implementation of quality leads to a more effective use of cost and resources on a construction site because less rework is necessary, which leads in return to better productivity and thus, to a decreased cost per unit and workers' morale enhancements. Based on the importance of quality, and in order to fulfil the client's requirements and to reach perpetual improvement in the quality of their products, at any time, construction companies need coordinated management systems and planning methods: this is Quality Management.

3.2. Quality Management Procedure

3.2.1. Brief Description

Since quality can be described by a wide range of ways, various definitions of the Quality Management (nowadays known as Total Quality Management) concept can also be found. In his book, *Total Quality Management: Key Concepts and Case Studies* (2017), Kiran describes (Total) Quality Management as a set of methods, principles, practices and organized efforts, together integrated in a system, which purpose is to lead to a constant improvement of the capacity to make and deliver high-quality services and products, as required by clients.

In addition, numerous other definitions of this method can be found according to authors' point of view or standard description. For instance, in the same book it is also stated that Quality Management "is a management approach for an organization, centred on quality, based on the participation of all its members and aiming at long-term success through customer satisfaction, and benefits to all members of the organization and to society." (Kiran, 2017, p. 3). Thus, according to the previous definitions, it can be said that Quality Management emphasizes much on customers' expectations and stakeholder needs.

Finally, a wider definition of Quality Management process could be that it does not focus only on the reach of quality or customers' requirements, but also on the achievements of all the objectives of a given project or organization. Here, Quality Management is viewed as a philosophy which purpose is to push as much as possible both material and human resources to fulfil the desired goals and to continually improve an organization (Gallego Navarro, 201?).

To sum up, the Total Quality Management system can be described as a composition of three paradigms, each one standing for one word:

- **Total**: this word stands for Organization wide. It affects all functions (from design to maintenance), all levels (from chairmen to operators), all staff members (from factory personnel to suppliers);

- **Quality**: it matches with the usual definition with all its variations. Quality emphasizes customer satisfaction as well as functional requirements and product specifications;

- **Management:** it focuses on the management procedure and its steps such as Plan, Organize, Control, Lead… This system should lead to efficient procedures and processes, effective planning and control, and constant improvement (Kiran, 2017).

In the '80s, Total Quality Management was particularly useful to improve quality because it was the main concern at that time. Nowadays, due to increased customers' expectations, a need to reach competitive cost and high performance, there is a necessity to use new methods like Integrated Quality Management. It is a combination of Quality Management, Environmental Management and Health & Safety Management, among other specifications.

Because they are unique, construction projects have their own quality specifications which differ from one project to another, contrary to industrial products. However, quality can still be reached by merging both project's requirements and organization with a Quality Management philosophy. It leads to the implementation of an Integrated Quality Management procedure, particularly suitable for construction projects (Rumane, 2013).

3.2.2. General Procedure and its Consequences

It is important to quickly investigate the general process of quality Management, giving the main steps, before going through its benefits:

1. **Problem/ need identification:** Firstly, to launch the whole process, it appears as essential to find a need to improve/ implement quality on a construction project or company or to solve an issue related to quality;

2. **Goal definition:** Once the problem has been found, goals need to be set to solve them;

3. **Solutions investigation:** Then, solutions should be investigated to reach the objectives;

4. **Solutions implementation:** These solutions are implemented and controlled at the same time, with data recording;

5. **Results comparison:** The results are compared to the expectations/ goals thanks to the data;

6. **Decision-making:** If the results match with the objectives, the process is successful, if not, there is a need to start again the whole approach until the needed quality level is reached.

Numerous tools for continuous process improvements, based on the previous stages, can be applied to various fields and particularly, in the construction industry thanks to the use of lean in construction. Nowadays, these tools are used for various applications, but most of the time, they lead to a better quality. Methods that could be implemented either for production purpose or on a construction site, to reach a higher level of perfection and quality are for example the PDCA/ Deming cycle, the Kaizen philosophy and the Six Sigma Principles (Kiran, 2017; Maarof & Mahmud, 2016; Swanson, 2014).

As a result, the way of thinking, acting and speaking of a company using the TQM concept is oriented differently from another organization. The whole approach is now oriented toward quality and customers' needs, being either in the industry or the construction field. Some changes of such a method can be viewed in Table 1 below.

From	To
Result-oriented	Process-oriented
Product-oriented	Customer-centred
Internally-focused	Stakeholder-focused
Sustaining imitation/ importation	Innovation/ improvement
"We always did it this way"	"Let us improve to suit the customer"
Routine management	Breakthrough management
Crisis management and recovery	Doing it right the first time

Table 1 – Results before/ after using Total Quality Management (Kiran, 2017)

However, according to Chen & Luo (2014), Quality Management experienced difficulties due to three main factors: product, process and organization. The first parameter emphasises the fact that quality control measures for single products are given in several specifications and regulations that tend to cross-reference each other, which leads to difficult understandings of these codes. Secondly, quality requirements are often controlled on the finished product and not during the other stages of the construction process. Finally, responsibility for quality failures cannot be identified easily since relationships between participants form a complex network. These gaps contribute to inappropriate project management and thus, to quality problems.

3.3. Quality Management for Construction Projects

3.3.1. Strategy according to the Different Stages of a Project

Considering the intended purpose of this report and as the construction industry deals mainly with projects, it seems of high importance to start this section providing an official definition of Quality Management specifically applied for (construction) projects. According to the Project Management Body of Knowledge Guide (PMBOK Guide), "Project Quality Management includes the processes and activities of the performing organization that determine quality policies, objectives, and responsibilities so that the project will satisfy the needs for which it was undertaken" (Project Management Institute, 2013, p. 555).

As well-known, the construction field is quite different from the traditional projects found in other sectors such as the automotive industry, the electronic manufacturing or other mass-producing businesses. It is mainly due to the fact that each construction project is different from one another and thus implies each time different participants, organization or strategies (Rumane, 2013).

Therefore, there are also some differences when applying Quality Management for construction projects. One of them is that Quality Management procedures should be performed equally at each stage of a construction project since all of them are interconnected.

First, considering the long-term impacts of the decisions taken by the Owner and the Design Professionals in the early stages and according to Belvedere, et al. (2000), the Quality Management process should start during the primary stages. Indeed, the quality of a construction project can be enhanced greatly by consulting the Construction Manager as well as the Operation & Maintenance Project Coordinator within the Design Stage. Considerations such as physical plant, control strategies, environment, cost, safety and staffing should be reviewed during discussions or meetings with the Owner and the Design Team.

Furthermore, Quality Management needs to be also performed during the Construction Stage of the project. As the construction evolves, more information is available for the team and the objectives become more accurate. Flexibility to adapt the design to these changes is part of the Quality Management strategy during this phase. As well, regular controls, coordination and planning activities are an important aspect of project quality.

Finally, the Start-Up and Operation Stages require in addition that certain levels of quality are reached. The focus of Quality Management here is to check and demonstrate that the finished facility meets the standards and client's requirements as well as the functional integration of the constructed systems, by conducting test activities, starting maintenances, preparing start-up plans, making corrections and reviewing inspections. Additionally, the O&M staff members should work with the project team at the beginning of the Operation Phase to correct potential defects, ensure optimal maintenance and high project quality levels while being used (Belvedere, et al., 2000).

3.3.2. Strategy according to the Main Participants

Quality Management should also be viewed from the point of view of each participant of a construction project. Project members have the power to take decisions and to act as to improve quality since they are directly involved in the project and have an impact on its quality:

- **The Owner**: he/ she chooses the team members, defines the needs and goals, selects the project's delivery system and establishes the risk allocation among the team. These items can greatly influence quality.

  His/ her tasks, in collaboration with the Design Professional, should consist in defining Quality Assurance and Quality Control (QA/ QC) strategies, standards and procedures that emphasis on the project's intentions.

- **The Design Professional**: this team member has a major effect on the quality of a project and should be chosen carefully. He or she has an impact on the project's design, the design activities and the planning.

He or she should generate and implement a Design QA/ QC Plan and review technical documents from the Constructor. This plan focuses on communication, staff needs and design procedures, among other issues.

- **The Constructor**: this participant follows the terms of the contract and is responsible for the progress of the construction. Depending on the level of involvement and chosen strategies, the project quality can highly vary.

  He/ she should be responsible for developing and carrying out the Construction QA/ QC strategy, which is reviewed by the Owner. This strategy addresses materials, staff members, communication, cost control, scheduling, safety, environment, etc. (Belvedere, et al., 2000).

"Project quality is the result of aggressive and systematic quality assurance and quality control efforts by each participant" (Belvedere, et al., 2000, p. xxi). However, in order for the various team members to apply an appropriate Quality Management approach and to properly fulfil the aforementioned duties, contract and bid documents should be clear in stating quality goals and work to be performed to achieve them. As well, these documents must be fully understood and agreed by all the participants before working on the project (International Federation of Consulting Engineers, 2004).

Chapter Summary

To sum up, both quality and Quality Management procedure have been defined previously, with their importance and purpose. It was seen that quality is necessary and thus need to be improved, and that it is possible to do so, using a specific methodology called (Total) Quality Management and the results that can be expected from such a procedure. Quality Management can directly or indirectly lead to improvements in various fields and for numerous processes. As everything is linked, these general changes lead to better quality of products and services as well as fulfilment of customers' requirements. As the construction field is quite particular, a specific use of Quality Management should be considered in order to produce satisfactory results.

Due to the unpredictability and complexity of the construction field, Quality Management seems to be an essential tool for this sector. Performances of a whole project can be improved, by reaching quality during manufacturing of products and their implementation on-site. However, Quality Management is not the only set of methods necessary to avoid troubles and to reach goals in a construction project. Risk Management is another must-have area within the construction field.

4. Risk Management: General Understanding

The other field implied in the study is going to be analysed in this chapter. The different risks and their consequences will be quickly investigated with the need to use Risk Management, as well as its purposes and advantages, in a general way. Then, the study focuses on the application of this field for construction projects, showing the necessary changes to be performed for these particular situations.

4.1. How to Describe a Risk?

4.1.1. Risks in Construction

Usually, for any project, risks can be divided into several categories which match to project's constraints. In the case of a construction project, the risks are the following:

- **Time delay:** The most well-known risk, being a threat, in the construction field is related to planning overrun: the agreed time of the contract is exceeded during the construction process. For example, time related problems on construction projects seem to be very common in Saudi Arabia: it has been found that during the last thirty years, between 60 to 70% of public construction projects were subjected to delays and the time completion was different from 10 to 30% from the initial contract;

- **Cost overrun:** Moreover, another very common issue is the budget overrun: there is a difference between the initial cost of a project and the final one. For instance, in Saudi Arabia, a total of $147 billion matches to cost overruns of public projects during the last three decades, which represent 80% of Saudi construction projects;

- **Poor quality:** The lack of quality in a project as defined in the previous chapter and such as poor physical performance of a building, lack of aperture or other defects is also a frequent risk;

- **Insufficient safety:** This is or should be the main concern of all managers on a construction site. Due to the number of equipment, tools, machines and engines use, an accident can easily and quickly happen and could lead to injuries, absenteeism or even death;

- **Environmental problems:** Poor weather conditions or even natural disasters can lead to heavy damages towards an infrastructure and thus, there is a need to repair it before continuing the whole project. It can also result in the inaccessibility of the construction site and the incapacity for the workers to achieve their tasks. The construction sector is inextricably linked to weather conditions;

- **Customer:** Two main risks are related to clients. Firstly, customers' lack of experience or knowledge in the construction sector leads to poor decision making as well as possible changes. It happens most of the time during the early stages of a project, but can also occur within the Construction Stage, which drives to complications. Secondly, deviations with clients' needs/ non-achievement of goals is also viewed as a high risk, but is due to the company and not the client itself;

- **Other risks:** Risks linked to subcontractors (bad relations…), to on-site management (wrong instructions…), to governmental institutions (barriers due to regulations…), supply risks (bad material quality…), criminality (on-site vandalism…), etc. (Algahtany, Alhammadi & Kashiwagi, 2016; Wang, Li & Wang, 2011).

Nevertheless, beyond the usual negative perception of a risk and the above harmful impact, risk can lead to beneficial consequences and thus, to enhance project's outputs. Indeed, based on the definition of the PMBOK Guide (Project Management Institute, 2013, p. 446), risk can be viewed as "An uncertain event or condition that, if it occurs, has a positive or negative effect on a project's objectives". As well, it can be found in the ISO 31000: 2009 standard (International Standards Office, 2009), the following definition of a risk: "effect of uncertainties on objectives" and below, the note 1 to entry states: "an effect is a deviation from the expected – positive and/or negative".

Although this situation is not typically experienced in the construction industry due to many reasons and factors, some risks leading to positive outcomes for a construction project can still be mentioned:

- **On-time schedule**: Faster task completion due to workers' efficiency, higher than expected, because well experienced or good working relations among them;
- **Under budget project**: Numerous price negotiations for materials and equipment thanks to highly skilled engineers, leading to increase company's benefits on the project;
- **High quality**: Workers aware of the project's demands and taking care of materials and tasks, which results in enhanced quality levels. Particularly true for projects such as hotel constructions, mansion rehabilitation or castle refurbishments;
- **Full safety**: On-site safety higher than expected due to workers' carefulness, initiative or eager to be protected individually or collectively;
- **Good environmental conditions**: Advantageous weather conditions along the project, allowing quicker task completion, improving workers' moral or faster deliveries;
- **Ideal customer**: Good relations with the customer resulting in the possibility to negotiate the budget, to modify the schedule or to change the payment dates. As well, no major changes occurring from the customer, having experience in construction and objectives well defined and properly understood by the company;
- **Other opportunities**: Good relations with subcontractors, appropriate management due to competent supervisors, no barrier because of regulations whereas the opposite was expected, etc. (Bazin, 2017; Marty, 2015; Pialles, 2015).

4.1.2. A Need to Control Risks

Based on the previous examples and according to Serpell, et al. (2015), a "risk is an uncertainty that can be measured, and uncertainty is a risk that cannot be measured" (p. 202). For Rumane (2013), risk is viewed as "the probability that the occurrence of an event may turn into an undesirable outcome" (p. 101). Risks are inevitable and occur at each stage of a project and for each participant. Risk is also defined as an unpredicted or unexpected possibility, able to lead to negative impacts on a construction project such as time, cost, quality or customers' requirement deviations and other problems (Algahtany, Alhammadi & Kashiwagi, 2016).

However, as previously mentioned, contrary to the previous definitions and the common way the word "risk" is perceived, risks can also lead to positive impacts. When benefits can be extracted from a risk, it becomes an opportunity. If outcomes coming from an operation/ task/ project are unknown, it will be called an uncertainty: there is a possibility for these outputs to be either a risk or an opportunity. Companies, organizations or individuals should be able to recognize opportunities or to turn the unwanted effects of a risk into something valuable for them (Bazin, 2017; Hessellund, 2017).

Nevertheless, and except from the previous definition, risks can result in conflicts between the owner and the producer, a bad view of the company, legal issues, low rate of return for the customer, loss of profit for the contractor or the impossibility to properly achieve a project. They are due to numerous causes, some of them being obvious, but the majority is unpredictable. Since they are not acceptable, risks must be avoided, turned into positive outcomes or, if not possible, they should be transferred, mitigated or accepted but they cannot be ignored. Such a task can be achieved thanks to Risk Management.

4.2. Risk Management Methodology

4.2.1. Succinct Definition

Like Quality Management, Risk Management is a process that is included in the Project Management whole approach and first appeared in the '30s, in the United States, to secure businesses. Due to the importance and complexity of nowadays projects, the goals organizations have to reach and clients' demands, there are high risks of deviations or uncertainties about the fulfilling of requirements, standards, or objectives of such projects, as well as achievement of proper management.

To reduce, mitigate or eliminate threats as well as to take advantage of opportunities, Risk Management seems to be appropriated, by trying to diminish the probability of a risk or trying to increase the likelihood of an opportunity and managing their various consequences on an organization or a project. Due to its success, it has been increasingly used during the past forty years (Abderisak & Lindahl, 2015; Serpell, et al., 2015; Serpella, et al., 2014).

Risk Management is a complete process that takes care of future problems, from the beginning, to the end. This process aims at anticipating the possibility of an unwanted or appreciable event to happen and to have impacts on a construction operation, to define the level of gravity of a risk and to provide measures to manage its consequences and/ or its probability and sometimes its detectability. To sum up, the main goals of Risk Management are to identify, assess and control risks thanks to various sets of methods, able to bring potential problems near zero or to zero, as soon as the risks have been accepted as being part of a project.

Since problems occur very often on every construction project, one of the main goals of a Project Manager is to mitigate these risks and it cannot be achieved properly without an efficient Risk Management strategy, carried out from the beginning of the project, to its end and sometimes even after, during the Maintenance Stage. To do so, knowledges, feedbacks and experience from previous events as well as an adequate methodology are required. However, and once more, even if risks are perceived negatively, they can also lead to positive consequences, which may result in time and money savings within a project. Risk Management can also be useful to detect these opportunities and to take advantage of them (Serpell, et al., 2015; Serpella, et al., 2014).

According to Serpell, et al. (2015), an adequate Risk Management process should focus on the following points in order to be properly implemented within an organization or a project (Figure 2):

- **Communication:** During a project, interactions are needed between all the participants with the use of a common language, to make the risks acknowledgeable for everybody;
- **Organization:** In an organization or a project, it is important to define the persons is charge of Risk Management procedure to ensure a full focus on it. Moreover, Risk Management values should be known and recognized to be part of the culture of a company;
- **Knowledge:** Knowledge and experience in Risk Management are essential to properly carry it out. Skilled employees in this field should be in charge of the procedure, either a Project Manager or a Risk Manager;
- **Integration:** Brainstorming is often necessary to identify all the risks in a project and to involve everybody;
- **Process:** Risk Management should be implemented, integrated and evaluated thanks to proper and various processes, from the beginning to the end of a project, to be efficient.

Figure 2 – An idealistic Risk Management model (Serpell, et al., 2015)

4.2.2. Global methodology and its Advantages

Before going through advantages of such a procedure, it seems necessary to describe briefly the general process:

1. **Risk identification:** First of all, there is a need to foresee potential risk(s) before the beginning of a project and they must be recognized to investigate them before they impact, negatively (or positively), the project. To do so, data on similar projects must be collected to find a list of feared/ desired events;

2. **Risk assessment:** Once the risks have been identified, it is necessary to assess qualitatively and quantitatively them, thanks to feedbacks and knowledge to grossly estimate their gravity/ consequences on the project and the need to minimize them;

3. **Risk selection:** There is a need to identify and select only the risks with the worst impacts (or the opportunities with the most profitable consequences) on a project since they are too numerous to be all considered and some might not be relevant for the project;

4. **Risk analysis:** The risk should then be deeply analysed in order to determine its various root causes;

5. **Risk response planning:** Based on the causes of the potential problem/ chance, solutions must be found and applied to prevent/ increase its occurrence and/ or applied during it;

6. **Risk monitoring and control:** Finally, during the implementation of solutions, careful controls must be carried out to follow the evolution of the risk and to be able to react consequently;

7. **Risk Management process recording:** If the whole process has been successful regarding the management of the risk, it is important to write it down as to reuse it in a future similar case and thus, to save time and money (El-Karim, El Nawawy, Abdel-Alim, in press; Hwang, Zhao & Toh, 2014; Serpella, et al., 2014).

Depending on the technique to be used, all these steps are not always strictly followed and sometimes, more steps are involved. Some examples of Risk Management procedures, mainly used for various situations in both industrial and construction sectors, are the HAZOP study, the MADS/ MOSAR methodology, the SWOT analysis and the Risk Management Plan (Bazin, 2017; Bell & Rochford, 2016; Crawley & Tyle, 2015; Marty, 2015; Perrin, et al., 2012).

According to Abderisak & Lindahl (2015), the Risk Management process is particularly useful to deal with risks and solve problems in both small and big construction projects due to the following advantages:

- Risk Management procedure is perceived as an important tool to improve overall performance of a project because problems/ opportunities can be anticipated;

- Moreover, it is essential for increasing cost performance and money savings of a construction project;

- In addition, it is considered as an important procedure to improve project scheduling, to decrease project time and to meet deadlines;

- Risk Management can also be useful to deal with quality concerns and performance;

- Finally, over time, the implementation of such a procedure could outweigh its cost by bringing all the aforementioned benefits.

However, in order to properly perform Risk Management and to take advantage of its various benefits, this tool should be strongly implemented and developed in the culture of big, but also small companies, to become a standard and be used in every project. Nowadays, Risk Management is mainly used in big projects because of their high cost and challenges, but would be also useful in small projects due to their tight schedule and budget.

Moreover, proper knowledge or training in this field and experience from the past are essential to allow such a system to work as well as communication between all the participants within a construction project (Hwang, Zhao & Toh, 2014; Serpell, et al., 2015).

4.3. Risk Management in the Construction Industry

4.3.1. Conventional Techniques Adopted

A formal description of Risk Management can be given, as well when specifically applied in the case of (construction) projects and according to the PMBOK Guide: "Project Risk Management includes the processes of conducting risk management planning, identification, analysis, response planning, and controlling risk on a project" (Project Management Institute, 2013, p. 555).

Just like in the case of every project, construction projects are subject to risks, at every stage and for all participants. However, due to their particular nature, building operations lead to additional risks that are not encountered in other industries such as on-site safety, participants' communication, outside working conditions or environmental and social/ neighbourhood issues… That is why, an appropriate Risk Management strategy should be implemented. For construction projects, usually the various members use a range of typical techniques that are suitable for managing risk in this field. Therefore, each participant should:

- Evaluate the project before any agreement with the other parties, in terms of feasibility and potential risks such as cost and revenues, requirements, time constraints, safety, environmental conditions and impacts, difficulty, public profile…
- Gauge the project team members as to appreciate the level of risk they are willing to assume, taking as a basis: reputation, financial strength, performance, staff experience, background information in terms of litigation, safety and relationships…
- Carefully choose, usually done by the Owner, and analyse the project delivery system and the risks associated with their legal roles. Design-bid-build, design-build, construction management, turnkey… All are different types of delivery system and therefore lead to different risks.
- Focus on the contractual arrangements available to minimize (or increase) and allocate risks, before the beginning of the operation: project scope, statement of actions, participants responsibility, indemnification in case of an unwanted event…
- Develop a plan to allocate and manage the potential future risks before any commitment to the project and the parties. The Owner, in collaboration with the Design Professional, allocates risks based on the most capable team member to accept and manage it.
- Be performant while working with the project in terms of task completion and avoidance of delays, delivery of high quality products and services, on-site total safety, regular communication with the other parties…
- Avoid conflict as much as possible or if not, negotiate or solve them amicably, by maintaining a team approach in which each participant is motivated, knowledgeable and willing to solve quickly and fairly an issue (Belvedere, et al., 2000; Cretu, Stewart & Berends, 2011).

4.3.2. Specific Tools to be Used

In addition to the aforementioned common strategies, other particular Risk Management tools can be used by the participants in a construction project. However, before applying them, potential benefits or losses due to these methods must be evaluated by all the parties:

- **Insurance:** Because construction projects involve a large number of participants and dangers, insurance arrangements can be vital. In this case, contract documents specify the type, the amount of insurance coverage and the parties to provide and pay for it. They are usually used for general liability, property damage, engine operations or compensation for the workers and can cover the different participants: insurance needs for the Owner, for the Design Professional, for the Constructor or for the Design-Builder.

- **Bonds:** Those are financial guarantees provided by third parties and are not insurance policies. Corporate commitments or staff assets can sustain a bond, which can be found in construction projects as bid bonds, used to protect the Owner from budget overrun during construction; performance bond, which protects the Owner from completion defaults; or payment bonds, for protecting the subcontractors and suppliers from not being payed.

- **Warranties:** Chosen to ensure a certain quality level of materials and services delivered by a construction company or suppliers. The warranties might be specified in a contract and can be general, such as a warranty that the project will run correctly for a given period of time, or specific like a warranty that an equipment will produce the required results (Belvedere, et al., 2000; Cretu, Stewart & Berends, 2011).

Chapter Summary

To summarize, the various risks and their impacts in the construction field as well as the need for Risk Management, its purposes and its various advantages to manage them has been investigated previously. Moreover, various common procedures that could be implemented in numerous fields to control risks have been provided as a general understanding. Risk Management can be viewed as a universal powerful method to identify, bypass, correct numerous problems or enhance opportunities and to reach objectives, using various tools. Some adjustments would however be necessary to ensure the efficiency of such a strategy for the construction sector.

Quality Management can also be used to achieve goals, but is mainly focused on quality. However, future potential problems linked to poor quality are not always obvious or cannot be easily found as well as relevant solutions. To properly identify and solve them, it seems obvious that Quality Management cannot lead to quality incomes without the use of Risk Management and Risk Management cannot solve quality problems without Quality Management. These two fields are inextricably linked together: the dependencies between them will be examined within the next chapters, through an analysis of the literature review and a case study.

5. Theoretical Links between Quality and Risk Management

Due to the lack of information that can be found in papers regarding the links between Quality and Risk Management and in order to provide a better understanding of these two fields, the following chapter aims in analysing the data from the previous literature review and providing the links between Quality and Risk Management as to clarify them. Based on these relations, a simple method will be developed as well, as to use Quality and Risk Management when merged together.

5.1. Complementarity of Quality and Risk Management

5.1.1. Roles Shifting

First of all, it can be stated from the paper of Chen & Luo (2014) that because poor quality levels lead to numerous and various risks able mainly to threaten a project, such as building collapse and safety issues, increasing quality will lead to mitigate these risks. Thus, applying Quality Management will improve this quality, which will reduce the number of unwanted events. Therefore, beyond quality, Quality Management is necessary to control risks in a construction project and as a conclusion, Quality Management can be viewed as a Risk Management strategy which focuses on quality matters and their consequences (Figure 3).

However, the quality of a project can be greatly influenced by chances or risks. Risks or threats, such as human mistakes like wrong material selection by supervisors, workers' misinterpretation of how to properly complete a specific task or lack of carefulness can lead to decrease quality levels. The casting of a concrete wall can be taken as an example, being known by the author from his previous practices: there is a need to carefully, slowly and continuously vibrate the concrete mixture as it is poured.

The lack of seriousness or workers' poor experience while performing this task can result in dramatic effects, noticeable only after removing the frameworks. Because the mixture is not homogenous, there are more gravels at the bottom of the wall and sand with water at the top, leading to an inappropriate wall surface appearance and decreased mechanical properties, which means poor quality of the work performed. Now, if the same level of carefulness is kept for all the exterior walls of the building and the concrete needs to be visible for architectural purposes, the whole project quality is going to suffer.

On the other hand, chances or opportunities, like suppliers willing to make valuable discounts for big projects, proximity of the construction site with a concrete plant or workers' seriousness and eager to perform well are non-negligible parameters that can enhance project quality and performance. For instance, old heritage buildings and monuments refurbishment or rehabilitation are common projects in France. For these demanding projects, at least in the French construction industry, usually workers/ artisans are keener to perform well and are much more concerned by what they are doing as well as motivated.

A company might want to look for and to exploit such an opportunity, asking its more motivated and skilled workers to make extra hours or to undertake the most difficult tasks. As a result, tasks are completed faster, with higher levels of perfectibility, and employees are more willing to work extra time. Even if very often for such projects, the workers hired are much more experienced because there is a need for everything to be almost perfect and the client's budget usually is sufficient, it appears that the staff members feel interested by the project they are working on, being part of their country's heritage.

This situation, which might not be expected initially by the Project Managers, allows more flexibility for the project in terms of time and money, and therefore, leads to improve overall quality and client's satisfaction. The company should take advantage of this situation along the project to successfully reach the objectives or even to go further.

This example is coming from the author's own experience, during one of his internship, as a worker, on the Eiffel Tower refurbishment in 2013. By talking with some artisans, he discovered that this project was of great value for them because being iconic and challenging, which encouraged them to be more meticulous. The operation was undertaken by the contractor Plendi, a subsidiary of the French group Vinci, specialized in heritage and luxury projects. The members of this company are only artisans who are passionate by their profession, which is the reason why they are willing to deal with some of the most demanding construction projects.

Even if Quality Management is used to improve quality levels, there are still some threats or opportunities able to influence quality, but that are not linked to it directly, such as time delays and tight budget or workers' high motivation and suppliers' good relations. Consequently, these hazards/ chances cannot be managed with Quality Management but only with Risk Management which deals with a wider range of risks, according to the definition given by Serpella, et al. (2014). Because these uncertainties will impact quality, mitigating them is somehow part of a Quality Management approach. Therefore, Risk Management can also be viewed as being a Quality Management strategy, specifically applied to reduce any kind of threats (Figure 3).

Figure 3 – Upside-down roles of Quality and Risk Management (Self-produced)

It should be carefully noticed that in both these situations, Quality or Risk Management should not be put apart. Indeed, saying that Quality Management is a Risk Management approach focused on quality, but with the same effects as traditional RM, does not mean that RM is unnecessary. In fact, it is still important as to avoid threats against quality, but it will not improve it, which is done by QM. The same pattern is found in the reversed situation: stating that RM is a Quality Management tactic for risks does not mean that QM should not be considered because it will help mitigating risks by improving quality, but it will not avoid problems regarding this quality.

Nevertheless, it does not mean as well that Quality and Risk Management are inseparable. Both can bring separately valuable advantages for a project, service or customer. For example, for a small project like a single house, leading to a low number of risks with a few impacts, implementing a Risk Management strategy might be useless and time consuming in regard to the benefits procured. But, a good level of quality is still necessary to meet the client's expectations and thus, Quality Management too.

As well, and based on explanations given by Gallego Navarro (2017), it can be said that for a big industrial construction project (e.g. factory construction) with numerous constraints such as time and budget issues, quality may not be the first priority so Risk Management can be used alone. However, in both situations, the use of QM and RM at the same time could lead to higher efficiency and better results in terms of needs satisfaction and project performance enhancement.

As another evidence that Quality and Risk Management were used separately, QM was first in use in the 80's while RM is a pretty new standard. At the beginning, inadequate processes or poor design led to low quality levels and so Quality Management was sufficient to solve these issues as it emphasizes modification of processes (Gallego Navarro, 2017). Due to world demands and constraints evolution, poor quality is nowadays related to a higher number of factors and even if both Quality and Risk Management were improved since then and can still be used independently, sometimes they might not be sufficient when implemented alone. For achieving better results, merging Quality and Risk Management together can be appropriate.

5.1.2. Fields Supplementation

Moreover, as mentioned by Padhy (2013) and Janipha, Ahmad, & Ismail (2015) in their papers, quality can be defined as being the satisfaction of implied or stated needs. These requirements focus mainly on budget, schedule and defined project scope, according to Rumane (2013). Therefore, the purpose of Quality Management is to improve quality levels as to ensure that those needs will be met. In other words, the objective of (Project) Quality Management is to ensure that the project reaches its goals.

As well, by reaching stated objectives, Quality Management focuses mainly on client satisfaction. Indeed, since project's goals are defined by a client, achieving them will ensure customer's approval. For example, if a modification is required by a customer before or within an operation, service or project, appropriate changes will be made consequently, thanks to adjustment of processes, procedures, documents, standards… Beyond the satisfaction of stated needs, the fulfilment of implied requirements such as on-site safety and building minimal mechanical properties, is a QM purpose that is not going to lead directly to the satisfaction of a client but the non-achievement of these necessities will result in client deception, which is a situation to be avoided imperatively.

In addition to the fulfilment of stated or implied demands, Quality Management can be used to meet higher perfectibility levels than expected or than required. It helps reach aims beyond the minimal project's objectives in an attempt to keep a valuable client on the long run, such as a city council, a commune or a governmental institution, because able to offer numerous opportunities or contracts for a company. Therefore, QM can be applied to reach the unexpected or to perform extra operations that are not mandatory, by changing the company policies or culture, such as task are completed with more seriousness and meticulousness and by training or sensitizing employees to perform better that what they were used to do.

Client satisfaction is thus reached by boosting quality and quality is enhanced thanks to Quality Management, which aims at improving the way a business operates and motivating the workforce. To do so, QM intends to innovate, as to surprise a customer and to gain in competitiveness, to increase productivity, as to satisfy customer growing needs, to improve customer services, as to let the client know that his/ her opinions are taken into consideration, and to decrease defects, as to limit users' complaints (Figure 4).

Companies have nowadays understood that it is essential for them to offer good quality services and products as to ensure customer full satisfaction. If clients are not contented, they will probably buy and trade with competitors. While improving their quality levels, businesses need to make sure that their suppliers have as well improved their own performance.

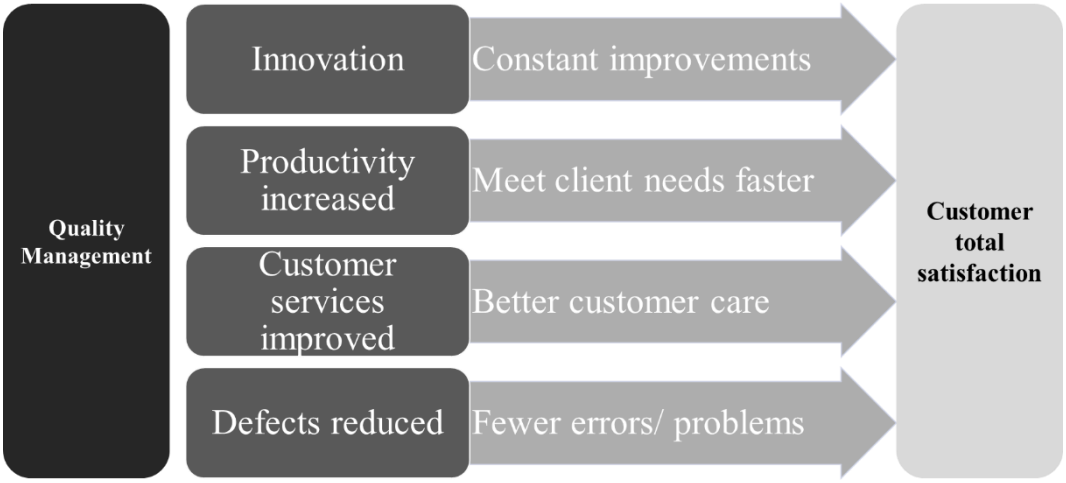

Figure 4 – How Quality Management emphasises on customer satisfaction (Self-produced)

However, this situation brings some questions: are the needs to be fulfilled the ones requested by the client? Is it certain that no deviation will appear while trying to reach these requirements? Based on the work of Serpell, et al. (2015) and explanations given by Bazin (2017), it can be stated that the goal of Risk Management is to guarantee that these needs are fully understood and to avoid nonconformity. In other words, as well, the (Project) Risk Management aims at reducing both probability and consequences of risks that would lead to deviations from the project goals and, at the same time, aims at increasing the probability and impacts of opportunities that would help reaching the project objectives.

For example, improving quality levels will result in less rework, less maintenance, less revisions and good product delivery, which means meeting the deadlines, fulfilment of the budget and achievement of the goals, leading to client's needs satisfaction. Nevertheless, Quality Management does not address problems such as: is the quality intended to be reached the one requested by the project or customer? How to make sure that no threats will affect the path toward quality? Is the budget in accordance with a proper focus on quality? Is the project's schedule appropriate to allow spending time on quality improvement? All these issues should be studied before taking decisions and are the concern of Risk Management.

By reducing threats and increasing opportunities, Risk Management emphasizes mainly on contractor's financial success. In fact, and first of all, the project is more likely to follow the initial schedule that was agreed with the client or even to finish before the handover. It will surprise the client, prevent penalties for late delivery and avoid last-minute rushes, including a necessity to hire additional employees or interim and extra hours to be worked, during the day or even the night.

The conclusion of this first risk mitigation, is a gain of money for the company on this project or at least, no or less losses. The project can therefore be considered as being beneficial or valuable and will lead to contractor's success, in terms of financial benefits and client satisfaction, which will result in more chances to get future contracts and money with that customer.

Secondly, thanks to the implementation of Risk Management, threats directly related to money can be avoided which will lead to follow the planned budget or even to go under it or at least to avoid as much as possible important and unnecessary expenses, resulting in a project good financial health. On the opposite, opportunities can be enhanced greatly, as to make non-negligible savings.

Thirdly, hazards linked to health & safety, environmental issues or supply problems can be bypassed, which is synonymous of less extra spending and therefore, lead to a profitable project for the contractor. Finally, a project's financial success comes from appropriate task completion, also known as the so-called “doing right the first time” which matches with suitable levels of quality. This way, rework will be avoided, as well as the need for additional labour force to make it, and thus, in savings.

To allow such a reduction of dangers or increase of chances, Risk Management focuses on anticipation of potential risks, what could happen, in which circumstances it can occur and how to make things changing positively or how to avoid the worst. As well, regular controls, checking and recording processes lead to avoid potential deviations from satisfactory quality, essential safety and required time and money contractual arrangements (Figure 5).

A project that is considered as being an asset for a company, because leading to positive outcomes and ensuring monetary achievements, will be profitable and somehow, sustainable for this business. Nowadays, at least in France, and mainly due to the crisis, a construction project that leads to a neutral balance, no benefit and no loss, is viewed as good project and companies tend to fight to win such a contract because machines are running, employees are working and the company stays on the market.

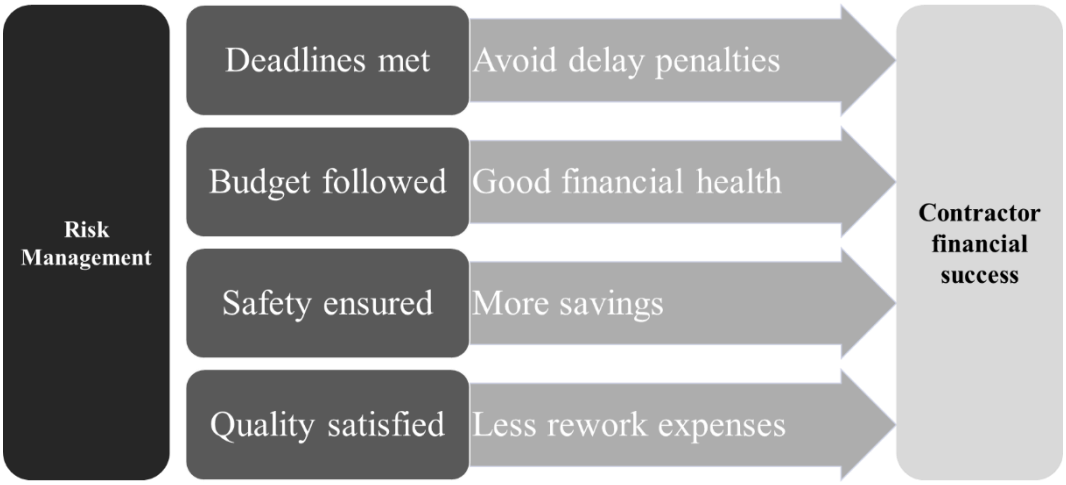

Figure 5 – Focus of Risk Management on contractor’s financial success (Self-produced)

As well, while Quality Management is used to plan and control the aims of a company, Risk Management is necessary to find suitable goals for this company, based on a risk analysis, in terms of market evolution, potential competitors, clients’ expectations, new regulations… which reinforces this complementarity (Gallego Navarro, 2017).

Finally, it should be mentioned that the combination Quality + Risk Management is more efficient than implementing these tools independently from each other. Indeed, trying to eliminate (or to increase in the case of an opportunity), mitigate or transfer a risk can be done at the expanse of quality because for a Risk Manager, the main priority is not the quality of the project but the resolution of the problem itself (e.g. Less focus on interior finishing to compensate time delays). Therefore, Risk Management could lead to a decrease in quality levels. In this situation, Quality Management would ensure that this quality stays at an appropriate or at the required level.

The same problem is found in the reverse situation: a Quality Manager is more likely to focus on quality improvement than on risk resolution which could result in issues for the project (e.g. Budget overruns because of expensive, unnecessary materials used for the exterior walls of a building). Risk Management's goal is to prevent such a situation to happen. In order to extract the best advantages from both worlds, Quality and Risk Management should be integrated together, for example, thanks to continuous and efficient communication between the Quality and the Risk Managers of the project.

As a consequence, it should be mentioned that Quality Management and Risk Management are complementary and somehow, dependent from each other. QM can be viewed as being part of the RM strategy, but RM can also be seen as a fraction of QM since QM deals with improvement of quality only and RM deals with avoidance of threats toward quality.

Both of these fields are essential and should be used at the same time to maximize the results of a project, an organization… It would not be that efficient to only consider the use of one tool without also considering the other. Nevertheless, and once more, QM and RM are interconnected, but they are not totally inseparable: benefits can still be extracted from both these fields, independently from each other.

Additionally, and according to Gallego Navarro (201?), one of the most difficult type of risks to manage is the one for which an organization or project team is aware that it may happen, with consequences that are known, but whose causes are unpredictable. These risks are commonly encountered in operational areas such as construction projects. Quality Management can help to address this issue since, first, even if these risks are totally random, they are most likely to be related to poor management of essential processes. Quality Management is indeed well-known to manage processes efficiently.

Secondly, because operational risks are extremely random and can happen at any time and anywhere within an organization or a project, they cannot be managed by only experts or top managers, but should instead be identified and controlled at all levels (e.g. operators). Such a way of thinking consists in implementing a risk-solving strategy that is widespread throughout a company, which requires cultural and organizational changes. Once more, Quality Management is suitable for the integration of processes linked to organizing and culture (Gallego Navarro, 201?). Therefore, this tool seems appropriate to help Risk Management solving risk-related problems.

At the same time, because of its nature, Quality Management is known as being a holistic approach which tends to improve or modify all processes within an organization (Bazin, 2017; Gallego Navarro, 201?). However, it needs to focus more on quality concerns and risks that have the biggest impacts on a company or a project.

There is a need for this method to prioritize the use of resources according to the most important or urgent issue to be solved by an organization. Such an approach is considered by Risk Management and represents in fact, one of the first stages of the whole methodology (Risk Selection). As a consequence, Quality and Risk Management can, somehow, "learn from each other" or can be used jointly.

To sum up, these complementarities, which match to the first link found between Quality and Risk Management, can be seen as a wheel, which could be called the Quality and Risk Management Cycle (Figure 6). Quality Management helps improving quality, which lead to decrease risks and therefore allow to fulfil part of the Risk Management strategy. At the same time, Risk Management is a tool used to reduce risks, which lead to less deviation from high quality levels and thus, help reaching part of Quality Management objectives.

Figure 6 – The Quality and Risk Management Cycle (Self-produced)

5.2. Similarity of the Management Tools

5.2.1. Same Main Goals

Another important relationship that was extracted from the literature review, is the fact that Quality and Risk Management are almost similar, as they both serve the same primary purposes. Indeed, according to Gallego Navarro (201?) and Kiran (2017), Quality Management is an approach cantered on solving quality issues and improving quality of services or products, in order to meet specific expectations, needs or requirements for a project or a customer.

As well, Risk Management is a strategy focused on mitigating threats affecting a project, service, product or turning out risks into opportunities, as to best fulfil necessities of a project or client (Serpell, et al., 2015). Therefore, both Quality and Risk Management methods emphasis achievement of project objectives or customer satisfaction. They have different roles, but the same goals (Figure 7).

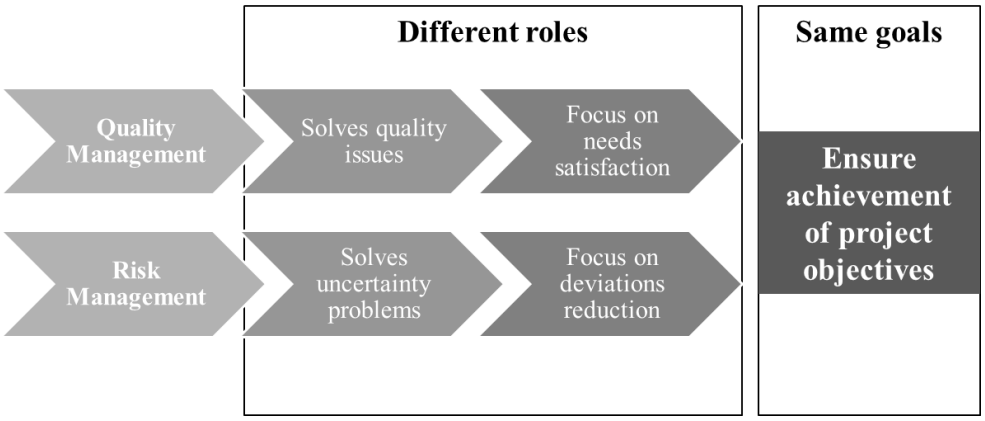

Figure 7 – Quality and Risk Management emphasis (Self-produced)

Moreover, the same idea is reinforced by the definition of quality and risk, both given by the International Organization for Standardization. Indeed, and according to the ISO 9001 standard, "quality is the degree to which a set of inherent characteristics fulfils requirements" (International Standards Office, 2015) and as per ISO 31000, "risk is the effect of uncertainty on objectives" (International Standards Office, 2009). Nevertheless, a requirement and an objective have, to certain extents, the same meaning and therefore, according to the ISO institution, Quality and Risk Management have similar aims: to respectively improve quality or to mitigate risks, as to reach desired or stated requirements/ objectives.

5.2.2. Equivalent Key Steps

In addition, if the goals of Quality and Risk Management are identical, the methodology to reach them is as well comparable, based on the description provided by Kiran (2017) and Marty (2015). The key steps for these two fields of study, as described in the state-of-the-art, match to their holistic approach in an attempt to meet desired levels of quality and risks. For each step, the procedure is slightly different, but the main aim reminds the same: in both Quality and Risk Management, causes and effects are analysed to determine the necessary preventive and corrective actions to be undertaken as to solve the issue and to stay or get in control (Figure 8).

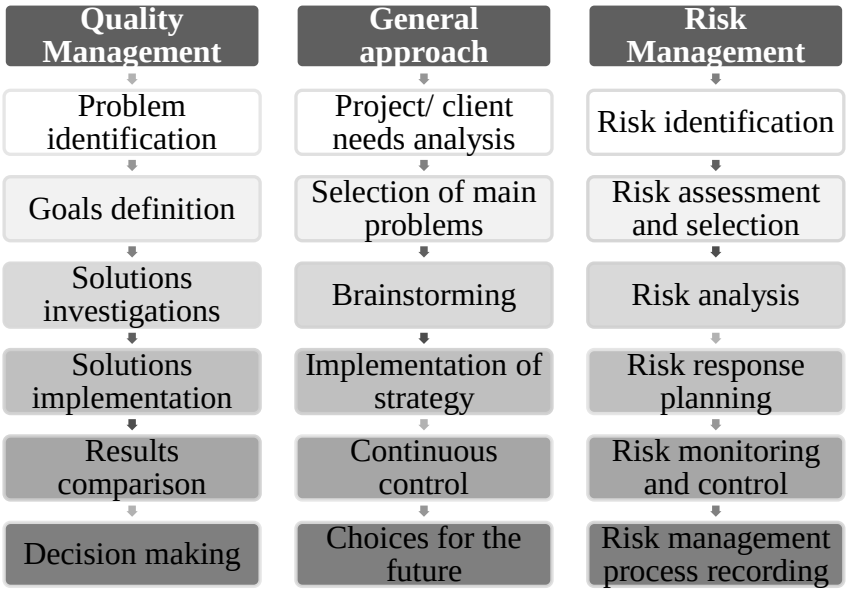

Figure 8 – Same problems approach for Quality and Risk Management (Self-produced)

Once more, even if Quality and Risk Management are similar in their purposes and way of reaching them, both are strictly necessary, separately or together, since still some differences remain: they deal with different issues (quality and risks) and with a different approach. Having two tactics can be beneficial sometimes to solve the same problem because the outcomes are different or a method remains appropriate while the other is not.

5.3. Coherences in the Construction Field

5.3.1. Quality and Risk Management along the Project

The previous boundaries investigated between Quality and Risk Management match mainly with common links, coming from the application of these tools not only for the construction industry, but for all sectors in general. It seems now appropriate to repeat this process in the case of the construction sector, based on the information found in parts ***3.3.*** and ***4.3.***, since Quality and Risk Management need some adjustments in order to be efficient in this field and to reach desired goals.

Indeed, in these sections, it was first discovered that both Quality and Risk Management would be more efficient if used during all the steps involved in a construction project, from the Design Stage to the Maintenance Phase. This statement is another link in favour of the similarity of these methods and proves that it applies also in the construction field (Figure 9).

In fact, based on Belvedere, et al. (2000), Quality Management should be implemented for each stage of a construction project. During the Design Stage, as to prevent the long-terms impacts due to early decisions, consulting key participants that will be involved in the Construction and Operation Stages. Within the construction phase as well, to manage changes resulting from higher amount and more accurate information, controlling, coordinating and planning the work. Finally, through the Operation Step, to verify the conformance of the facility with the requirements and expectations, testing, maintaining and reviewing the infrastructure.

As well, Risk Management must be used for the whole duration of a construction project, according to Belvedere, et al. (2000) and Cretu, Stewart & Berends (2011). First, it should be applied before the project starts, for evaluating it, the team members, the delivery system, the contractual arrangements and for developing a Risk Management and Allocation plan. Secondly, during the project itself, focusing on performance and task completion and avoiding conflicts with the other members.

However, an important point needs to be added regarding the interconnectivity between Quality and Risk Management, when used to carry out (construction) projects. After some careful reading of the PMBOK Guide (Project Management Institute, 2013) as well as an analysis of the comments made by Mr. Bazin (2017) during one of his lectures at the VIA University College, the following statement can be drawn: Quality and Risk Management are not fully connected or used together along the entire project.

Indeed, and as mentioned previously, Quality and Risk Management are important and should be merged together during the project itself, from the Design to the Maintenance Stage. If the achievement of project objectives is ensured by Quality Management, the probability to reach them and the action plan to be followed in to order avoid deviations is the role of Risk Management. Based on this definition and according to the PMBOK Guide, QM and RM are inseparable during the project itself.

But Risk Management is used alone and independently of Quality Management before the project starts since, during what could be called the Initiation Stage, the objectives of the project are not well defined because the company still needs to decide to either accept the project or not, based on a risk/ benefit analysis, which is undertaken using Risk Management. Quality Management can then be performed once the project has been accepted and its objectives are clear, as well as Risk Management in parallel.

5.3.2. Quality and Risk Management among the Participants

It was also found in the literature review that both the management procedures should be carried out by all participants of a construction project, as to lead to better results. This point reinforces once more the similarity between Quality and Risk Management, and in the case of the construction industry (Figure 9).

Indeed, as mentioned before, Quality Management should be considered by the Owner, selecting the most appropriate team members and delivery system, defining the project needs and allocating the risks. It should be considered as well by the Design Professional, managing accurately the project design, design activities and planning. And finally, by the Constructor, carefully following the terms of the contract, being deeply involved and choosing appropriate strategies (Belvedere, et al. 2000).

As well, Risk Management could be implemented by every participant of a construction project since all should evaluate the project in terms of risks, gauge the team members and avoid conflicts. Additional missions are undertaken by each participant: the Owner is responsible for choosing the project delivery system, the Design Professional is in charge of allocating the risks depending on the participants, and the Constructor deals with tasks adequate completion and on-site problems (Belvedere, et al., 2000; Cretu, Stewart & Berends, 2011).

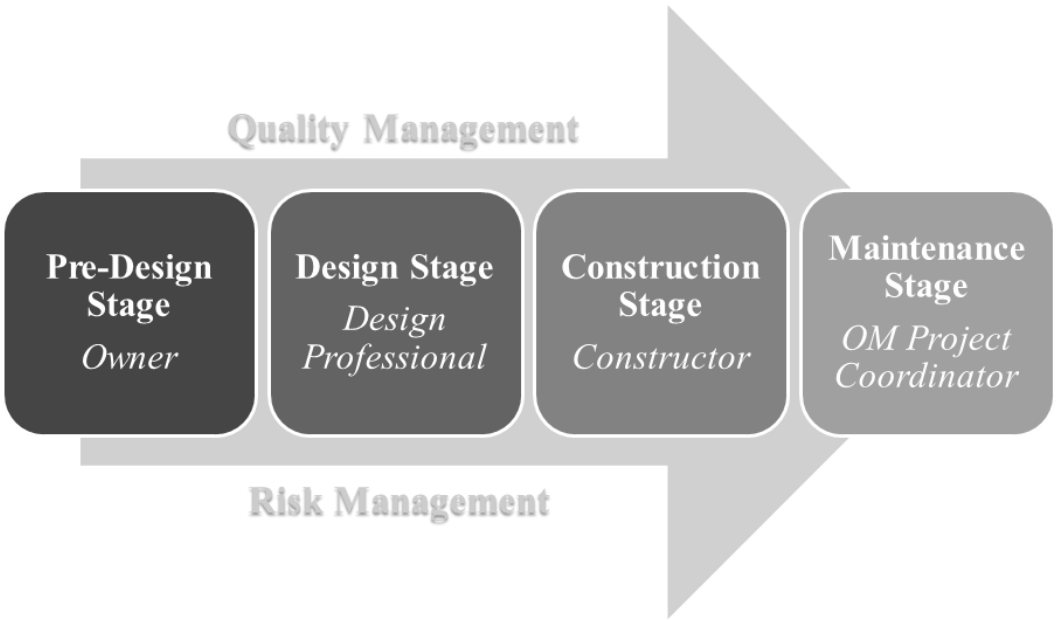

Figure 9 – Quality and Risk Management for construction projects (Self-produced)

5.4. Potential Synergies of the Management Systems

5.4.1. Recapitulation of the Links between Quality and Risk Management

The similarities, links and boundaries were presented and detailed previously and a brief introduction on the need to merge Quality and Risk Management together was given. It is now high time to recap these coherences as to highlight even more the necessities to use both managements systems in parallel and to provide an outline of method to be followed when trying to combine them. Construction projects, or even any project in general, could benefit from such a synergy.

Along the past three sub-sections, various common points between Quality and Risk Management were identified (Figure 10):

- **Complementarity n°1:** Quality Management can be considered as a Risk Management strategy specifically applied to control quality meanwhile Risk Management can be viewed as a Quality Management tool to control risks;
- **Complementarity n°2:** Quality Management ensures fulfilment of project's objectives whereas Risk Management intends to avoid deviations from these requirements. At the same time, QM focuses on client's satisfaction while RM concentrates on contractor's financial success;
- **Resemblance n°1:** The purpose of both Quality and Risk Management is to achieve project's aims or client's demands;
- **Resemblance n°2:** The method of Quality and Risk Management to meet customer and project's goals is similar, at least in terms of key steps;
- **Resemblance n°3 (in construction):** Quality and Risk Management are used the same way when applied to construction projects: implemented by all participants and at each stage.

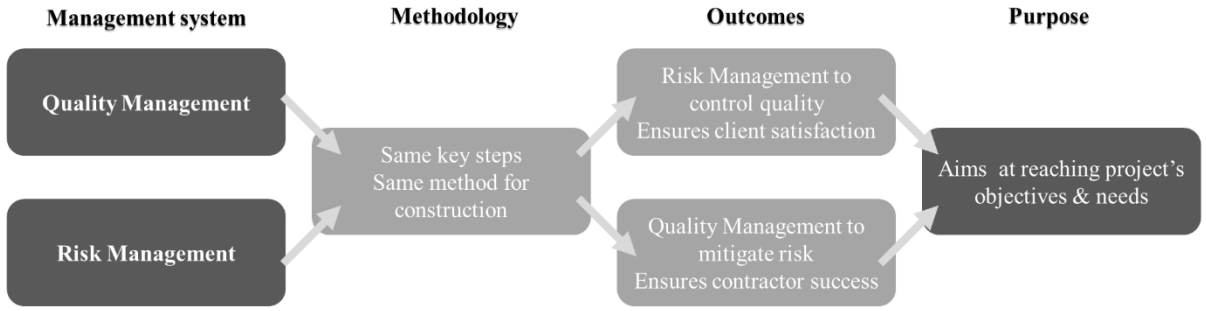

Figure 10 – Overview of Quality and Risk Management systems (Self-produced)

5.4.2. Consideration of the Systems' Relationships in a Project

From the aforementioned ideas, a methodology could be extracted as to consider Quality and Risk Management as a single entity, or a unique management approach. This procedure or a similar one should be analysed and implemented for each new project:

- **Step 1 – Project Initiation/ Pre-Design Stage:** The client first takes the decision to launch the project, after a favourable Quality and Risk Management analysis, aiming at investigating the future potential risks and quality concerns of the project. As well, it will help him choosing the right Design Professional. Finally, the client, in collaboration with the Design Professional, conceives the first drafts and plans of the project. Applying Quality and Risk Management will assist him to reach his/her objectives and to avoid deviations in terms of budget, schedule, quality…

To do so, it is necessary for the client to ask himself the right questions, taking as a basis the desired project/ future project:

- What are the benefits for the Owner/ third parties of carrying on the project?
- What are the risks of launching such a project? What hazards directly impacting the project and its surrounding social/ physical environment should be controlled? What opportunities should be taken as an advantage for the project? What are the consequences and how to manage them?
- What levels of quality should be expected from such a project? What quality problems might appear along the operations? What are their impacts and how to enhance quality?
- Is there any risk going to directly affect the project quality and that would result in creating new threats, making previous risks worse or increasing opportunities? How to manage quality/ risk concerns?

Answers to the above questions will be found while implementing a Quality and Risk Management tool jointly. However, implementing such a strategy before the project starts would actually not lead to "physical"/ visible results, but to better anticipate and foreseen random events/ deviations/ problems, which might help the client take decisions on launching the project or not and if so, what are the best options to ensure its proper completion.

- **Step 2 – Project Design:** The project schedule, detailed plans, features and characteristics are defined by the Design Professional, based on the client's requirements and the project objectives become clearer, with the willpower of mitigating risks and controlling quality along the project thanks to a Quality and Risk Management approach. Additionally, a Constructor who fits the project's goals will be chosen, these aims being well defined and stated, with an appropriate methodology to reach them.

Here, the strategy consists for the Design Professional to answer the following questions, based on client's needs:

- Is the schedule appropriate in terms of task distribution, duration or allocation? Is the task sequence/ programme logical?
- Are the plans following client's requirements? Are they clear/ detailed enough, such as they will be understood easily by the engineers/ constructors and mistakes will be avoided?
- Does the project design, modelling, appearance match to client's wishes? Is the design feasible technically?
- Are the project objectives and purposes well defined, specific and accurate? Can it be possible to reach them?

The answers to these questions are reached using the same strategy as previously mentioned. The outputs will be however different at this point of the project. Implementing what could be called a Risk-Quality Management approach would result in better control of unforeseen or planned situations that might happen during the Design Stage as well as anticipation of potential concerns/ opportunities which may occur during the Construction Phase.

- **Step 4 – Construction Stage:** The Constructor will need to apply Quality and Risk Management together to make sure optimal levels of quality are reached, minimal levels of hazards are ensured and all opportunities are taken during building operations. It means reduction of health & safety threats, faster task succession, work completed properly, less environmental impacts, fulfilment of regulations, enhanced communication among the team…

Such enhancements are reached by the Constructor by first taking into account the next set of questions:

- Are the construction methods in accordance with the budget fixed by the client, the schedule determined by the Design Professional and the client, and the plans provided by the Design Professional?

- Are the proposed strategies suitable to allow optimal task completion along the project? Is quality going to be fully integrated within the Construction Stage?

- Are safety, environmental, regulatory and social risks recognized as being part of the operations? Is the Constructor aware that they are able to result in negative impacts?

- Is the Constructor going to ensure that solving traditional issues linked to construction will not lead to less focus on project main goals?

Once more, Quality and Risk Management together will result in addressing these problems, the same way as previously but for the Construction Stage only. The results are similar, but applied to this point of the project: mitigation of key issues relative to this specific phase and that were not solved within the Design Stage and anticipation of future matters linked to the next step, the Operation & Maintenance Stage.

- **Step 5 – Maintenance & Operation Phase:** Finally, the Operation & Maintenance Project Coordinator could take advantage of the combination Quality + Risk Management since quality levels would stay the same as the ones aimed before the project and reached after completion, and this, all along the life of the building. As well, maintenance problems would be reduced as to ensure full operability of the construction.

Aforementioned results will be achieved while integrating the next interrogations to future strategies:

- Is the quality of the project as it was after completion going to stay the same during the Operation Stage? What parameters could affect it during the use of the project (users, operations, external factors…)? How to maintain it all along the building life?

- What threats can occur during the project utilization and that are able to disrupt operations? Is there any risk remaining from the construction or previous stages that could be addressed within the present phase?

- How maintenance is going to affect the finished building, such as it stays as much as possible with the same state as it was straight after completion? Can maintenance lead to deterioration of the project?

- If necessary, how to improve the current state of the finished project by making still needed corrections leading to positive results or to improve it even more?

The Quality/ Risk Management methodology to be used here can assist the Operation & Maintenance Project Coordinator to solve issues related to this stage, but also problems that were partially solved or not resolved at all during the previous phases as well as anticipating and addressing oncoming concerns until the end of the project's life.

Finally, in order to achieve the entirety of the goals mentioned all along this sub-chapter, the methodology could be to use traditional Management tools, but with a different approach. For instance, a Quality Management strategy such as the PDCA Cycle, applied to general risks and not only towards quality, would result in reducing dangers/ boosting chances and enhancing overall quality. As well, a Risk Management method like the Risk Management Plan specifically focused on quality and not only on general risks could be beneficial for the project the same way as the previous approach.

As well, merging Quality Management technics with Risk Management methods means taking advantage of the outputs of both the systems plus to benefit from additional positive consequences. It would be suitable to combine QM tools like Cost-Benefit Analysis, Control Charts, Cause and Effect Diagrams or Design of Experiments with RM tactics such as Information Gathering Methods, Contingent Response Strategies, Probability and Impact Matrix or Quantitative Risk Analysis and Modelling Techniques.

To conclude and as a result, it should be stated that applying both Quality and Risk Management together would affect each and every aspect, stage and participant of a project, which means that they take part and positively impact all sub-systems of the Project Management strategy. Both systems can be viewed as being essential parameters or even as being the core of Project Management (Figure 11).

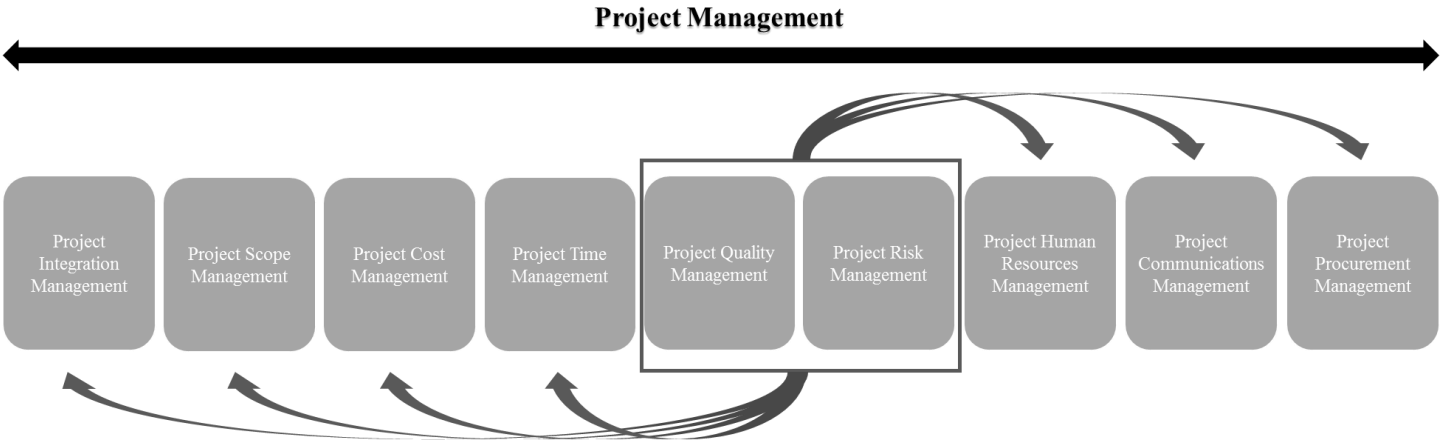

Figure 11 – Quality and Risk Management along Project Management (Self-produced)

Chapter Summary

In this section, it has been seen the relationships between Quality and Risk Management, based on the literature review written in this report (Figure 12). Papers previously mentioned and talking about either Quality or Risk Management were analysed and used as references to fill the gap, which was the absenteeism of information regarding potential theoretical links between these fields of study. The relationships discovered within this investigation were first, a complementarity between Quality and Risk Management, in terms of role and intended results as well as the fact that both strategies are essential for a company, organization or a project.

Secondly, a certain resemblance regarding their aims and the methodology applied to reach them was found, in a general way. Finally, an additional similarity was extracted from the state-of-the-art and for the construction industry only: it was about the specific implementation of both Quality and Risk Management for a construction project, related to its stages and the various members involved. An overview of a method that combines QM and RM, and to be applied for new projects was also presented, as to take advantage of these links. However, it should be noticed that these coherences are purely theoretical, as coming from bibliographic sources only. Therefore, it seems important to investigate those connections from a practical point of view as well, as to confirm or invalidate them, since the theory and the practice are not always identical. Moreover, benefits or drawbacks from the developed methodology could be found with a real application. Such tasks will be achieved thanks to a case study.

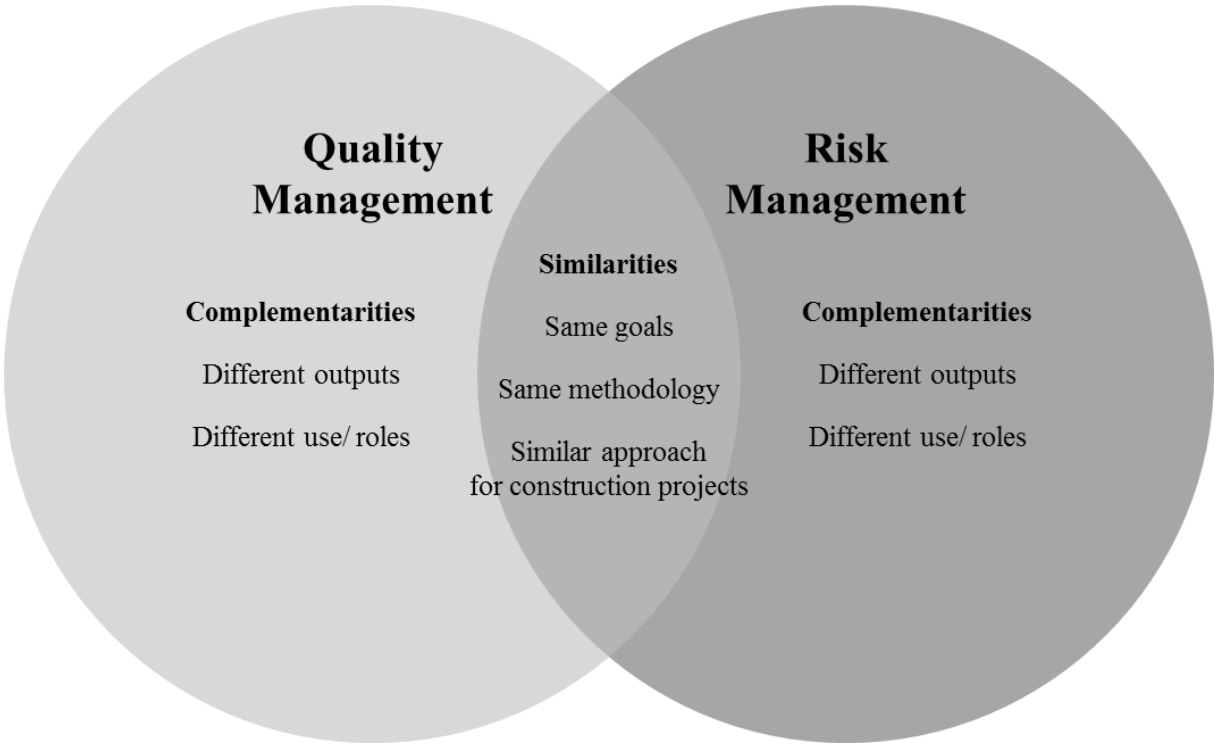

Figure 12 – The coherences and dependencies between QM and RM (Self-produced)

6. Application of QM and RM on a Construction Project

This last part consists in an investigation of an existing construction project and its main quality matters and potential risks. Analysis and explanation of these outputs are also going to be presented as to show the dependencies between the two key topics that can be found on a real application, in order to complete and confirm or not the theory.

6.1. Context of the Case Study

6.1.1. Justification for the Data Source

Regarding the research method used for the writing of the present section, it was chosen to investigate a case study. Indeed, since risk and quality issues lead to almost the same consequences for all construction projects, the examination of a particular construction site and its various threats could be generalized to the majority of construction works. Within this investigation, a correctional research will be applied, as to find the common areas between Quality and Risk Management and to further explain them.

Methodologies like participative, evaluative, ethnographic, or historical research, surveys or experimental method are not relevant for the purpose of this thesis, as they do not lead to the requested data and were thus not selected.

6.1.2. The Ilot B9 Construction Project

The construction project to be investigated was experienced by the author, during a 3-month internship, from June to August 2015, as an Assistant Site Manager. The contract was won by Eiffage Construction Nord Aquitaine, a subsidiary of Eiffage Construction, which is a big French construction group with worldwide activities. This internship was a requirement of his own university, the ESITC Caen engineering school. The operation occurred in Bordeaux, France, on the Ilot B9 construction site (Figure 13), which is part of a wider collective dwelling project in the northern part of the city and whose purpose is to host a total of 12 000 inhabitants within 440 000 m² of dwellings (Pialles, 2015).

Figure 13 – Model and 3D model of the Ilot B9 Project (Pialles, 2015)

Regarding the portion of the project in which the author was directly involved, it consisted of the construction of a 9-storage building complex with 151 apartments, a public facility, a central garden as well as a 145-place parking (Figure 14). The price of the project was estimated to be about €20 million, with a maximum of 120 workers and a duration of 3 ½ years. This project was particularly complex due to architectural and design requirements, a poor quality of soil, proximity to the sea, and lack of space for storage (Pialles, 2015).

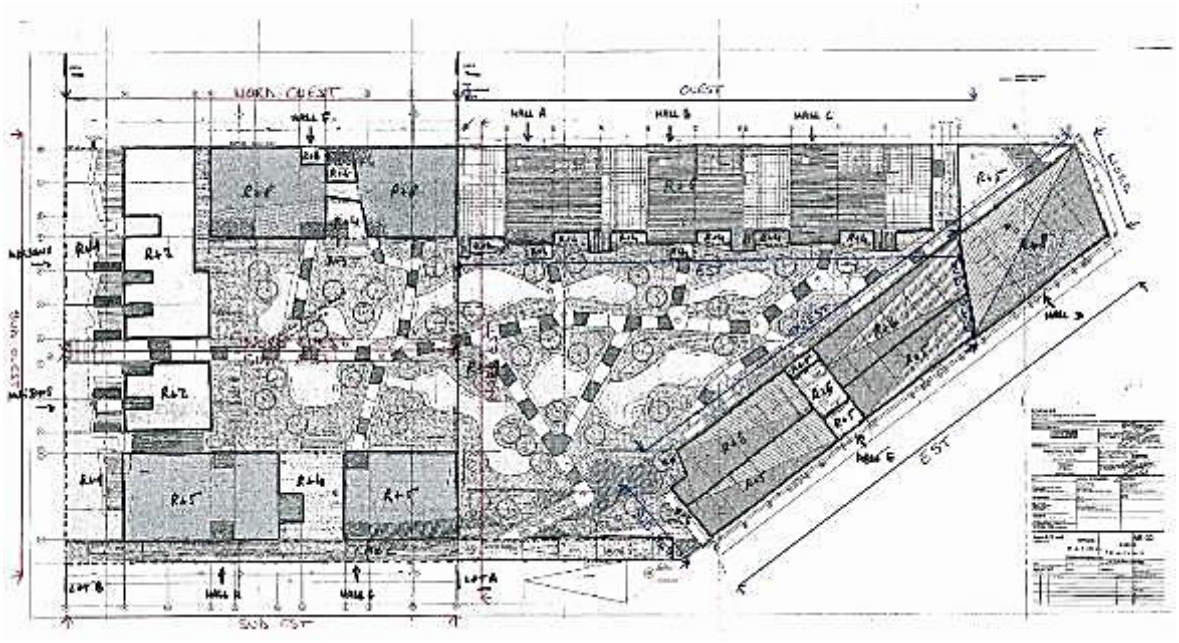

Figure 14 – Plane view of the whole project (Pialles, 2015)

It is now necessary to identify the quality matters and risks associated with this project, as well as what was done or what could have been implemented to solve these problems. The investigation is performed through specific Quality and Risk Management tools: the Risk Management Plan and the Deming Cycle. From this point, links will be found and theorized to other projects. The aim here is not to fully explain these tools, but to extract the key data as to sort out the boundaries between Quality and Risk Management.

6.2. Data Collection and Explanation

6.*2.1. Quality Matters of the Construction Project*

First of all, it seems important to provide some examples of quality concerns that were directly linked to the Ilot B9 Project (Table 2). By definition, quality refers to the satisfaction of projects and clients' needs: the statements below only cover the most important needs of this project which are aperture, regulations and design issues. In this situation, a lack of quality could have led to serious consequences which would have finally created a waste of time, a waste of money as well as bad reputation for the company. The following table matches to the identification of the main concerns regarding the quality of the project.

Quality concerns	Description	Consequence in terms of risk
Varnishing of exterior concrete walls	The exterior walls of the buildings were not covered so the finishing of the concrete needed to be perfect and a varnish layer was added	Risk to damage the concrete surface/ not to meet client's requirements
Trapezoidal shape of the concrete walls	Some exterior walls were trapezoidal and thus needed specific framework/ carefulness to be built	Risk not to achieve the appearance desired/ not to meet client's requirements

Quality concerns	Description	Consequence in terms of risk
Cleanliness of the construction site	Due to lack of space and regular visits from the municipality, the site needed to be as clean as possible	Risk to give a poor image of the company/ risk of being hurt or waste of time because paths are obstructed
Altimetry and distances between stringers	A difference of one cm between the plans and the reality would have caused an impossibility to build the levels above	Risk of building collapse or instability leading to failure of the project or extra work to be performed
Absenteeism of defects for plastic water pipes	Perforation of the drinkable water pipes placed under the building or even small defects was forbidden according to regulations	Risk not to fulfil regulation requirements/ rework necessary

Table 2 – Quality issues found on the Ilot B9 Project (Self-produced)

These quality issues are going to be analysed using a Quality Management tool. The PDCA Cycle (Plan-Do-Check-Act), also called Deming Wheel or Shewhart Cycle (Figure 15) is an iterative four-step management procedure developed by Dr. W. Edwards Deming in 1950, an American, and used for control and continual improvement of products and processes within a company or an organization. Even if the number of steps is limited and even if the desired goal is reached, the cycle remains infinite: as the world constantly evolves, the procedure never stops; the need to higher quality is perpetual (Kiran, 2017).

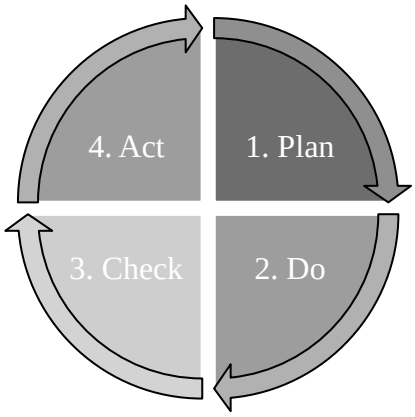

Figure 15 – Representation of the Deming Cycle (Kiran, 2017)

Applied to the construction site, the results found to improve quality levels with this method are described below (Table 3). For all the issues, an absenteeism of positive results after the phase Check would have led to re-perform the steps before until satisfactory results are reached. Even if the results are positive, regular controls should be performed during the Act stage to prevent any deviation as well as additional 4-stage cycles for improvement purposes. This table covers the remaining key steps of a traditional Quality Management approach: Goals Definition and Investigation of Solutions (Plan), Implementation of Strategies (Do), Comparison of Results (Check) and Decision Making (Act).

Quality emphasis	Plan	Do	Check	Act
Varnishing of exterior concrete walls	Create a list of measures to follow not to damage the concrete surface	Varnishing of a concrete sample following these measures	Are both concrete and varnish surfaces smooth enough?	If yes, staff can apply the varnish layer for the whole building
Trapezoidal shape of the concrete walls	Study of feasibility, materials and equipment necessary	Trial on a sample with the equipment ordered	Is the concrete shape adequate while removing the mould?	If yes, use of the moulds/ techniques for the walls
Cleanliness of the construction site	Study of a strategic location to place the trash containers	Meeting with the workers for awareness purposes	Does this location seem strategic for the workers?	If yes, the containers will be placed in the appropriate location
Altimetry and distances between stringers	One worker should be in charge of controlling the work during and after	The controls consist in sensitization of the other workers and on-site measures	Are the stringers correctly positioned?	If yes, other stingers can be built
Absenteeism of defects for plastic water pipes	Work in the same location as the pipe operations should be avoided	The area is enclosed or marked to prevent intrusions	After placing the pipes, has any defect been detected?	If no, pipes can be buried and marks/ fences removed

Table 3 – The Deming Cycle applied to the Ilot B9 Project (Self-produced)

6.2.2. Risks Associated with the Construction Site

As well, it is vital to give an overview of the main risks linked to the Ilot B9 Project. The following table (Table 4) stands for the Risk Selection (Main risks), Risk Identification (Description) and Risk Analysis (Impact on quality) stages. It should be noted that the risks encountered on this project and mentioned below match to threats with negative impacts and not to opportunities with positive consequences. Because it was a complex project and due to the location of the site, few opportunities could have been taken as an advantage. One of them however, not stated here because with a small influence, was the close proximity of the construction site with a supplier of tools, equipment and other do-it-yourself kits as well as numerous discounts offered.

Main risks	Description	Impact on quality
Lack of safety	Numerous trucks and excavator movements as well as continuous crane operations were affecting workers' tasks	Workers focus was more on engines moves and personal safety than on the quality of the work performed
Poor working conditions	Coactivity was one of the major concerns on this site and led to less efficiency because of a lack of space	Tasks were stopped very often because of this coactivity, so finishing levels were low
Environmental issues	The earth of the site was polluted by antimony, a toxic chemical component, and needed to be removed continuously after being excavated	A lot of focus, work, money and time was spent on this earth removal and thus, less on reaching high quality levels
Budget overrun	The contract was signed for a price that was very tight for Project Managers or to meet project expectations	Prices were negotiated as much as possible and high-standing materials were replaced by low-cost ones
Time delays	Weather conditions such as heatwave were experienced at that time and were slowing down workers' performance	Workers were less efficient, but the deadlines were still the same which led to less time spent on the tasks, as to compensate the delays

Table 4 – Risks of the Ilot B9 Project (Self-produced)

These risks are going to be mitigated with the Risk Management Plan (Table 5), a tool developed by Mr. Bazin, professor at the ESITC Caen Engineering School and expert in Risk Management. In fact, this method was used mainly in the automotive industry, but can as well be applied in the construction field. As other methods, it allows to assess risks that could affect a project as well as solutions to minimize it. This tool is divided into six key steps: Data Collection, Listing of Feared Events, Risk Evaluation, Sorting out the Risks, Risk Mitigation and Decision Making (Bazin, 2017; Marty, 2015).

The following tables only explains the main procedure, merging all the above steps together. Based on them and the formula below, the results that can be obtained are shown in the last table:

$$\boldsymbol{C = L \times S \times D}$$

Where:

- C = criticality: the level of acceptability of the risk for the project,
- L = likelihood: the probability for the unwanted event to happen during the project,
- S = seriousness: the consequences of the risk on the project,
- D = detection: the possibility not to detect the risk before its occurrence.

Likelihood		
Score	**Rate**	**Definition**
4	Very Likely	Once a day
3	Likely	Once a week
2	Possible	Once a month
1	Unlikely	Once a year

Seriousness		
Score	**Rate**	**Definition**
4	Very serious	Degradation of the activity/ Delays/ Budget overrun
3	Serious	Disturbance of the activity/ Recurrent impact on the quality of the work
2	Bad	Disturbance of the activity caught up by the team/ Punctual impact on the quality of the work
1	Low	No consequences for the company/ for the project

Detection		
Score	**Rate**	**Definition**
4	Undetectable	No clue for the risk to happen before it effectively happens
3	Random	Root cause difficult to detect or measurement not reliable
2	Possible	Root causes should be detected by controls, but may be overlooked
1	Insured	Current controls are insuring systematic detection of the event root cause(s) before defect occurs

Criticality		
Score	**Rate**	**Definition**
48-64	Critical Risk	Critical Level ~ Do not permit activity to commence.
27-36	High Risk	Risk must be mitigated and risk level reduced to Yellow or Green.
12-24	Moderate Risk	Investigate controls to minimize risk. Provide supervision and monitoring of agreed controls until accepted as routine.
1-9	Minor Risk	Acceptable risk. Review when process changes, or when circumstances change.

Table 5 – Risk Management Plan process (Bazin, 2017; Marty, 2015)

This technique is now applied to the Ilot B9 Project and the results are listed in the table below (Table 6). Here, the other steps of the Risk Management approach are provided: Risk Assessment (Initial category), Risk Response Planning (Control measures) and Risk Monitoring (Final category).

Event	Initial category				Control measures	Final category			
	L	S	D	C		L	S	D	C
Lack of safety	4	4	4	**64**	Moves of trucks and engines should be limited to specific areas and alleys only	2	4	3	**24**
Poor working conditions	3	3	4	**36**	Coactivity should be reduced in locations where high-quality levels are required	1	3	4	**12**
Environmental issues	4	4	2	**24**	Big amount of earth should be removed at once to limit the number of operations. As well, stored earth needs to be covered	4	2	1	**8**
Budget overrun	4	4	3	**48**	As labour force costs more than materials, strategies should focus on making savings on labour force instead of on materials	2	4	3	**24**
Time delays	4	3	4	**48**	Implementation of a morning schedule to reduce the amount of work hours spent under the sun	2	3	3	**18**

Table 6 – Risk Management Plan for the Bordeaux project (Self-produced)

6.3. Discussion and Comparison of the Main Outputs

6.3.1. Analysis of Results from the Study

Taking into account the aforementioned results found thanks to the use of Quality and Risk Management tools, the PDCA Cycle and the Risk Management Plan, the following section should focus on an analysis and discussion of these outputs, as to explain the interconnectivity between QM and RM and to fully understand them.

First relationship: First of all, and after an investigation of the quality matters experienced on the Ilot B9 Project, it can be stated that a lack of quality led to various risks. These risks were linked to safety, client satisfaction, visual appearance, regulation requirements, company image, cost and time, which finally could have influenced part of the project or even led to its failure.

Moreover, it was demonstrated, using the PDCA Cycle, that these quality issues could be solved and that this mitigation would eventually reduce or eliminate the threats associated and thus their various consequences on the project. That is why, to prevent various types of risks, there is a need to perform Quality Management on a construction project.

It can be noticed that even if the quality matters of this project were particular due to the complexity of this specific construction site and due to client's precise demands, their consequences can be generalized to any kind of construction project. Therefore, Quality Management could improve not only quality, but can also lead to diminish project risks and should therefore be considered even on project with lower quality expectations (Table 7).

As well, it seems important to mention that risks on the Ilot B9 construction site, and apart from their usual impacts, were affecting negatively the overall quality of the project which could have led to create or amplify threats resulting from it, such as the ones mentioned before.

That is why, based on the results found during the investigation on how to reduce or eliminate these risks, it can be mentioned that Risk Management must as well be implemented on construction projects. The result would be lower and fewer general consequences, thus, a reduction of the impacts on quality and finally, a decrease of other undesirable effects resulting from this lack of quality and a global benefice for the whole project (Table 7).

Once more, the categories of risk cited (environment, safety, delay…) match to typical issues that are experienced on almost every construction project, but the risks themselves were quite particular for the reasons previously mentioned (design requirements…). However, because their impacts on quality and on the project remain the same for other cases, Risk Management should not only be restricted to this unique situation.

Quality Management			**Risk Management**		
Result on quality	**Consequence on risks**	**Main outcome**	**Result on risks**	**Consequence on quality**	**Main outcome**
Appropriate varnishing of exterior concrete walls	Good appearance of the final product	Satisfaction of client's needs	Suitable on-site safety	More focus on quality	Avoidance of deviations from the stated needs
Realization of desired concrete wall shapes	Reality conform with architectural model		Proper working conditions	Efficiency in task completion	
Cleanliness of the construction site	Carefulness of client's product		No environmental issues	More workers available to perform demanding tasks	
Correct positioning of stringers	The design follows the plans		Budget compliance	More money can be spent for quality purposes	
Absenteeism of defects for water pipes	Fulfilment of regulations		Followed schedule	More time dedicated towards quality	

Table 7 – Complementarity of Quality and Risk Management (Self-produced)

Based on the results from Table 7, it seems essential to state that one of the links between Quality and Risk Management is their complementarity, which can also be viewed as a sort of dependence. Quality Management is used to reach and improve quality and consequently to avoid risks linked to it meanwhile Risk Management is necessary to avoid risks able to threaten quality (as well as other common hazards) and that cannot be managed using the other tool. Both of these fields are therefore essential and complementary.

As well, this complementarity comes from the different outputs from the management tools: Quality Management leads to satisfaction of the customer, based on needs and requirements properly defined, understood and followed thanks to Risk Management.

Second relationship: Another point that should be mentioned, and after an analysis of the PDCA Cycle and Risk Management Plan (RMP) applied to the construction project, is the way problems are solved in general. The traditional methodology is composed of a certain number of steps that, by taking a careful look, are almost identical in nature and number (Table 8).

<table>
<tr><th colspan="3">Quality Management</th><th colspan="3">Risk Management</th></tr>
<tr><th>PDCA steps</th><th>General method</th><th>Goals</th><th>RMP steps</th><th>General method</th><th>Goals</th></tr>
<tr><td>Identification of quality needs</td><td>Problems/ needs identification</td><td rowspan="5">To solve quality issues/ To improve quality as to meet project expectations</td><td>Initial risk category</td><td>Problems/ needs identification</td><td rowspan="5">To solve future problems/ To reduce risks as to meet project expectations</td></tr>
<tr><td>Plan</td><td>Solutions investigation</td><td rowspan="2">Control measures</td><td>Solutions investigation</td></tr>
<tr><td>Do</td><td>Strategy implementation</td><td>Strategy implementation</td></tr>
<tr><td>Check</td><td>Comparison of results</td><td rowspan="2">Final risk category</td><td>Comparison of results</td></tr>
<tr><td>Act</td><td>Decision making</td><td>Decision making</td></tr>
</table>

Table 8 – Similarity of Quality and Risk Management (Self-produced)

Furthermore, by following the main steps of both these management approaches, it can be noticed that they lead to common goals and resemblance, which are basically to enhance project performances and to reach project targets/ requirements. As a conclusion, another coherence that could be mentioned, is the similarity, at least in terms of goals for a project and methods to achieve them, of Quality and Risk Management. Even if the outputs are specific due to the particularity of the project, the methodology used and aims to be pursued, and thus, this resemblance, stay the same for other construction projects.

However, it is of great importance to mention that the above tools represent only a tiny portion of strategies that can be encountered in Quality (e.g. the Six Sigma Principles, the Kaizen Philosophy…) and Risk Management (e.g. the Fault Tree Analysis, the HAZOP Study…). As the Deming Cycle and the Risk Management Plan are basic tools, the steps here seem almost similar in nature and goals from one method to another. A comparison of more complex tools would have probably led to more differences among these steps, in terms of nature, outputs and number, but the overall approach and goals would have still remained the same.

Third relationship: Other similarities were found when implementing Quality and Risk Management on the Ilot B9 Project. As demonstrated below (Table 9), both strategies are applied and are efficient for every stage and for each participant of the project. Even if the owner is not mentioned here as being involved in the Quality and Risk Management processes, information from Pialles (2015) suggested that this team member, which was the city of Bordeaux, had to choose the various participants of the project as well as the delivery system, the location of the project… These decisions were taken after carefully studies and considerations that lasted for several years before the project actually started and it typically counts for a Quality and Risk Management approach.

Quality Management			Risk Management		
Quality focus	**Project stage concerned**	**Participant**	**Risk emphasis**	**Project stage concerned**	**Participant**
Varnishing of exterior concrete walls	Construction & Maintenance phases	Constructor & OM Project Coordinator	Lack of safety	Construction phase	Constructor
Trapezoidal shape of the concrete walls	Design & Construction phases	Design Professional & Constructor	Poor working conditions	Construction phase	Constructor
Cleanliness of the construction site	Construction phase	Constructor	Environmental issues	Design & Construction phases	Design Professional & Constructor
Altimetry and distances between stringers	Design & Construction phases	Design Professional & Constructor	Budget overrun	Design & Construction phases	Design Professional & Constructor
Absenteeism of defects for plastic water pipes	Construction phase	Constructor	Time delays	Design & Construction phases	Design Professional & Constructor

Table 9 – QM and RM similarities on the Ilot B9 Project (Self-produced)

Another point that should be mentioned: the risks provided in this case study do not cover the Maintenance Stage and do not impact the OM project coordinator. However, for this specific project, risks affecting this stage and team member can be easily encountered. As an example, and due to the proximity of the facility to the sea, a crawl space and a holding water tank were built under the complex. Part of the Maintenance Stage should therefore focus on taking care of this area which implies risks since too much water inside the basin can lead to flooding of the parking areas and deterioration of the foundation.

Consideration of all the relationships: A total of three different coherences was found previously between Quality and Risk Management. It is now high time to highlight the advantages brought by a consideration of both systems together (Risk-Quality Management strategy) and these links, for the Ilot B9 Project and based on quality issues and risks previously found. This consideration consists in merging the PDCA and RMP strategies as shown in Table 10:

Quality Management steps	Risk Management steps	Risk-Quality Management steps	Some results on the project
Identification of quality needs	Initial risk category	Investigation and analysis of threats, opportunities, quality matters and other project concerns and objectives	On-site safety is anticipated; working conditions are considered; awareness is given towards stringers location
Plan	Control measures	Planning and development of strategies and procedures; Implementation and application of solutions and measures	The construction site remains clean; the shapes of the walls are respected; environmental regulations are applied
Do			
Check	Final risk category	Verification and control of outcomes' efficiency; Definition of new actions to undertake and process recording	The walls quality is controlled after varnishing; the budget is constantly reviewed; maintenance of the pipes is kept in the records; actions are taken to match the schedule
Act			

Table 10 – The Risk-Quality Management system for the Ilot B9 Project (Self-produced)

As to summarize/ generalize the previous comments and to give some conclusions, the Table 11 below provides the various benefits of Quality and Risk Management when implemented independently on each aspect of a (construction) project and their advantages when both management systems are considered together. This hybrid composed of two Project Management knowledge areas matches with a single entity that could be named the Risk-Quality Management Strategy.

The implementation of such a brand-new approach results in a practical and efficient identification and management of quality matters, threats and opportunities, and their likelihood and consequences. It allows as well enhanced performances and better administration of a project and a more effective use of allocated resources along with better outcomes. Finally, it results in fulfilment of client's requests, project and law requirements and faster and more appropriate decision-making. All these benefits combined would finally lead to a better image for the company, an increased number of customers and therefore, a good financial health and a strong presence on the market.

	Quality Management	Risk Management	Risk-Quality Management
Project Integration	Improve interactions and processes between the Project knowledge areas	Avoid conflicts between Project parameters	The Project Management strategy becomes strong and efficient
Project Scope	Ensure project objectives are met	Reduce deviations from project goals	Project goals are fully understood and reached
Project Cost	Reduce expenses due to avoidance of mistakes	Mitigate threats towards budget/ increase opportunities to reduce costs	Budget is strictly followed or even reduced
Project Time	Less rework is necessary which leads to save time	Unforeseen hazards are managed faster so that more time is allowed for necessary tasks	The project is under schedule allowing spending time on extra activities
Project Human Resources	Result in better working conditions and wellbeing of the workforce	Allow labour force to stay focus on the main goals and to manage risks efficiently	Human resources are well allocated and tasks are completed efficiently
Project Communications	Improve communication between team members through well-defined processes	Focus on brainstorming and other collective actions to appropriately mitigate risks	Participants are communicating better resulting in less conflicts
Project Procurement	Lead to good quality of products as it becomes a company minimal requirement	Anticipation of nonconformities from suppliers is considered	Deliveries are not a brake/ constraint to task completion

Table 11 - Synergies between Quality and Risk Management (Self-produced)

6.3.2. Comparison between Practice and Theory

This section aims at comparing the results between what was expected from the theory, which was an analysis of the literature review and the practice, being the investigation of a case study. The first common point found was the complementarity between Quality and Risk Management.

From the theoretical point of view, this complementarity is due to the fact that these two fields can partly substitute each other. As it was seen, Quality Management can be used to reduce various sets of risks, which is the intended role of Risk Management, meanwhile Risk Management can lead to preserve the already existing quality, which is thought as being part of a Quality Management procedure.

As well, in the state-of-the-art it was also found that these tools are completing each other. While Quality Management focuses on improvement of quality to ensure the satisfaction of needs, Risk Management emphases on understanding and reduction of deviations from these needs.

According to the practical perspective, a certain complementarity between Quality and Risk Management was also discovered. Indeed, based on the consequences obtained on the project while using these tools, it was found that using Quality Management was leading to solve quality problems of the project and because these issues were source of risks, it was therefore resulting in avoiding them. As well, Risk Management intended to reduce risk levels on the Ilot B9 Project that were directly affecting its quality. Thus, it appears as evident that Quality and Risk Management can be used beyond their primary purposes and their roles can be switched to better serve the project.

Moreover, the other complementarity found in the papers, which is the supplementation of the two strategies, can be somehow extracted from the case study as well. For example, a tight budget was experienced on the project. Risk Management helped investigate solutions to carry out the project under this budget, which avoided deviation from client' needs. At the same time, Quality Management ensured that client needs were met by improving quality.

Regarding the similarity between Quality and Risk Management, it can be stated that their goals are the same: both these fields intend to bring the project to a successful end, in terms of budget, schedule, client's needs, regulation requirements, safety, project aims, design, aperture… Both lead to danger reduction and quality improvement, which covers the previous items, as to best serve the intentions of the construction project.

Furthermore, even if the methods used were different, the PDCA Cycle as a Quality Management tool and the Risk Management Plan as a Risk Management strategy, the traditional steps Problems Identification and Analysis, Solutions Investigation and Implementation, Results Monitoring and Recording were followed, which reinforces the similarity between these management procedures.

Finally, this resemblance between Quality and Risk Management is even supported further since both the analysis of the state-of-the-art and the investigation of the case study confirmed that these strategies are similar on some points for the construction industry as well. Indeed, the additional common points are that the management tools should be applied for every stage of a construction project and by each participant, according to the papers. Similar results were obtained when applying QM and RM in the case of the Ilot B9 Project: their implementation in several stages and by various members led to satisfactory consequences and optimal benefits.

As a conclusion, it can be noted that, the theoretical links that can be encountered between Quality and Risk Management were confirmed by a practical use of these two fields of study, on a real construction project. As these boundaries seem to be the same, according to the papers and the reality, it reinforces their acceptance and can therefore be used as to explain them to someone who is not initiated into management practices in general or in the construction field in particular.

Chapter Summary

In this chapter, and just like the previous one, some relations between Quality and Risk Management were found, this time coming from an application of these tools in the case of a real construction project. After a brief explanation of the research method chosen, a case study, and the context of this construction project, the Ilot B9, a short overview of the problems experienced with this project in terms of quality and risks, was provided: design requirements and on-site issues. From there, Quality and Risk Management were applied, using specific tools, as to solve them: respectively, the PDCA Cycle and the Risk Management Plan.

As a consequence of the implementation of these management strategies and the resulting outputs, practical links were discovered. Quality and Risk Management were found as being complementary in terms of use and outputs, and similar in terms of objectives, general methodology, and specific approach to a construction project. These outcomes seemed to match with the theoretical analysis and can thus be accepted more easily. In order to sum up the results found all along this project and to properly conclude this Final Dissertation, the next section should be a wrap-up of the present report with answers to the main problem.

7. Conclusions and Proposals

7.1. General Statements and Overview

It seems unbelievable nowadays to offer services and products without minimal levels of quality. World's evolution in terms of expectations, requirements and needs is such that the delivery of high quality goods became a standard everywhere. Consequently, proper quality needs to be reached, improved and maintained continuously, implementing the well-known Quality Management approach and ensuring that the process is strongly anchored in companies or organizations' policy.

Quality Management is a management strategy that is used to improve the overall quality of processes and methods as to enhance products or services quality. The intended final goal for these goods is to meet requirements and client's satisfaction. Such a task is accomplished by the mean of various tools and technics, some being officially standardized and in use. This description, given in the present report, matches with the first objective of this thesis, which was to provide definitions and explanations regarding Quality Management, for a general use, as to answer the main problem: *How can Quality Management be fully understood using Risk Management as part of the explanation and vice versa?*

As well, each and every human endeavour linked to production and customer services involve risks and uncertainties. Because of their potentially negative impacts and the fact that there is no way for humans to innovate or to live in today's societies and technologies without risks, they must be understood, evaluated, turned into opportunities, eliminated, transferred or mitigated. Such tasks can be undertaken thanks to the use of the famous and brand-new Risk Management field.

As studied along this dissertation, Risk Management is viewed as a procedure to avoid, transfer or mitigate risks able to threaten a product, service or project as well as to take advantage or to increase the benefits of an opportunity. Its desired goal is to ensure that initial and stated objectives will be met with no deviations, using different means and methods. The Risk Management system is recognized publicly and recommended by renowned institutions. Such a definition was another intended aim of this thesis: to describe Risk Management, on a general basis.

However, the problem remains the same for the construction industry: as soon as a construction project has to be launched, quality becomes a parameter that describes the final product of this project and thus, becomes a requirement that must be fulfilled. The Quality Management procedure will make sure to reach the definition of quality according to the client's needs. Based on this statement, there is a risk not to fulfil this purpose and consequently, a need to avoid as much as possible this fatality. The purpose of the Risk Management system is to bypass constraints and problems that could lead to a poor-quality product.

To ensure that Quality and Risk Management will lead to desired results in the construction field, some parameters would have to be taken into consideration such as implementation of these strategies for all participants and at every stage of a project or the use of specific technics usually applied and appropriate for the building sector. The explanation of QM and RM, specifically for construction projects, was the third goal of this study. As seen, both these tools can be understood while explained separately, either for a common use or for the construction industry, but better and deeper understanding would be reached if considered together.

7.2. Specific Conclusions and Results

The last focus of this Final Dissertation was to investigate the potential coherences and boundaries that link Quality and Risk Management together. Such an approach was based on the writing of a literature review focused on the existing knowledge, an analysis of this state-of-the-art, as well as an investigation of a case study, which was a construction project experienced by the author. A comparison between the theory, the literature review, and the reality, the case study, allowed confirming these connections.

The first relationship that was discovered is the complementarity between Quality and Risk Management, regarding their roles and expected results. To intend reaching quality lead to deviations and is thus viewed as a risk that need to be managed thanks to Risk Management. At the same time, a lack of quality drives to risks that can threaten a construction project, and consequently must be controlled thanks to Quality Management. Moreover, while QM focuses on client's satisfaction, RM emphasises on contractor's financial success. Therefore, Quality Management underpins Risk Management and the reversed situation remains true.

The second link found was the similarity of these two fields of study, in terms of goals and general methodology, while use on a general basis. Both intend the improvement of projects or organizations' performance, as to fulfil desired objectives and to satisfy client's expectations. In both fields, the step-by-step process to accomplish this mission range from a detailed analysis of the problem, to the investigation of solutions and decision-making.

Finally, the last connection extracted from the study was the resemblance between Quality and Risk management, when specifically applied to the construction sector. It appeared that these tools are identical in their approach of achieving construction project aims. Basically, the stratagem is to implement both procedures for each stage of the project and by all participants in order to get the most efficient task completion and the best results.

7.3. Main Interpretations and Resulting Outcomes

Lastly, this dissertation focused on the resulting outcomes coming from the links found between Quality and Risk Management, which are the benefits that could be extracted from these strategies, when merged, and the need to consider them together. Such a work could be used by someone non-initiated or a building company with the intention of encouraging it to pursue its construction endeavours utilizing these tools and to fill the gap between them, as to lead to better performance for construction projects.

It is nowadays important for companies or projects to develop and maintain a holistic management program that coordinates both quality and risk silos since their overall objectives are the same: to protect the project and to ensure its survival to the benefit of its client. This concept is even more important for the construction industry since it is a particularly challenging sector, because the environment and its associated hazards or opportunities are continuously changing as the project evolves.

Therefore, it seems essential to implement what could be called a Risk-Quality Management approach instead of considering both fields separately. This way of thinking would not be only an evaluation of the risks towards quality, but as well, a consideration of quality towards risks. The application of such a strategy could bring several advantages and results in:

- Reduction of mistakes,
- More proactive approach to mitigating risks and enhance opportunities,
- Improved project performance,
- More effective project management,
- Better resources utilization,
- Compliance with regulations,
- Higher transparency in decision-making,
- Minimized likelihood of unwanted events,
- Enhanced organization's reputation,
- Greater communication among the team members,
- Better results and outcomes,
- Improved decision-making at all stages,
- Systematic identification of quality issues.

7.4. Future Line of Work and Possible Suggestions

After a careful reading of the present report and as mentioned above, it should be recognized that there is a need to identify and manage risks as being part of an acceptable and a functioning Quality Management strategy. Thus, Risk Management should be implemented accordingly and vice-versa: quality is to be considered as being a portion of an appropriate and effective Risk Management procedure and therefore Quality Management should be carried out alongside with it.

To conclude this thesis and as a proposal, future works could be the creation of an official and formal standard document, gathering both Quality and Risk Management systems together, and in collaboration with recognized institutions such as ISO or FIDIC for instance. The main content and purpose would be a sensitization to the need of applying the procedures together, their benefits, how to implement them at the same time, what are the necessary resources or minimal requirements, as well as recommendations on when to use them.

While this report was written in a common language and with some personal knowledge, the new document would intend to be used as a guideline for best management practices and therefore would be written with a proper tone, based on Project Management authors and experts' experience. The final goal is to edit a universally recognized book for integrating Quality and Risk Management together, as to spread it worldwide, which would require additional investigations and further works.

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8.2. Photos and Pictures

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P.S.: The references provided in this section match to the four pictures located on the front page of the present report. They were placed separately as to avoid an overload of the cover.