Project Class and Project Risks

An Empirical Research on the Relationships between Infrastructure Engineering Projects and Project Risk Events

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Preface

I was delighted to do this research on the relationships between project classes and risk events. It stimulated me to push my limits and to contribute to something important. Due to this thesis I was able to finally use the things I had learned in college and apply it in practice and, more importantly, I have learned some new things regarding statistics as well.

This research was the first major project that I have executed in my entire time at the university. Thanks to the support of both my mentors; Mark Wolswijk (Siemens) and Leo Rodenburg (The Hague University of Applied Sciences), and my colleagues at RCM, I have managed to successfully complete this research.

Fortunately, this research was not only the beginning of studies at RCM nor the end of studies, as it opened new doors for future research. I believe that this research is of added value for RCM's management, but I also believe that future research regarding project classifications and project risks will significantly contribute to RCM's knowledge. I suppose that the quest for knowledge never ends and that research is always needed. Therefore, I think that this research will be of importance to all its readers. I hope that this study will enlarge your views on project management, project classification and project risks and that it will trigger you to think of this topic.

Yours sincerely,

Jasper T.L. de Zwart

Management Summary

Road and City Mobility (RCM) is a business unit of Siemens Netherlands. RCM's core business is to provide infrastructure solutions for its customers. Generally, 80% of RCM's revenue is generated by projects; the other 20% of the overall revenue is generated by the sales of products (e.g. electronic variable traffic signs). Therefore, it is of great importance that RCM keeps looking for new projects. Projects are normally acquired via European tenders, meaning that competitors all over Europe can enroll for that project. It regularly happens that projects do not turn out to be as planned, this is also applicable for RCM. The management of RCM acknowledged that this is true. However, they know that certain risk might occur for certain projects, but this is somewhat of a gut feeling. The relationship between project class and risks has not been analyzed yet. The aim of this research is, therefore, to prove whether there is a relationship between project class and project risk events. This information will provide the management of RCM with predictions of risks that might occur for certain project classes. Hence, RCM's management is able make a well thought consideration of even signing the contract, based on the risk events that were predicted for that project.

Thus, the main research question can be formulated as follows: *"What relationships can be determined between RCM's project classifications and risk indicators?"* The main research question was supported by four sub research questions: *"What are project classifications and why are they applied?" "What are risk indicators and why are they applied?" "How does RCM classify projects?" "What are the relationships between project classification and risk indicators?"*

Project classification is the process of grouping projects together in different classes. Different classes of projects have different characteristics. The three main purposes of project categorization are: 1) strategic alignment (assign priority for projects), 2) capability specialization (project delivery capability) and 3) promote project approach (provide a common language for project management).

When we look at how Siemens describes the purposes of its classification framework, we can see that they are very alike. Siemens classifies its projects for four main uses: 1) as a criterion for determining the escalation level, 2) as a criterion for engaging Legal and other experts, 3) for determining the level of detail of minimum requirements for the process, such as documentation requirements and 4) for choosing and assigning project managers to carry out the project, with the required certification level. We can see that Siemens' purposes 2, 3 and 4 correspond with the literature's purposes 2 and 3.

Generally, Siemens classifies its project based on a questionnaire. This questionnaire contains fifteen questions in the field of financial, contractual, technical and organizational matters. Based on the answers to each question, a final point is given to that project. A project receives a project class of either A, B, C or S, according to its order volume and points. However, the algorithm that assigns the project class depends very much on order volume. Let *X* be a small project of a low order volume of EUR 500,000 and the highest points (higher points, means higher risks). Project X will never be a B project even if it has significant identified risks, simply because its order volume is below EUR 10,000,000 (note that A projects have the highest order volumes and S, small, projects have the lowest order volumes). This classification framework did not look that promising for correlating project classes with risks, at first sight. Therefore, a literature based system engineering framework was used for this

research as well. However, Siemens also implemented a classification of risks for each project, which is divided into: corruption risk and business risk. Both risk assessments can have a score of 1, 2 or 3 (1 meaning high risk and 3 meaning low risk). Siemens uses both assessments for assigning a project with a risk class. The risk class, however, is simply that the higher score leads (corruption risk of 3, business risk of 2, leads to a score of 2). Moreover, the assessments are also questionnaire based, where contractual risks weights the most in the algorithm of assigning a risk score. Therefore, the risk code was not used during this research.

In this research, project types (system engineering classification framework) and LoA class (Siemens classification framework) were studied in terms of risks. Risks are considered to be events that can have negative consequences for project objectives. These risks are, however, unique for each project. But, just as projects, grouping them into risk indicators makes it possible to run statistical tests. Hence, the purpose of risk indicators is that they make statistical analysis possible. Because of this, researchers can make conclusions regarding these risk indicators, leading to increased knowledge of risk events.

Now that project classification and risk indicators have been discussed, we can move to the next part: analysis. Data of 17 projects were gathered and each project controller filled in a questionnaire regarding risk indicators for their project. The questionnaire was Likert scale based with six risk scales (0 risk had no impact, 1, risk had almost no impact, …, 5 risk had significant impact). The risk list contained a total of 38 risks, which were divided into six macro risk indicators: contractual and legal risks, technical risks, quality risks, cost risks, project team and management risks and sub-contractor risks.

Results of the tests (Chi-square tests) had shown that the system engineering classification framework does not distinguish risk for certain project types. Therefore, in this case, this framework is not a sufficient framework when it comes to the relationship between project types and project risk events. The Siemens classification framework does show a difference in terms of occurred risks and the impact of the risks occurred. The results showed that small projects (S projects) face some risks with limited impact. B projects tend to have the most risk impact points (meaning that risks score high points on the Likert scale). Hence, there is a difference in terms of risks occurred and impact of those risks for Siemens' project classes. Therefore, Siemens' classification framework is a sufficient tool when it comes to the impact of risks for projects. In addition to that, different projects face different risks. However, many risks are the same for each type of project, but differ in terms of the Likert scale. The tests showed that technical risks dominated the macro risk indicators for all projects, making it an important macro risk indicator. When we zoom in a bit further, we can see that the most significant risks for all project types are: delay in solving technical disputes, tight planning, change order negotiation and unclear design specifications and requirements. However, other risks differ for each project types.

Based on the findings, we can state that there is a relationship between project types and risk indicators. Bigger, more complex projects tend to have more risk events with greater impact on the project than smaller, less complex projects. Thus, using Siemens' project classes as a way to predict risks can be effective, as the classes differ in terms of risks. However, I would recommend having a closer look at a project's technical characteristics before signing the contract, as technical risks were the most severe risks in the risk indicator list.

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1. Introduction

Road and City Mobility (RCM), a business unit of Siemens' division Mobility (region The Netherlands), focuses on the delivery of engineering projects in the field of infrastructure products and solutions (think of traffic LED signs and traffic command & control systems etc.). With an annual revenue of EUR 35mln for fiscal year 2015, the business unit is one of Siemens Netherlands' main profit centers. About EUR 28mln (80%) of RCM's revenue is the result of RCM's different projects. Project management is, therefore, of great importance for RCM as projects are accountable for most of its revenue.[1]

As projects generate most revenue for RCM, picking the right projects is essential for the continuity of the business unit. Generally, infrastructure projects are acquired via European tenders, where lots of different contractors can enroll for the project. Winning a tender is one thing, successfully completing it is a whole different task since "large engineering projects are characterized by substantial irreversible commitments, skewed reward structures in case of success and high probabilities of failure" (Miller & Lessard, 2001, p. 437).Thus, knowing what to expect of a project plays a major role in deciding whether to enroll for that tender.

Obviously, the management of RCM acknowledges the high risk profile of large engineering projects. Thus, in order to enroll for the right projects, RCM needs to know, upfront, what risks can be expected during the realization of that project, so that they will not burn one's finger. Hence, they would like to know what risk can be predicted upfront, so that they can make a well considered decision whether RCM should or should not sign the contract.

[1] The information in this section was provided by the business unit controller of RCM.

In other words, RCM's management would like to know if certain conclusions can be drawn regarding the relationship between project classification and project risks. Moreover, not only the relationships, but the predictability of risks based on project classification also matters. The results of this study will provide RCM's management with the right information to make a well considered decision regarding enrollment for a tender.

2. Research Questions

The purpose of the study was described in the previous section, however, the object of the study will be described in this section as the corresponding research questions will be discussed in this section as well.

The objective of this study is to statistically proof whether there are relationships between project classes and project risks. Testing the hypothesis whether there is a relationship between the two is only one part of this study. The main objective is to determine which risks occur most for certain project types. Hence, with this information, RCM's management is able to predict most risks for a certain type of project before even signing the contract.

To meet the objective of the study, the main research question should be stated as clearly as possible (and should fully relate to the objective of the study). The following main research question is formulated to cover all objectives of the management's demand;

"What relationships can be determined between RCM's project classifications and risk indicators?"

To preserve the quality and the accuracy of the study, the following four sub research questions have been formulated in order to fully support the main research question. Moreover, these sub research questions are divided in different areas to make them clearer.

Theoretical Framework

1. "What are project classifications and why are they applied?"

2. "What are risk indicators and why are they applied?"

Current Situation

3. "How does RCM classify projects?"

Statistical Sub Research Question

4. "What are the relationships between project classification and risk indicators?"

For more information regarding the research method for answering the statistical sub research question, I refer you to section five (Methodology) of this research paper. The research method for answering sub research questions one, two and three is discussed below.

Sub research questions one and two are somewhat more theoretical based. Therefore, information regarding these topics (project classification and risk indicators) was accessed via academic journals. Previous studies have been analyzed and processed in this research in such a way that the results fully cover the regarding sub research questions.

The third sub research question is about the actual situation of project classification at RCM. Thus, analyzing the classification process of Siemens (RCM follows Siemens standards) is the best method of answering this sub research question. In order to get a good understanding of the process, I attended a web based training with respect to Siemens' classification process. Furthermore, the commercial sales manager was able to explain to the whole process, as commercial sales managers find themselves in the classification process for almost every bid.

3. Theoretical Framework

This chapter covers the theoretical background of this research. It primarily focuses on the theoretical sub research questions regarding this paper. In this section, project classification[2] and project failure (and the possible key indicators for failure of a project) will be discussed.

3.1 Projects and Project Management

It regularly happens that people refer to projects when they are talking about work they need to do. However, the definition of a project is more complex than only work one has to do. Wysocki (2011, p. 3) defines a project as a "… sequence of unique, complex, and connected activities having one goal or purpose and that must be completed by a specific time, within budget, and according to specification." Organizations undertake projects to convert their strategy into new products, services and processes. Strategy is fundamentally deciding how the organization will compete (Gray & Larson, 2008). The strategy will determine how the organization reaches its goals, objectives etc. Thus, projects are key for converting the organization's strategy and staying competitive in today's business environment.

Since projects are key for an organization's success, managing a project is of great importance in this rapid changing business environment (Gray & Larson, 2008). Project management can be seen as a special management methodology that focuses on achieving business goals and implementing strategies (Srivannaboon & Milosevic, 2006). The project manager is the one who is

[2] In this paper, I refer to classification systems that sort things into mutually exclusive sets (such as the classification of species).

responsible for managing the project. One important, primary activity of a project manager is project risk management (Project Management Institute, 2008). Project risk management has gotten more attention over the past years, as more complex and bigger projects arise. Risks can jeopardize the success of a project, therefore the project manager should monitor risks and try to mitigate them (Kendrick, 2015).

3.2 The Purpose of Project Classification

Many organizations that have a large number of projects classify their projects for strategic purposes. Archibald (2013) defined a couple of strategic purposes, for instance: project selection, prioritize selected projects, allocate resources to projects etc. A project will add the most value when the project meets the organization's objectives. Therefore, project selection is one of the first and most critical activities in project management (Copertari, 2011). Furthermore, organizations have a limited amount of resources, thus classifying projects will help organizations with the selection process, so that they can pick the project which will add the most value (Gray & Larson, 2008). Project classification also gives an indication of a project's risk profile, which can be of use for project selection and for the project manager as an indication of expected risks during realization. Moreover, project classification can be useful from a management style point of view, as different types of project require different management styles (Archibald, 2013).

Crawford et al (2006) found that the project portfolio management literature and the project management literature differ in the view on the purpose of project classification. According to project portfolio management literature, the purpose of classifying projects is to prioritize them. Project management literature, on the other hand, focuses on capability development and on tailoring management style to suit the project type. Despite the different perspectives towards the purpose of project classification, Crawford et al (2006) defined three purposes; 1) strategic alignment (assign priority for projects), 2) capability specialization (project delivery capability, assign appropriate resources and tools) and 3) promote project approach (provide a common language for project management). These three purposes will be seen as the main purposes of project classification, as lots of different researchers agree with their statement.

3.3 Project Classification Frameworks

A lot of research has been done in the field of project classification and different researchers apply different project classes. Gray and Larson (2008), focused on three project classes: compliance, operational and strategic. Projects within these classes differ among characteristics in terms of order volume, complexity, technology, personnel etc. Wysocki (2011) argued that there are four types of projects (simply A/B/C/D) and that projects should be classified according to: risk, length, costs, complexity and technology. These project types are not specifically designed for individual industries, but more as a universal project classification framework, meaning that they are not directly applicable for RCM.

Shenhar and Bonen (1997)[3], on the other hand, did research regarding project classification for system engineering projects. They suggested a two-dimensional classification model for systems engineering projects. According to their classification framework, projects are classified into four levels of technological uncertainty (risks) and three levels of project scope. The technological uncertainty consists of: low-tech (A), medium-tech (B), high-tech (C) and super-high-tech projects (D). Based on project

[3] Their research is discussed more in debt, since almost all RCM's projects are system engineering projects. Therefore, this research is the most applicable one based on the literature review done in this section of the paper.

definition, typical products, industries, development and testing, system requirements, design cycles and design freeze and management and systems engineering style criteria, a certain project type (A-D) is applicable for that project. Table 1 gives an indication of the different project types and their different levels. Furthermore, the system scope level adds a new dimension to the project type. This system scope level can either be assembly (1), system (2) or array (3) based on certain criteria: definition, typical products, typical function and operational aspects, project organization, main system engineering thrust, planning & control and documentation and management style and attitude. Table 2 explains the different levels of system scope and shows the criteria for each level. An organization can classify projects based on the criteria presented in both tables; A1 projects are considered as low-risk, easy to handle projects, whereas D3 projects are the most difficult projects in terms of risk and technical complexity.

3.4 Project Risks

We are all confronted with risks, whether it is in our everyday life, in business or in projects. Unmanaged risk is dangerous, because it can lead to unforeseen outcomes (Hillson & Simon, 2012). Due to this fact, (project) risk management is essential to stay in control of every situation.

Before one can correctly apply risk management in any situation, the definition of risk should be defined. Although the word *risk* can be found in every English dictionary, there are still discussions between practitioners and professionals regarding the definition of the word *risk* (Hillson & Simon, 2012). PMBOK[4] (2008) defines risk as an uncertain event or condition that can have an effect on one or more project objective. Traditionally, risk were mainly perceived as bad things; meaning that risks only influence a project in a negative way. However, based on the PMBOK's (2008) definition, risk can be all uncertain events which affect at least one project objective, whether risk have positive or negative consequences. Nowadays, uncertainties that are beneficial for a project are considered to be *opportunities*, meaning that the modern view on the definition of risk is that risks can both influence the project in a negative way as well as in a positive way. Obviously, the main debate between the two groups is about the definition of risk; between the traditional view (risk are only uncertainties with negative consequences) and the modern view (risk can be seen as uncertainties with both negative and positive consequences). The traditional view on risk (i.e. all risks are bad) will be the view on the definition of risk for this research, as this research only focuses on uncertainties that negatively influence a project.

3.5 Project Risk Management

According to the Project Management Institute (2008), risk management can be seen as a primary activity of the project manager. Furthermore, Project Risk Management (PRM) is essential for failure proofing a project and is, therefore, a main task of the project manager (Kendrick, 2015). PRM can be seen throughout the entire lifetime of a project, meaning that PRM starts at the beginning of a project and last until project closure. In small projects, PRM may be informal, but for large projects, developing and publishing a risk management plan may be wise (Kendrick, 2015). Nowadays, (large) projects that are delivered for governmental institutions often come with a risk management plan, ensuring a properly managed project.

[4] Project Management Body Of Knowledge (PMBOK) is a guide from the Project Management Institute (PMI, the professional society for project managers).

Table 1 First dimension: project type

Project type	A	B	C	D
Name	Low-Tech	Medium-Tech	High-Tech	Super-High-Tech
Variable				
Definition	No new technology	Some new technology	Integrating new, but existing technologies	Key technologies do not exist at project's initiation
Typical Products	Buildings, constructions, roads, bridges, utility	Commercial, additional models; derivatives or improvements	New military system, new commercial family of products - first of its kind.	New, non-proven concept; new family of systems
Industries	Construction, production, utilities, public works	Mechanical, chemical aerospace, some electronics	High-tech industries. Computers, aerospace, electronics.	Advanced, high-tech and leading industries. Electronics, aerospace
Development and Testing; Prototyping	No development, no testing, no prototypes	Some development and testing; some prototypes	Considerable development and testing; prototypes are necessary	Extensive development of technologies and system components; intermediate program is usually used.
System Requirements	Set by customer prior to project's execution	Joint effort of customer and contractor	Strong involvement of contractor	Extensive contractor's involvement. Many changes and iterations
Functional Allocation	Simple, straightforward, most often static functions	Dynamic functions, more than one mode	Dynamic, complex, sometimes hard to define operation modes	Dynamic, complex, often ambiguous and multimodal
Design Cycles and Design Freeze	One cycle, Design freeze prior to project's initiation	One or two cycles. Early design freeze, no later than first quarter	At least 2 cycles. Design freeze usually during first or second quarter	More than 2, sometimes 4 cycles. Late design freeze, usually during second or third quarter
Management and Systems Engineering Style	Firm and formal style. Sticking to the initial plan	Moderately firm style. Ready to accept some changes. Increased interaction, some informal	Moderately flexible style. Expecting many changes. High interaction, formal and informal	Highly flexible style. Living with continuous change and 'looking for trouble.' Must control changes and risks. Extensive ongoing interaction

Source: Shenhar and Bonen (1997)

Proper PRM, starting with a risk management plan and risk management during execution, is becoming a standard in projects nowadays. Moreover, PRM is a requirement in many contracts, since failure of these types of projects can have significant consequences. For construction and engineering projects, these significant consequences can even mean death; a tunnel can collapse during drilling or an engineer can get electrocuted during installation. However, PRM not only focuses on that type of risk (safety-related risks), but it focuses on all risks that can have consequences for a project in terms of; time, cost, quality, safety etc. In short, PRM focuses on all risks that can have consequences for a project, it is basically a process that is key for failure proofing your project.

3.6 The Purpose of Risk Indicators

The implantation of a sufficient risk management plan (or a sufficient PRM process), reduces project risk events (Miller & Lessard, 2001). Moreover, a good understanding of risk

Table 2 Second dimension; system scope level

System Scope Level	1	2	3
Name	Assembly	System	Array
Variable			
Definition	A collection of components and modules combined into one unit, and performing a single function of a limited scale	A complex collection of many units and assemblies that is capable of performing an independent function of a large scale	A large widespread collection or network of systems functioning together to achieve a common purpose
Typical Products	A power supply; a computer's hard-disk unit; a battery	A building; a computer; a radar; an aircraft	A city's highway system; an air fleet; a communication network of a large geographical area.
Typical Function and Operational Aspects	Autonomous function or limited man-machine interaction	Serving a complex operational mission. Extensive interaction of man-machine during operation	A wide range mission, achieved by the conglomeration of many systems. Interaction of many people in its use and operation
Project Organization	Performed within one organization, usually under a single functional group. Almost no staff in project	A main contractor; a management team and matrix or project from and many subcontractors; technical, administrative and SE staff	An umbrella organization: a program management office coordination independent subprojecst; staff expert, legal, administrative, finance etc.
Main System Engineering Thrust. (Activities are added with higher levels)	Concurrent engineering and design for manufacturability, reliability etc. Integrated product teams.	System requirement and functional allocation. System integration and overall effectiveness problems. Detailed system engineering management plan.	Coordination of various system development and installation. Many environment and regulations concerns.
Planning, Control, and Documentation	Simple planning, often manual. Less than 100 activities. Simple control, mostly technical documents	Complex planning; advanced computerized tools. Hunderds or thousands of activities. Formal and tight control on technical and program matters; extensive technical & managerial documentation	A central planning of a 'master plan', followed by detailed planning at various levels. Up to tens of thousands activities. Managerial or program control through formal documentation. Technical matters at lower levels.
Management Style and Attitude	Mostly informal style; family like atmosphere	Formal and bureacratic style. Some informal relationships with subcontractors and customers	Formal and tight bureaucracy

Source: Shenhar and Bonen (1997)

events, whether it is based on previous experience or on literature, can help project managers to reduce project risk (De Bakker et al., 2012). However, you never know what the outcome of a project might be, but through the review of data from earlier work one can improve his predictions of the potential results (Kendrick, 2015). Many studies researched project risks for certain type of projects or even individual projects, meaning that they all found different risk events. However, certain risks might differ, but can be grouped into risk indicators. Grouping risks into risk indicators make project risks for different projects comparable. Many studies (Yim et al., 2015; Zou & Li, 2010; Miller & Lessard, 2001) used similar macro risk indicators (high-level risk groups, e.g. financial risks, technical risks etc.) for their research. They divided their macro risk indicators into smaller groups, micro risk indicators (low-level risk groups, e.g. financial risk: cash flow delays, increased material price etc.). By this, they managed to quantify risks into groups and were able to give conclusions regarding project. Risk indicators enable researchers to quantify risks for analysis, coming up with conclusions and recommendations for certain project types. This information can then be published and is accessible for public interest. Project managers are able to access this information and because researchers found that certain risk indicators occur for certain type of projects, project managers can improve their predictions. Hence, risk indicators are of great importance for understanding risk, as they make statistical analysis possible. Because of that, risk indicators are essential for understanding risks in projects, making them key for sufficient PRM.

3.7 Risks in Engineering Projects

Each project faces different risks, since every project is different. However, certain project types face similar risks, meaning that for each type of project, risks can be predicated upfront. Miller and Lessard (2001), based on the IMEC study, concluded that risks for large engineering projects can be divided into three categories: Market-related risks (think of; financial risks, demand risk, supply risk etc), technical risks and institutional risks (social acceptability risks, risks related to regulators etc). Market-related risks dominated the overall risks by 41.7%, technical risks were about 37.8%, followed by institutional risks of 20.5%. This means that of all risks occurred during the project, 41.7% of the total risk can be categorized as market-related risks. The research was based on 60 large engineering projects and projects were classified into seven project groups, also including: Urban-transport projects and road & tunnel systems (both engineering projects are applicable for RCM). The research suggested that urban transport projects and road & tunnel system face similar technical and institutional/social risks whereas both differ in market related risks (road & tunnel systems face higher market-related risks).

Miller and Lessard (2001) used a rather abstract risk area set (only three macro-risk indicators), whereas Yim et al. (2015) identified five macro risk indicators: external environment, organization, high level management performance, functional manager and team and project specific risk. However, Yim et al. (2015) did not specifically focus on engineering projects, but their schema can be used as a general risk indicator schema for project risk events.

Zou and Li (2010) applied six macro risk codes for their research (they investigated risks in the Nanjing Subway Line 2 project). The six macro codes that they used for their engineering project were: economic and financial, planning, contractual and legal, design, geological and construction risk. Construction risk was further divided into seven sub-groups: safety risk, interface risk, quality risk, cost risk, time risk, health and environmental risk and human risk. First, Zou and Li (2010) analyzed past risk events in subway projects and developed an initial risk coding list. The initial coding list was sent to two experienced professionals who were involved in the Nanjing Subway Line 1 and 2. The initial coding list was revised based on the recommendations of the two professionals, making it the final risk indicator list. The identified risks in their study match risks events in RCM's projects. Moreover, the Nanjing Subway Line 2 project can also been labeled as a system engineering project, as it uses the same engineering process and since the Nanjing Subway Line 2 tunnel is an integrated system (e.g. tunnel automation systems, rolling stock, power supply etc.). In addition to that, the requirements were set by the client and the contractor needed to design a proper system. Therefore, their final risk indicator schema can be used as a first step towards my risk indicator list. I refer you to section 5.4 Data Collection for the final risk indicator list for my research.

4. Project Management at Siemens

Corporate Siemens set a standard process for project management for Siemens parties all over the world. This process is simply called: PM@Siemens, and is created to set a uniform project management system. However, PM@Siemens is not a management system which tells the project manager exactly what to do; it will only provide the project manager with guidance for the overall project management process (Siemens Nederland N.V., 2015). This section covers PM@Siemens and, more importantly, explains how project classification and risk assessment are part of PM@Siemens. Figure 1 illustrates the overall LoA Tool process.

4.1 PM@Siemens, the Process

The project management process generally contains two stages: the project sales stage and the project execution stage. Each project stage can be divided into multiple phases and in these different phases there are so-called milestones and quality gates[5] that are equal for all projects. For example, the first phase in the process is lead management for a project, the corresponding milestone for this process phase is the Go/No Go decision. More phases follow and the first quality gate meeting happens at the third project phase, were corporate Siemens either approves of declines the project bid. During this moment, the country division/business unit submits their bid for their corporate Siemens counterparts. This quality gate meeting is about the approval of the project by corporate Siemens, therefore, many topics are discussed including project risks and project classification. Where project classification is generally a onetime activity, risk identification (and PRM) is an activity that follows the entire lifecycle of a project.

Other important quality gate meetings are the order receipt clarification and the release for customer acceptance meeting. The last two described quality meetings are only mandatory for project type A/B/C, small projects are excluded from these obligations (Siemens Nederland N.V., 2015).Note that I am not going to discuss the overall PM@Siemens process as it adds no additional value for this research.

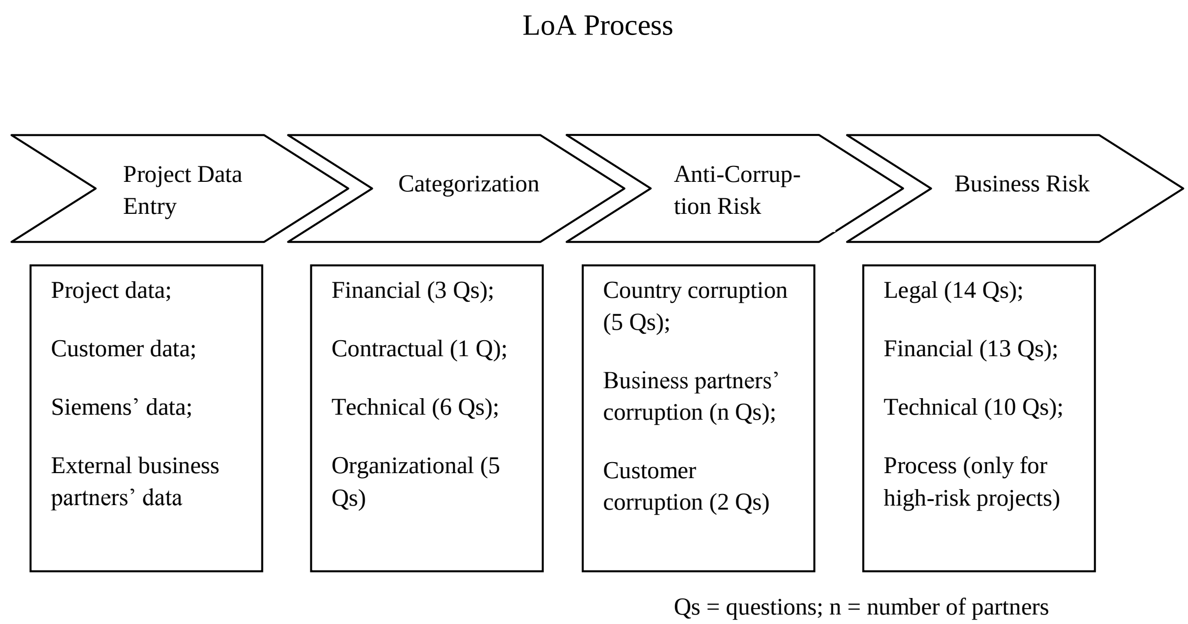
4.2 Project Classification at Siemens

Project classification is done in the first phases of a project and is part of the Level of Authority (LoA) process. The LoA process is the internal approval procedure for customer projects according to PM@Siemens. This process applies to all divisions and countries worldwide, regardless of their involvement in a project as e.g. supplier, partner or leader of a consortium. It limits the authority to approve the acquisition of projects and the submission of bids to specific management levels. Furthermore, the main goals of the LoA process are to ensure: 1) that risks deriving from the complexity of the project structure are identified and manageable, 2) that the solution offered is feasible and available and 3) that the cost calculation is realistic and Non-Conformance Costs[6] are kept at a minimum (Managing Board of Siemens AG, 2015). The LoA process is supported by the PM@Siemens LoA tool and in this tool, a set of factors and risks is analyzed to identify the necessary management level to take the final decision for a

[5] Quality gates: a specific marking in a project milestone where the project team and project management discuss the achieved results in terms of quality and decide how to continue the project.

[6] PMSiemens Glossary: Nonconformance costs (NCC) are costs which are found to deviate from the calculated order costs of the AEK over the whole period of the project, including the warranty period, i.e. NCC are additional costs (including provisions for the future), less cost reductions and any cost reimbursements arising from claims.

Figure 1 The LoA process at Siemens



bid. In general, the LoA process is compulsory for all customer projects that exceed the order volume of EUR 1m. As stated before, project classification happens during the LoA process. Generally, project classification is mandatory for projects with an order value of > EUR 2.5 million. These projects are placed in the category of A/B/C and Small projects (A being the most difficult projects, with a high order value and S projects represent Small projects, generally with an order value between EUR 100,000 and 2,500,000). The key criteria in determining the project category are the financial conditions, the contractual conditions, the technical complexity and the organizational considerations (Siemens AG, n.d.).

The purposes of project categorization at Siemens can be divided into four main uses (Siemens AG, n.d.); 1) as a criterion for determining the escalation level in the PM@Siemens LoA tool, 2) as a criterion for engaging Legal and other experts, 3) for determining the level of detail of minimum requirements for the process, such as the documentation requirements and the application of the quality gate principle and 4) for choosing and assigning project managers to carry out the project, with the required certification level according to the project manager competence profile.

4.3 Project Classification in the LoA Tool

The first stage of the LoA tool, after filling in project data, is the project categorization section. In this section, a project is assigned with a project category of either A/B/C. Note; when projects meet the qualifications of an S-type project, based on the project data, project classification is not mandatory and these projects are exempted from filling the categorization section. The project categorization section consists of a questionnaire in the previously described fields; financial, contractual, technical complexity and organizational considerations. A total of 15 questions are asked and the LoA tool computes, based on an algorithm, the matching project category. The results of the questionnaire are then plotted into a spider chart, which gives a visualization of the results.

At first sight, the question-distribution for each field (financial, contractual etc.) seems a bit skewed. The financial questionnaire only consists of three questions. In addition to that, the contractual condition only contains one question, simply: is the organizational unit (Siemens) a sub supplier/sole supplier or a consortium leader/member of a joint venture/has an operator model/has a turnkey project, whereas technical complexity and organizational considerations are accountable for the remaining questions. However, the impact of the three questions for financial (financial targets, think of profit and gross margin > organizational targets? and factors that can negatively influence cash flow) and contractual (position of Siemens in the overall project chain) highly increase the total number of points[7]. This means that the weights of these questions are relatively high. Table 3 shows the limits of the different project classes. As you can see, order volume contributes the most when it comes to project classification.

Table 3 Project categories and their limits

Category	Limit
A	Order volume > EUR 500mln and >1,000 points OR order volume > EUR 600mln
B	Order volume > EUR 10mln and 500 points OR order volume > EUR 300mln but not A
C	Order volume > EUR 2.5mln but not A or B
S	Order volume < EUR 2.5mln

4.4 Project Risks in the LoA Tool

Risk assessment is, next to project categorization, an important section in the LoA tool as the outcomes of the risks questionnaires also determine the escalation level. The risks sections of the LoA Tool consist of two different risk areas: 1) Anti-Corruption Risk Assessment (ACRA) and 2) Business Risk Classification (BRC). The results of the questionnaires leads to a risk score, this risk score can be either 1/2/3 (1 represents a high risk project and 3 represents a low risk project). As a general rule; the higher risk class leads, i.e. when a project scores an ACRA of 2 and a BRC of 1, the project risk profile will be recognized with a risk level of 1. The following paragraphs shortly explain the different risk areas.

The ACRA is mandatory for all projects that are obligated to fill in the LoA tool. This section of the LoA tool focuses specifically on corruption risks. In this section, the project manager has to evaluate corruption risks for this project, mainly by searching towards keywords in combination with all the involved parties. The project manager can do this by searching for matches on the internet. The project manager, for instance, uses a search engine and search for the following criteria: Bribery AND "Supplier X", Fraud AND "Client Y", etc. When no suspicious articles pop up, the project manager can state that the corruption risks is low (risk level 3). Moreover, each country receives an Anti-Corruption (AC) score. In combination with the internet search and the AC, a final risk grade is given. Note that all projects included in my research are executed in The Netherlands, meaning that this research will not take a country score into consideration as all projects are executed in the same country.

Usually, the ACRA for Siemens Netherlands is not that exciting, since The Netherlands has a good AC score and corruption is not a common event. BRC, on the other hands, is more interesting as project specific risks are accounted for. During the BRC, different experts are asked to fill in a questionnaire. The different experts fill in the questionnaire with regards to their field of expertise; these fields can be divided into; legal, financial and technical. Each field of expertise has its own questions with risks that are applicable to the project. The legal questionnaire, for instance, contains questions regarding liability, permits, clear contract, guarantees etc., each question (regarding a specific topic) is considered as a potential risk. Remarkably, a questionnaire regarding resources

[7] Projects are categorized based on order value and points. Points are calculated based on the answer of each question (the riskier the answer, the more points that question gets).

(e.g. availability, capability etc.) is not present in the BRC, whereas project categorization does take organizational considerations into account. One can argue that risks related to human resources are incorporated in the LoA tool under project categorization. However, as stated before, questions regarding human resources are not incorporated in the BRC, which might suggest that risks related to the organization are not considered as potential risk events.

Nevertheless, the BRC is a useful tool for estimating project risk. Based on the answers to the questions, the LoA tool computes the corresponding risk level. Together with ACRA score (higher score leads), a final risk score is added to the project classification result, making it (read: LoA Tool) a two-dimensional classification framework. Projects with a coding of A1 are considered to be high risk, complicated projects and they need to address the highest level of authority for project decisions, whereas C3 and S3 projects can be seen as low risk, not-so-difficult-to-handle-projects. Keep in mind that ACRA and BRC has nothing to do with order value. Therefore, S3 projects fall in the same escalation level as C3 projects. With other words, the risks sections within the LoA tool are equal for most projects and this section does not discriminate projects on order value.

5. Methodology

This section covers the research method for the statistical sub research question. All steps taken during this research are discussed below and are divided into different sections from research design to data analysis. Moreover, this section shortly discusses the objective of the study again to refresh the mind and to emphasize the relevance of this research to the objective.

5.1 Purpose of the Study

The study will test whether there is a relationship between project types and project risks. By doing this, RCM's management will be able to predict upfront, i.e. before signing the contract, what risks they can expect for the offered project.

5.2 Research Design

This research will be a quantitative research, as projects and project risk indicators are classified. Risk events are, however, different for each project, meaning that risks can even deviate from projects within the same category. Although risks are not identical for projects, risks can be grouped together as they often share similar matters.

As described earlier, quantifying risk into risk groups/indicators make different analysis's possible, e.g. hypothesis testing and correlation analysis. Note that hypothesis testing and correlation analysis will be addressed the most, since they are applicable for the regarding sub research question.

5.3 Data Sources

I have multiple data sources at my disposal; LoA data (upfront risk identification), project risk registers and the lessons learned database. Furthermore, the project controllers can also be addressed for project risk events, as they executed their projects and were heavily involved in the different projects. Note that the sample of projects only contains projects > EUR 500,000 and that started/have been completed within the past five years. Only looking back five years will give me the most reliable information, as a lot has changed within the industry. Moreover, things that happened a long time ago might be forgotten. Furthermore, RCM has a uniform reporting system since that time, therefore, only projects within that period can be seen as a reliable data sources. Moreover, the projects should have a volume of over EUR 500,000 as this size of project volumes is interesting for RCM's management.

Table 4 Projects and their characteristics

No.	Description	Project Type*	Project Scope	Siemens Category	Contractual Position?	Technology
1	Tunnel systems and command	C	2	C	Consortium	Existing, but new environment
2	Tunnel systems	B	2	S	Sub	No new technology
3	Road LED signs	B	2	S	Sub	No new technology
4	Tunnel systems and command	C	3	B	Prime	Existing, but new environment
5	Road LED signs	B	2	C	Sub	No new technology
6	Tunnel systems	B	2	C	Sub	Existing, but new environment
7	Road LED signs	B	2	S	Sub	No new technology
8	Station systems	C	2	B	Prime	Existing, but new environment
9	Traffic command centre	D	3	B	Prime	Existing, but new environment
10	Traffic command centre	D	3	B	Consortium	Existing, but new environment
11	Road LED signs	B	2	C	Sub	No new technology
12	Road LED signs	B	2	B	Sub	No new technology
13	Tunnel systems	C	2	C	Sub	Existing, but new environment
14	Road LED signs	B	2	S	Sub	No new technology
15	Tunnel systems and command	D	3	C	Prime	Existing, but new environment
16	Road LED signs	B	2	S	Sub	No new technology
17	Tunnel systems and command	C	2	S	Sub	Existing, but new environment

* Project type is used as a relative variable. Shenhar and Bonen (1997) suggested that D projects are new, for instance, the space shuttle program. The projects that are categorized as D projects, can be seen as the most difficult projects for RCM. However, that does not mean that these projects are equal to the complexity of NASA's space shuttle program.

Only focusing on completed projects of the past five years gave me a small data source. Therefore, adding started projects (lifetime > 0.5 years) will increase my sample size. The 0.5 year cut does not jeopardize the research in terms of completeness of the overall project risks, as a lot of risk events are categorized and most risks can be identified at an early stage of a project's lifetime (table 4 illustrates which projects were in the sample). The project's data and the corresponding LoA data, project risk registers and lessons learned database were retrieved before starting the research. Upfront analyses of the LoA data, project risk register and lessons learned database showed that these databases were not complete; therefore these databases were not used as the main data sources for this research.

5.4 Data Collection

As described in the previous section, the project's corresponding databases were not that promising. Therefore, a different data collection method was used as a way to retrieve the project's risk data. A questionnaire based approach was used as a technique to retrieve the needed data. The next section describes how the questionnaire was formed.

First, the projects had to be categorized in order to make the project data suit the analysis requirements. The projects were classified based on the classification framework of Shenhar and Bonen (1997) as their framework perfectly fit RCM's project characteristics. Siemens' LoA classification was also used as a classification framework. Note that the risks assessment scores of the LoA tool were not taken into account, as the score is just a case of 'the higher score leads'. This means that do not make a clear distinguish between projects and the risk assessment score is therefore useless for this study. Also, keep in mind that the LoA classification framework discriminates projects based on order volume; meaning that even small

Table 5 Risk indicator list

Macro risk indicators [abbreviation]	Micro risk indicators
Contractual and Legal risks [CON]	Delay in solving contractual issues [CON-1]
	Unfavorable contractual payments [CON-2]
	Delay regarding customer's review time for documents [CON-3]
	Change order negotiation [CON-4]
	Significant penalties related to milestones [CON-5]
	Compliance: permits, jurisdiction, insurance etc. [CON-6]
	Infinite liability [CON-7]
Technical risks [TEC]	Delay in solving technical disputes [TEC-1]
	Tight planning [TEC-2]
	Unclear design specifications and requirements [TEC-3]
	Amendment of national standards [TEC-4]
	Insufficient design time [TEC-5]
	Design mistakes [TEC-6]
	Design variations [TEC-7]
	Lack of experienced designers [TEC-8]
	Delay in approving design drawings [TEC-9]
	Poor "as maintained" input information of client's current systems [TEC-10]
Quality risks [QUA]	Use of inappropriate equipment and systems [QUA-1]
	Inexperienced personnel [QUA-2]
	Insufficient supervision and system testing [QUA-3]
	Damage during installation [QUA-4]
	Current installations do not meet requirements [QUA-5]
	End-user demands differ from contract requirements [QUA-6]
Cost risks [COS]	Low gross margin set in tender price [COS-1]
	Material price escalation [COS-2]
	Labor price escalation [COS-3]
Project team & management risks [PTM]	Lack of communication within project team [PTM-1]
	Change of key personnel [PTM-2]
	Poor prioritizing by (functional) manager [PTM-3]
	Missing team spirit [PTM-4]
	Missing standard procedures [PTM-5]
	Lost of knowledge during the transfer from the sales team to the realisation team [PTM-6]
	Shortage of personnel [PTM-7]
Sub-contractor risks [SUB]	Capability of sub-contractor [SUB-1]
	Cost disputes with sub-contractor [SUB-2]
	Penalties imposed by sub-contractors [SUB-3]
	Insufficient communication with sub-contractor [SUB-4]
	Compliance of sub-contractor's contractual requirements [SUB-5]

projects can have significant risk events, but are not acknowledge in Siemens' LoA classification. The next step was to create a risk indicator list for categorizing risk events. Table 5 shows the final risk indicator list, which is divided into macro and micro risk indicators. First, the list was created by combining risk indicators from the study of Zou and Li (2010), as their applied risk list can be applied to RCM's project as well, and by the findings of one detailed project risk database. Secondly, two experienced project controllers, who were also accountable for 70% of the projects in the sample, were asked to review the initial risk indicator list. They were asked to review the list based on completeness (whether they were able to plot most risks for their projects in the list). The initial list was revised based on their founding's and was used as the foundation of this research.

Each project controller was asked to fill in the questionnaire for the project(s) they were accountable for. The questionnaire, basically, was an extension of the final risk indicator list. The questionnaire contained all the risk indicators and the project controllers were asked to answer whether that risk indicator was identified. Moreover, they were asked to give every risk indicator a rating, based on a Likert scale of 0 to 5. Table 6 summarizes the scales and their labels. For this research, the scale number will be referred to as Risk Impact Scale (RIS).

Table 6 Scales and their labels.

Scale No.	Label
0	Risk did not occur
1	Risk had almost no impact[8]
2	Risk had some impact
3	Risk had medium impact
4	Risk had major impact
5	Risk had significant impact

5.5 Data Analysis

After the data was gathered, the variables were plotted into Microsoft Excel (2007) and IBM SPSS (version 20) for analysis. The gathered data was entered into the database and each record contained the following variable: macro risk indicator, micro risk indicator, project number, project type, system scope, LoA class, risk identified and the RIS. The total data set contained 646 records with all the previously named variables. The total of 646 records can be explained by the Number of Projects × Number of Micro Risk indicators (17×38=646).

[8] In this research, *impact* is considered to be a negative outcome for the project's objectives and can have consequences in: time, cost and/or quality.

Table 7 Variables and their measure

Variable	Measure
Macro risk indicator	Nominal
Micro risk indicator	Nominal
Project number	Nominal
Project type	Nominal
System scope	Nominal
LoA class	Nominal
Risk identified	Nominal
RIS/RIP	Nominal/interval/ordinal

Table 7 shows the different variables with variable level of measurement. For this research, I followed Stevens' (1946, 1951) view on measurements in science (note that I do not agree with Stevens' view on requirements for statistical procedures, this will be later explained in this section). Stevens argued that there are basically four levels of measurement in science that are called; nominal values, ordinal values, interval values and ratio values. These four scales unify both qualitative (nominal scale) and quantitative (the other three scales, to some degree) variables. Nominal values are also known as mutual exclusive categorical variables; it differentiates data into different qualitative classifications (i.e. ZIP codes, gender, nationality, etc.). An ordinal variable is one where the order in a specific set matters. Think of ranking different paintings or the ranking of movies. An interval variable is a measurement where the difference between two values is meaningful, i.e. temperature (100 degrees and 80 degrees). A ratio has all the same properties of an interval value, but also has a clear definition of 0.0. When the variable equals zero, there is none of that variable; think of weight and height (ratio variables). Temperature on the other hand is not a ratio variable, since 0 degrees Celsius does not mean "not heat". Temperature expressed in degrees of Kelvin, however, is a ratio variable as 0.0 Kelvin really means "no heat".

Stevens (1946, 1951) received much criticism on his work as he first suggested that specific measurement scales (the four named before) are included as requirements in the use of statistical procedures. Many articles in the statistical journals clearly showed that measurement scales are not related to statistical techniques (Gaito, 1980). Meaning that Stevens' view on level of measurement as requirements for statistical procedures is not binding. Because of this, I can use the RIS as a nominal value and as an interval value at the same time for different statistical procedures. Note that when tables refer to RIS, the data is seen as nominal values (scales 0 till 5). When tables refer to Risk Impact Points (RIPs), the data is perceived as interval data.

Most of the variables are considered to be nominal values (qualitative data) and only RIPs can be seen as quantitative data. When RISs are converted into RIPs, a Normal distribution is far from met (see Appendix 1: SPSS Output for RIS Histogram). Therefore, all statistical tests in the next section only contain nonparametric tests, as the data does not comply with the requirements (Normal distribution) for parametric tests.

6. Results

This section covers all the statistical tests and procedures that were performed during this research. Every paragraph treats a different procedure to test the hypothesis of that paragraph. Every test is done two times; one test uses Shenhar and Bonen's (1997) two dimensional project type and system scope classification framework and the other test uses Siemens' LoA classification framework. Note that some tables of Shenhar and Bonen's (1997) project types and Siemens'LoA classification framework are inserted in this paper. The tables which contain the test and the results of the test can be found in the appendix of this report (mostly SPSS outputs).

6.1 Relationship Between Project Type and RIS

This paragraph covers the question whether there is a relationship between a project type and macro/micro risk indicators. Since the data does not comply with the requirements for parametric tests, the nonparametric Chi-square test is used to test whether there is a relationship between project type and RISs. The Chi-square tests the null hypothesis of interest, in a two-way table, H_0: there is *no association* between the row variable and the column variable. The alternative hypothesis H_a simply states that there is an association between the two variables. The alternative hypothesis does not specify any particular direction of the association.

The Chi-square test requires the count of each cell in the $r \times c$ table. The observed count of each cell can be found in table 8. Next to the observed counts, the Chi-square test also requires the expected counts. The expected counts can be calculated as follows:

$$Expected\ counts = \frac{row\ total\ \times\ column\ total}{n}$$

When this formula is applied to table 8, we can state that the expected count for a B2 project with a RIS of 0 equals 188.47 (342×356/646). The null hypothesis is tested by the Chi-square statistic, which compares the observed counts with the expected counts, using the next formula:

$$X^2 = \sum \frac{(observed - expected)^2}{expected}$$

Under the null hypothesis, X^2 has approximately the Chi-square distribution with *(r-1)(c-1)* degrees of freedom (df). This means that our table has df=10 *(6-1)(3-1)*. The Chi-square test is only adequate for practice when less than 20% of the cells have an expected count of less than 5 and all individual expected counts are 1 or greater. Thus, RIS 4 and RIS 5 were combined to comply with the minimum expected cell count of 5 (without combining, 11.1% were below the 5 count cut which still complies with the requirements of a Chi-square test, but just to be sure). By doing so, the new degrees of freedom became df=8.

Table 8 Observed number of RISs

	Project type			
RIS	B2	C2	D3	Total
0	280	46	30	356
1	41	57	24	122
2	16	33	20	69
3	5	35	16	56
4	0	15	16	31
5	0	4	8	12
Total	342	190	114	646

The data was entered in SPSS and the result of the tests is significant, meaning that we can reject the H_0*:* there is *no association* between risk impact scale and project type (P=0.000, X^2=246.94, df=8 and α =0.05). The P-value is the probability that from a future set of data the test statistic (in this case X^2) will be the same or larger than the test statistic in current data. The P-value can be obtained by using the Chi-square table (Appendix 5); look up the row for the degrees of freedom (in our case df=8) and find the P-value for X^2 in the table. We found that the P-value is smaller than 0.005 (SPSS calculated a P-value of 0.000). If the P-value is very small, then the null hypothesis is false. Hence, when the P-value is smaller than the pre-specific level alpha (for this research, α always equals .05, i.e. 5%), than the null hypothesis can be rejected (Moore, 2010). Since, the P-value is smaller than our pre-specific alpha (.000<.05) we can reject the null hypothesis of *no association* between project type and RIS. However, when we take a closer look at column B2 in table 8, we can see that this column has a lot of influence on the Chi-square test, as this column skewed the data set. Therefore, we should consider extracting column B2 from the data set. Another Chi-square test is performed and based on the result of this test, we can say that we failed to reject the null hypothesis (P=0.055, X^2=9.239, df=4[9] and α =0.05). This means that there is an association between project type B2 and RIS, which tend to be a RIS of 0. In other words, projects of the type B2 tend to have risks (as described in table 5) with no impact whatsoever. On the other hand, we failed to reject the null hypothesis for an association between C2, D3 projects and RIS.

Nevertheless, the same Chi-square test has also been executed for the Siemens' LoA classification framework. In this case we have no assumption of a skewed data set (table 9 does not show a skewed data set, but does show that B projects have a somewhat more equal RIS distribution). As the dataset does not look skewed, we can include all project types in the test. Again, SPSS indicates that 16.7% of the cells have an expected count less than 5. Just to be sure RIS 4 and RIS 5 were combined, meaning that the new degrees of freedom are df=8.

The results of the Chi-square tests indicate that we can reject H_0*:* there is *no association* between risk impact scale and project type (P=0.000, X^2=109.90, df=8 and α =0.05).

Table 9 Observed number of RISs

	LoA class			
RIS	S	C	B	Total
0	175	123	58	356
1	30	51	41	122
2	11	27	31	69
3	5	16	35	56
4	4	4	23	31
5	3	7	2	12
Total	228	228	190	646

Based on the Chi-square tests, we can state that, no matter what classification framework, there is an association between project type and macro risk indicators. However, a difference between C2 and D3 projects in terms of RIS are not that clear. Note that we only failed to reject the null hypothesis with a P-value of .055 and an alfa of .05, making the difference only .005. Moreover, the Chi-square tests indicated that there is an association between project type/LoA class and RIS, but it did not indicate what kind of relationship.

[9] Df=(r-1)(c-1)=(5-1)(2-1)=4

Hence, to determine the direction of the relationship between the two variables a Spearman's correlation was performed to determine the relationship between project type and RIS. Spearman's correlation measures the correlation between ordinal variables (in this case RIS and project type/LoA class). Project type and LoA class are nominal variables and not ordinal variables. However, converting them into a ranking (Project type: B2=1, C2=2 and D3=3; LoA class: S=1, C=2, B=3), makes it possible to run a Spearman's correlation. The results of the test, called Spearman's rho (table 10 shows the interpretation of the values), indicates that there is a moderately strong correlation between project type and RIS (Spearman's rho=.574, sig. =.000 and n=646). However, when we execute the same analysis for only project type C2 and D3 we can state that there is a very weak correlation between project type and RIS and the result is not significant (Spearman's rho=.068, sig. =.239 and n=304). Note, that the larger the absolute value of the correlation coefficient, the stronger the correlation is. But, also keep in mind that the smaller the P-value the more significant the relationship is, as the P-value tells how unlikely a given correlation coefficient will occur given no relationship in the population (Moore, 2010).

The same correlation analysis is executed for LoA class and RIS. The results of this test show that there is a weak correlation between LoA class and RIS, but the result is significant (Spearman's rho=.394, sig. =.000 and n=646). Note that there is almost a moderately strong correlation between LoA class and RIS, with only a difference between weak and moderately strong correlate of .006 (.040-.394=.006).

Table 10 Interpretation of correlation coefficient

Absolute value	Interpretation
.00-.19	Very weak
.20-.39	Weak
.40-.59	Moderately strong
.60-.79	Strong
.80-1.00	Very strong

Source: Moore (2010)

The results shown in this paragraph only contained information regarding project type/LoA class and RIS. The results show that there is an association between project type/LoA class and RIS. The correlation analysis also suggested that there are reasons to believe that there is a correlation between the variables, as two out of three tests are significant. However, we failed to statistically prove a difference between project type C2 and D3 in terms of RIS. Nevertheless, the LoA class proves to be a promising classification framework so far.

6.2 Macro Risks Indicators in Projects

Table 11 (figure 2 is a visualization of the table) shows the total number of RIPs for each project type per macro risk indicator. Remarkably, C2 projects score the most RIPs for five projects. D3 projects score 216 RIPs with only three projects which are accountable for the RIPs overall score, meaning that the average RIPs for D3 are higher than the average RIPs for C2 projects. The mean RIPs suggest that, in fact, D3 projects have the highest mean of RIPs and that B2 projects face a mean of only 9.8 RIPs.

Table 11 RIPs per macro risk indicator and project type

Macro Risk Indicator	Project Type			Total RIPs
	B2	C2	D3	
CON	29	62	36	127
TEC	39	104	84	227
QUA	4	47	26	77
COS	4	19	10	33
PTM	12	53	42	107
SUB	0	23	18	41
Total RIPs	88	308	216	612
Number of projects	9	5	3	17
Mean RIPs	9,8	61,6	72	

Yet again, to test whether there is an association between project type and the proportions of macro risk indicators, another Chi-square test is performed. The null hypothesis is, not surprisingly, H_0: there is *no association* between project type and macro risk indicator in terms of

RIPs distribution. The alternative hypothesis is simply, H_a: there is an association between project type and macro risk indicator in terms of RIPs distribution. The exact same Chi-square test was executed for the Siemens' LoA classification framework. Table 12 (figure 3 is a visualization of the table) shows the macro risk indicators RIPs for Siemens' LoA project types.

Table 12 RIPs per macro risk indicator and LoA class

Macro Risk Indicator	LoA Class			
	B	C	S	Total RIPs
CON	58	47	22	127
TEC	110	84	33	227
QUA	35	23	19	77
COS	21	9	3	33
PTM	60	26	21	107
SUB	26	15	0	41
Total RIPs	310	204	98	612
Number of projects	5	6	6	17
Mean RIPs	62	34	16,3	

The performed Chi-square test suggest that we can reject the null hypothesis for both classification frameworks, since Shenhar and Bonen's (1997) classification framework was significant at α =.05 (P=0.004, X^2=25.73 and df=10) and Siemens' LoA classification was significant at α =.05 (P=0.017, X^2=21.59 and df=10).

Figure 2 RIPs per macro risk indicator for project type

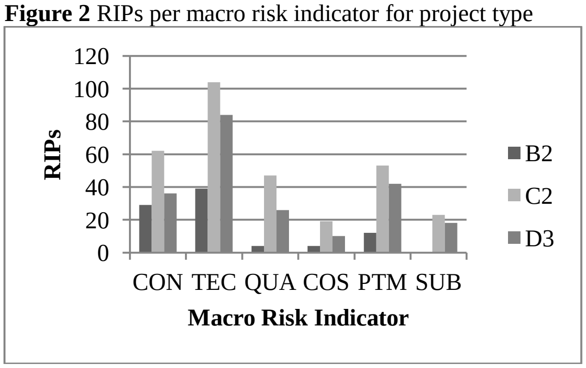
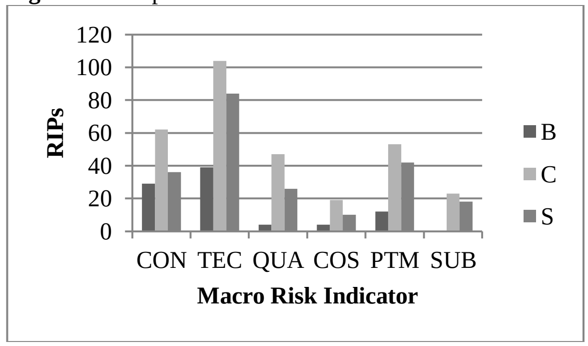


Figure 3 RIPs per macro risk indicator for LoA class



We can now state that there is an association between project type (whether it is by Shanar and Bonen's framework or Siemens' LoA framework). However, the Chi-square test does not indicate what kind of association there is. Thus, looking at figures 2 and 3 will help us understand what macro risks indicator occur most for certain project types. Figure 2 indicates that for all project types, the macro risk indicator TEC (Technical Risks) occurs most during projects and are for project types B2, C2 and D3 resp.: 44.32%, 33.77% and 38.39%. Figure 3 suggests that technical risks are also the most common risks for Siemens' LoA project classes. The different project classes B, C and S all have a high proportion of technical risks, resp.: 35.48%, 41.18% and 33.67%.

6.3 Micro Risks Indicators in Projects

Macro risk indicators are a bit abstract and only provide information regarding risks at higher levels. In order to get a good understanding of project types/LoA classes and risks, we have to zoom in on the macro risk indicators. This paragraph specifically focuses on micro risk indicators, to provide a greater understanding of the risk events.

Tables 17 and 18 (page 28) are basically a zoom in on tables 11 and 12, they show the RIPs at the micro risk indicator level for project types and LoA classes. However, the data in this table does not say much. The percentages for each micro risk indicator are rather small, since there are 38 micro risk indicators. In order to show the risks that really matter, a top-10 evaluation is performed for all project types and LoA classes. Figures 4 to 9 inclusive visualize the top-10 risks; it is possible that some projects have more than ten micro risk indicators in their visualization as some rankings may include ties. This means that one rank can contain multiple micro risk indicators. When we look at figure 4, we can see that rank 5 has two micro risk indicators (CON-2 and CON-3) with a RIP score of 6.

Figure 4 Top-10 micro risk indicators for project type B2

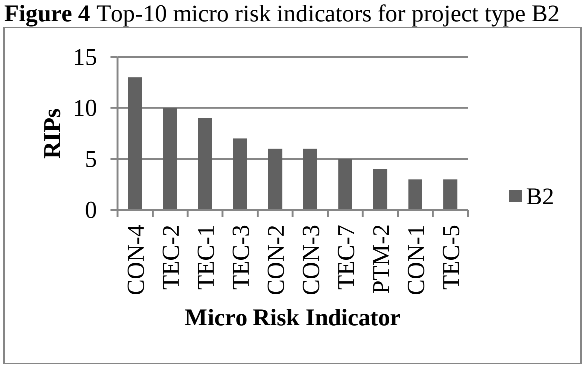


Figure 5 Top-10 micro risk indicators for project type C2

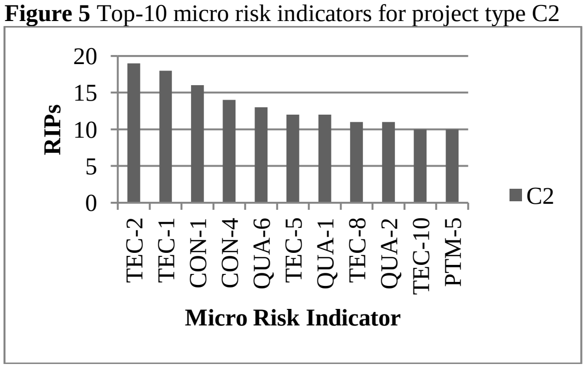


Figure 6 Top-10 micro risk indicators for project type D3

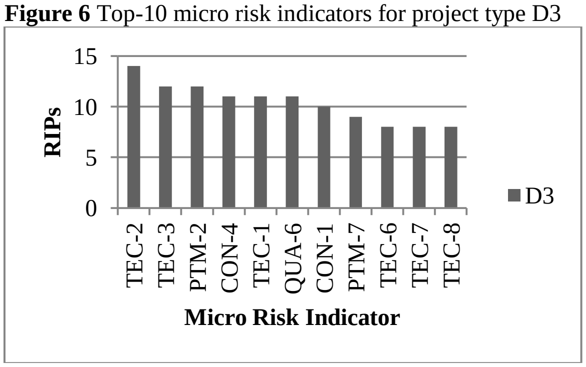


Figure 7 Top-10 micro risk indicators for LoA class B

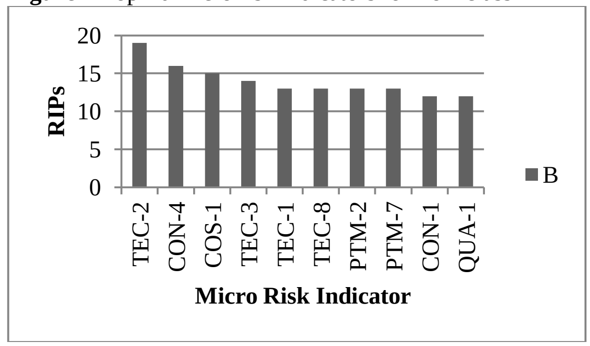


Figure 8 Top-10 micro risk indicators for LoA class C

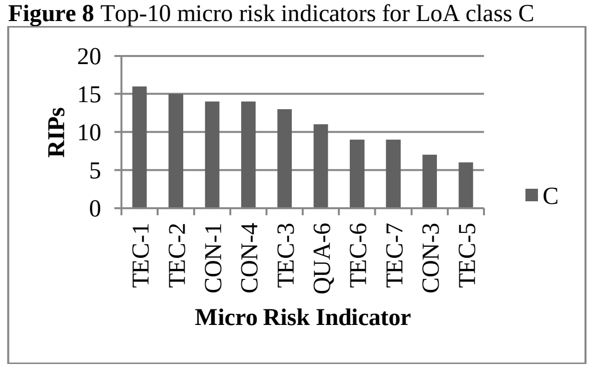
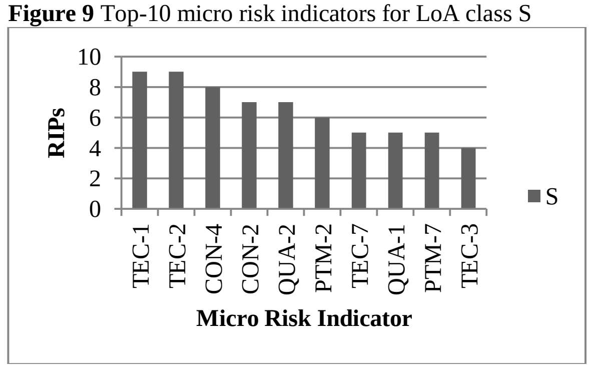


Figure 9 Top-10 micro risk indicators for LoA class S



Since the findings in section 6.2 indicated that project type B2 is significantly different than project type C2 and D3, we can state that for B2 projects the expected risks should be the ones that are mentioned in figure 4 (the definition of the risk codes can be found in table 5). However, as we failed to reject the null hypothesis in section 6.2 (that there is no association between project type and macro risk indicator), we cannot state that there is a difference in micro risk indicators for C2 and D3 projects. This means that we are unable to determine what risk ranking might be applicable for the project when enrolling for a C2 or D3 project.

On the other hand, we found that LoA class projects do differ in terms of both RISs and RIPs for different risks. Hence, we are able to predict specific risks for certain type of projects. When entering a LoA class B project, for instance, one can expect the micro risk indicators as shown in figure 7.

Not surprisingly, some micro risk indicators (e.g. TEC-1, TEC-2 and CON-4) occur in all top-10 rankings. This suggests that, regardless of project type/LoA class, that micro risk event will most likely occur, with impact on project objectives. Before making a ranking of the overall top-10 risks based on RIPs, a Kendall's tau-b rank correlation test is performed to measure the ordinal association between the different project types.

The Kendall's tau-b rank correlation, named after Maurice Kendall, who developed it in 1938, is a measurement of an ordinal (i.e. rank) correlation. It measures the similarity of the orderings in a ranked data set (Kendall, 1938). This test is often used in statistical hypothesis testing whether two variables may be statistically dependent or independent. The Kendall's tau-b rank correlation test is a non-parametric test that tests, under the null hypothesis of independence of variable X and Y, that the sampling distribution of τ has an expected value of zero. The Kendall's tau-b coefficient is defined as:

$$\tau_B = \frac{n_c - n_d}{\sqrt{(n_0 - n_1)(n_0 - n_2)}}$$

Where,

$$n_0 = n(n-1)/2$$
$$n_1 = \sum_i t_i(t_i - 1)/2$$
$$n_2 = \sum_j u_j(u_j - 1)/2$$
$$n_c = Number\ of\ concordant\ pairs$$
$$n_d = Number\ of\ discordant\ pairs$$
$$t_i = Number\ of\ tied\ values\ in\ the\ i^{th}\ group\ of\ ties\ for\ the\ first\ quantity$$
$$n_d = Number\ of\ tied\ values\ in\ the\ j^{th}\ group\ of\ ties\ for\ the\ second\ quantity$$

Let (x_1, y_1), (x_2, y_2), …, (x_n, y_n) be a set of observations (in our case n=38, as we have 38 micro indicator risks) of joint variables of (x_i) and (y_i) such that all values are unique. Any pair of observation (x_i, y_i) and (x_j, y_j), where $i \neq j$ are said to be concordant. Whenever the ranks for both elements agree, when $x_i > x_j$ and $y_i > y_j$ or $x_i < x_j$ and $y_i < y_j$ are said to be discordant. In case of other equations, the pair is neither concordant nor discordant.

The test was, however, run in SPSS and the results of the Kendall's tau-b rank correlation test can be seen in table 13 (this table contains the rankings of all 38 micro risk indicators for each project type/LoA class). The correlation interpretation is the same as the interpretation for Spearman's correlation coefficient. For the interpretation I refer you to table 10.

All Kendall's tau-b coefficients are significant at the .01 level (2-tailed), meaning that we can reject the null hypothesis that all rankings are independent. This means that there are indeed some similarities between rankings of micro risk indicators for project types/LoA classes.

A notable finding is that D3 projects and B projects (the most complex projects regardless of classification framework) have a correlation coefficient of .745, which means that there is a strong correlation between D3 and B projects in terms of micro risk indicator rankings. This is also true for both classification framework's least complex projects as B2 and S projects have a correlation coefficient of .631 (strong correlation). However, medium complex projects (C2 and C projects) show a moderately strong correlation (τ_b=.487), whereas C2 and S projects have a high correlation coefficient of .651, indicating a strong correlation.

Table 13 Kendall's tau-b correlation coefficient

	B	C	S	C2	B2	D3
B	1	,389**	,520**	,734**	,478**	,745**
C	,389**	1	,336**	,487**	,556**	,547**
S	,520**	,336**	1	,651**	,631**	,484**
C2	,734**	,487**	,651**	1	,507**	,625**
B2	,478**	,556**	,631**	,507**	1	,419**
D3	,745**	,547**	,484**	,625**	,419**	1

** Correlation is significant at the 0.01 level (2-tailed).

Fortunately, looking at inter-classification framework correlation only says something about the correlation between the two frameworks and nothing about micro risk indicators and project types/LoA class within the framework. The next paragraphs will, therefore, only look at the correlation coefficient among one framework (either Shenhar and Bonen's framework and Siemens' LoA framework).

Thus, when we have a look at only the LoA class projects, we can see that there is weak correlation between LoA classes B and C and a moderately strong correlation between B and S projects (which is a bit unusual as B projects can be seen as RCM's most complex projects and S projects as RCM's least complex projects). Nevertheless, these numbers indicate that there is only a weak correlation between B projects and C projects in terms of ranking. In the contrary, all coefficients are significant, indicating that there is indeed a correlation in terms of ranking micro risk indicators. Since, there are no strong correlations between LoA class projects, we can state that there is a difference in terms of ranking, meaning that the projects are different and that they face different risks.

When we have a look at project types (Shenhar and Bonen's classification framework), we can see that the correlation between the most complex and least complex project (resp. D3 and B2) show a moderately strong correlation of .419. The other correlation coefficient indicates that there is a somewhat stronger correlation in terms of ranking of micro risk indicators for the other project types.

Based on all the cells in the correlation matrix, we can conclude that there is a correlation in terms of ranking between project types/LoA classes, since no cell has a value of zero. Therefore, making an overall ranking of the top-10 micro risk events is justified as there is a correlation between project types/LoA classes in terms of ranking. Figure 10 shows the overall RIP score for each micro risk indicator and ranked them in descending order.

Figure 10 Ranking of micro risk indicators

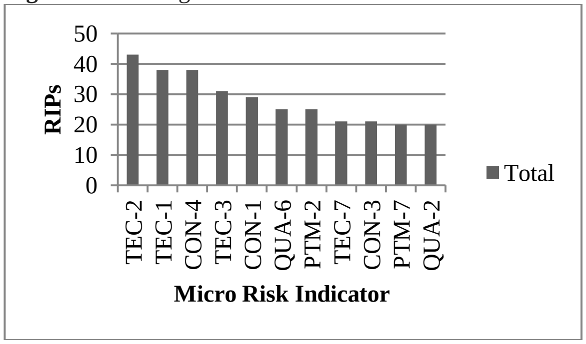


Table 14 is an extension of figure 10, as it shows all the micro risk indicators and their total RIPs. We can see that many technical risks (TEC) fall in the left hand side of the table, meaning that technical risks have a high RIP score. Moreover, Contractual and Legal risks also find themselves more often in the left hand side of the table.

Furthermore, table 15 shows the top ranking of the risks (as seen in figure 10) with the corresponding description to make the ranking more understandable.

Table 14 Overall ranking of all micro risk indicators

Rank	Risk	RIPs	Rank	Risk	RIPs
1	TEC-2	43	19	PTM-5	15
2	TEC-1	38	21	TEC-9	13
2	CON-4	38	22	PTM-3	12
4	TEC-3	31	23	PTM-4	11
5	CON-1	29	23	SUB-2	11
6	QUA-6	25	25	CON-6	10
6	PTM-2	25	25	SUB-5	10
8	TEC-7	21	27	CON-5	9
8	CON-3	21	27	TEC-4	9

10	PTM-7	20	27	COS-3	9
10	QUA-2	20	27	PTM-6	9
12	TEC-8	19	27	SUB-1	9
13	CON-2	18	32	SUB-4	8
13	TEC-10	18	33	COS-2	7
13	QUA-1	18	34	QUA-3	6
13	TEC-5	18	34	QUA-5	6
17	TEC-6	17	36	SUB-3	3
17	COS-1	17	37	CON-7	2
19	PTM-1	15	37	QUA-4	2

Table 15 Ranking of top-10 micro risk indicators

Rank	Micro risk indicator
1	Tight planning
2	Delay in solving technical disputes
2	Change order negotiation
4	Unclear specifications and requirements
5	Delay in solving contractual issues
6	End-user demands differ from contract requirements
6	Change of key personnel
8	Design variations
8	Delay regarding customer's review time for documents
10	Shortage of personnel
10	Inexperienced personnel

After interpreting the results of the results of the overall ranking list, this overall list was uploaded into SPSS to run a final analysis. This analysis was, again, a Kendall's tau-b rank correlation between the different project types/LoA classes and the overall ranking list.

Table 16 Correlation coefficient between the overall ranking and project type/LoA class

	LoA class			Project type		
Overall Ranking	B	C	S	B2	C2	D3
Corr. Coef.	.795**	.580**	.630**	.612**	.792**	.792**

** Correlation is significant at the 0.01 level (2-tailed).

Table 16 shows the results of this correlation analysis. As we can see, all values are significant at the .01 level (2-tailed), meaning that we can reject the null hypothesis of total independent rankings. Furthermore, we can suggest that B, C2 and D3 projects have a very strong correlation with the overall ranking. The overall risk ranking list can be addressed for predicting risks events when enrolling for B, C2 and D3 projects, as they have a (very) strong correlation with the overall ranking. However, the top-10 ranking list of an individual project type/LoA class should always be taken into consideration, as this is ranking is leading.

To conclude this section, we can state that all project types/LoA classes have a different ranking of micro risk indicators. However, some risks (TEC-1, TEC-2, TEC-3 and CON-4) are high risk events that occur for almost every project type/LoA class. Some risks specifically distinguish B class projects from the other LoA class. The risks TEC-8 and COS-1 mainly occur for the biggest, most complex projects of RCM. Furthermore, bigger projects also scored more RIPs than smaller projects, indicating that they have indeed more risk events with higher impact on project objectives. Smaller projects tend to have less risk events with less significant consequences on project objectives. Hence, we can argue that there is indeed a difference between projects in terms of the severity of risks and the number of risks as well as the type of risks. With other words, there is indeed a relationship between project type/LoA class and project risks.

Table 17 RIPs per micro risk indicator and project type

Micro Risk Indicator	Project type B2	Project type C2	Project type D3	Total
CON-1	3(3.41%)	16(5.19%)	10(4.63%)	29
CON-2	6(6.82%)	9(2.92%)	3(1.39%)	18
CON-3	6(6.82%)	8(2.60%)	7(3.24%)	21
CON-4	13(14.77%)	14(4.55%)	11(5.09%)	38
CON-5	0(0.00%)	7(2.27%)	2(0.93%)	9
CON-6	1(1.14%)	6(1.95%)	3(1.39%)	10
CON-7	0(0.00%)	2(0.65%)	0(0.00%)	2
TEC-1	9(10.23%)	18(5.84%)	11(5.09%)	38
TEC-2	10(11.36%)	19(6.17%)	14(6.48%)	43
TEC-3	7(7.95%)	12(3.90%)	12(5.56%)	31
TEC-4	0(0.00%)	4(1.30%)	5(3.24%)	9
TEC-5	3(3.41%)	8(2.60%)	7(3.24%)	18
TEC-6	1(1.14%)	8(2.60%)	8(3.70%)	17
TEC-7	5(5.68%)	8(2.60%)	8(3.70%)	21
TEC-8	0(0.00%)	11(3.57%)	8(3.70%)	19
TEC-9	2(2.27%)	6(1.95%)	5(3.24%)	13
TEC-10	2(2.27%)	10(3.25%)	6(2.78%)	18
QUA-1	0(0.00%)	12(3.90%)	6(2.78%)	18
QUA-2	3(3.41%)	11(3.57%)	6(2.78%)	20
QUA-3	0(0.00%)	3(0.97%)	3(1.39%)	6
QUA-4	0(0.00%)	2(0.65%)	0(0.00%)	2
QUA-5	0(0.00%)	6(1.95%)	0(0.00%)	6
QUA-6	1(1.14%)	13(4.22%)	11(5.09%)	25
COS-1	0(0.00%)	9(2.92%)	8(3.70%)	17
COS-2	2(2.27%)	5(1.62%)	0(0.00%)	7
COS-3	2(2.27%)	5(1.62%)	2(0.93%)	9
PTM-1	1(1.14%)	8(2.60%)	6(2.78%)	15
PTM-2	4(4.55%)	9(2.92%)	12(5.56%)	25
PTM-3	1(1.14%)	7(2.27%)	4(1.85%)	12
PTM-4	0(0.00%)	5(1.62%)	6(2.78%)	11
PTM-5	2(2.27%)	10(3.25%)	3(1.39%)	15
PTM-6	2(2.27%)	5(1.62%)	2(0.93%)	9
PTM-7	2(2.27%)	9(2.92%)	9(4.17%)	20
SUB-1	0(0.00%)	4(1.30%)	5(3.24%)	9
SUB-2	0(0.00%)	6(1.95%)	5(3.24%)	11
SUB-3	0(0.00%)	3(0.97%)	0(0.00%)	3
SUB-4	0(0.00%)	5(1.62%)	3(1.39%)	8
SUB-5	0(0.00%)	5(1.62%)	5(3.24%)	10
Total RIPs	88(100%)	308(100%)	216(100%)	612
Number of projects	9	5	3	17
Mean RIPs	9,8	61,6	72	

Table 18 RIPs per micro risk indicator and LoA class

Micro Risk Indicator	LoA class B	LoA class C	LoA class S	Total
CON-1	12(3.87%)	14(6.86%)	3(3.06%)	29(4.74%)
CON-2	8(2.58%)	3(1.47%)	7(7.14%)	18(2.94%)
CON-3	10(3.23%)	7(3.43%)	4(4.08%)	21(3.34%)
CON-4	16(5.16%)	14(6.86%)	8(8.16%)	38(6.21%)
CON-5	6(1.94%)	3(1.47%)	0(0.00%)	9(1.47%)
CON-6	5(1.61%)	5(2.45%)	0(0.00%)	10(1.63%)
CON-7	1(0.32%)	1(0.49%)	0(0.00%)	2(0.33%)
TEC-1	13(4.19%)	16(7.84%)	9(9.18%)	38(6.21%)
TEC-2	19(6.13%)	15(7.35%)	9(9.18%)	43(7.03%)
TEC-3	14(4.52%)	13(6.37%)	4(4.08%)	31(5.07%)
TEC-4	7(2.26%)	2(0.98%)	0(0.00%)	9(1.47%)
TEC-5	11(3.55%)	6(2.94%)	1(1.02%)	18(2.94%)
TEC-6	7(2.26%)	9(4.41%)	1(1.02%)	17(2.78%)
TEC-7	7(2.26%)	9(4.41%)	5(5.10%)	21(3.43%)
TEC-8	13(4.19%)	4(1.96%)	2(2.04%)	19(3.10%)
TEC-9	8(2.58%)	5(2.45%)	0(0.00%)	13(2.12%)
TEC-10	11(3.55%)	5(2.45%)	2(2.04%)	18(2.94%)
QUA-1	12(3.87%)	1(0.49%)	5(5.10%)	18(2.94%)
QUA-2	9(2.90%)	4(1.96%)	7(7.14%)	20(3.27%)
QUA-3	2(0.65%)	3(1.47%)	1(1.02%)	6(0.98%)
QUA-4	1(0.32%)	1(0.49%)	0(0.00%)	2(0.33%)
QUA-5	1(0.32%)	3(1.47%)	2(2.04%)	6(0.98%)
QUA-6	10(3.23%)	11(5.39%)	4(4.08%)	25(4.08%)
COS-1	15(4.84%)	1(0.49%)	1(1.02%)	17(2.78%)
COS-2	2(0.65%)	4(1.96%)	1(1.02%)	7(1.14%)
COS-3	4(1.29%)	4(1.96%)	1(1.02%)	9(1.47%)
PTM-1	8(2.58%)	4(1.96%)	3(3.06%)	15(2.45%)
PTM-2	13(4.19%)	6(2.94%)	6(6.12%)	25(4.08%)
PTM-3	7(2.26%)	2(0.98%)	3(3.06%)	12(1.96%)
PTM-4	5(1.61%)	6(2.94%)	0(0.00%)	11(1.80%)
PTM-5	8(2.58%)	5(2.45%)	2(2.04%)	15(2.45%)
PTM-6	6(1.94%)	1(0.49%)	2(2.04%)	9(1.47%)
PTM-7	13(4.19%)	2(0.98%)	5(5.10%)	20(3.27%)
SUB-1	6(1.94%)	3(1.47%)	0(0.00%)	9(1.47%)
SUB-2	7(2.26%)	4(1.96%)	0(0.00%)	11(1.80%)
SUB-3	2(0.65%)	1(0.49%)	0(0.00%)	3(0.49%)
SUB-4	4(1.29%)	4(1.96%)	0(0.00%)	8(1.31%)
SUB-5	7(2.26%)	3(1.47%)	0(0.00%)	10(1.63%)
Total RIPs	310(100%)	204(100%)	98(100%)	612(100%)
Number of projects	9	5	6	17
Mean RIPs	62	34	16,3	

Percentages indicate the weight of each micro risk indicator for the total RIPs for the column.

7. Conclusions and Recommendations

This section, as the name suggest, covers the conclusions and recommendations of this study. The conclusions will be divided into different paragraphs, as each paragraph covers its own section of this paper. The recommendations, however, will be written in one paragraph.

Project classification is the process of grouping projects into one higher class. Classifying projects makes it possible to distinguish different projects. In addition to that, project classification has three main purposes: 1) strategic alignment (assign priority for projects), 2) capability specialization (project delivery capability, assign appropriate resources and tools) and 3) promote project approach (provide a common language for project management). The three purposes of project classification do not differ that much with the purposes of project classification at Siemens. Siemens classifies its project for four uses: 1) as a criterion for determining the escalation level, 2) as a criterion for engaging Legal and other experts, 3) for determining the level of detail of minimum requirements for the process and 4) for choosing and assigning project managers to carry out the project, with the required certification level. When we compare theory with practice, we can see that the purposes of project classification are actually quite similar. The classification process of Siemens is, on the other hand, somewhat different than what some literature prescribes.

Siemens classifies its projects based on a questionnaire of 15 questions. This questionnaire contains questions regarding financial topics (3 questions), contractual topics (1 question), technical topics (6 questions) and organizational topics (5 questions). Based on the answer to each question, an algorithm computes the over points and based on order value and on the overall points, a project classification (A/B/C/S, where A is the biggest project in terms of order volume and high risk points and S is the smallest project in terms of order volume and technical difficulty) is assigned to the project. However, project size has such a great influence on the project class that the smallest projects, even when they have significant indications of high risks, are still assigned to the easiest-to-handle-projects class. The weight of each question in the Siemens LoA tool for project classification is, therefore, a bit skewed. Nevertheless, Siemens LoA classification framework was still used for classifying projects in this research, as RCM is obligated to use the Siemens' LoA classification framework. To compensate for this, another classification framework, which was suggested by literature, was used to classify the projects in the sample size. This framework was suggested by Shenhar and Bonen in 1997 and they specifically focused on system engineering projects (which is applicable to RCM)

In order to predict certain risks for a specific project type, the risk events had to be classified in some way. Each project faces different risk events, however, these risk events can, just as projects, be classified into risk groups or so-called risk indicators. In this research, risks were grouped into macro risk indicators, which contained smaller groups, called micro risk indicators. Classifying risks makes it possible to generalize the overall risk group. And these assumptions of risk indicators combined with project types are useful for practice. Literature suggested that a great understanding of risk, whether it is based on previous experience or based on research, can help project managers to reduce project risks. Moreover, classifying risks into risk indicators makes it possible for researchers to analyze those risks. These results can then be publishes and contribute to the public knowledge of project managers regarding project risks.

The research was designed to determine the relationship between project types and project risks. The projects in the sample were classified based on Siemens' LoA and Shenhar and Bonen's classification framework. All the test were run twice, one with Siemens' LoA classification and one with Shenhar and Bonen's classification. Table 8 and 9 suggested that the smallest, most easily to handle projects show low RIPs, indicating that S and B2 projects are less risky than C, B, C2 and D3 projects. However, Shenhar and Bonen's classification framework failed multiple times in distinguishing C2 and D3 projects, as the different Chi-square tests were not significant, whereas Siemens' LoA classification framework showed a consistent difference between project classes. Nevertheless, both frameworks suggest that more complex projects (C, B, C2 and D3 projects) have more occurred risks with higher impact on the project objectives (see tables 11 and 12). In addition to that, the results also indicated that Technical risks contributed to most to the overall RIP of a project, regardless of project type/LoA class. Whereas technical risks turned out to be the highest risk group, risks related to costs (e.g. labor price escalation) turned out to be least important macro risk indicator. Moreover, figure 4 till 9 show us that four risks pop up as the most significant risk for every project, regardless of project type/LoA class. These four risks are: tight planning (TEC-2), delay in solving technical disputes (TEC-1), unclear design specifications and requirements (TEC-3) and change order negotiation (CON-4). Moreover, these risks were also highly ranked in table 14, indicating that these risks are have significant impact on project objectives. However, some risks differ very much in terms of occurrence and impact. B class projects, for instance, are specifically marked by the lack of experienced engineers (TEC-8) and by a low gross margin set in the tender price (COS-1) (see figure B). These risks occur less for smaller projects and have less impact on project objectives.

Based on the results of the Kendall's tau-b rank correlation test for project types/LoA class and the overall ranking list, we can conclude that more complex projects have a (very) strong correlation with the overall risk ranking list. This is due to the fact that bigger, more complex projects contributed the most in terms of RIPs.

In short, we can conclude that bigger and more complex projects face more risks and these risks have more impact on project objectives than smaller, less complex projects. This means that there is definitely a relationship between project risks and project type, as all LoA class projects are different in terms of RIS distribution and RIPs distribution. The system engineering framework, on the other hand, also shows that there is a relationship between B2 projects and risks. However, that framework does not distinguish risks for C2 and D3, since all tests resulted in: there is no difference between project type C2 and D3 in terms of RISs and RIPs.

Thus, I would recommend the management of RCM not to use Shenhar and Bonen's systems engineering framework, as this framework does not indicate a difference between C2 and D3 projects. The predictability of risk events decreases for this classification framework, since we failed to reject that there is no difference between the two. Therefore, I recommend Siemens' LoA classification framework, since there is a difference between all classes in terms of risks. When enrolling for a project, the management of RCM should take a look at the ranking of micro risk indicators for that specific project type. However, since the LoA classification mainly focuses on order volume and on contractual issues, I also recommend analyzing the technical characteristics of that project before signing the contract. They should especially do this for B-class projects, as the ranking shows many technical risks that can have significant impact on project objectives. I would also recommend having a closer look at the planning for each project, since this risk is by far the most significant one. The other high impact risks; delay in solving technical disputes, unclear design specifications and requirements and change order negotiation, are risk events that will most likely occur for all projects. However, avoiding these risks is hard since they are just part of the game. Please note, that I am not going to explain why some risks occurred and how RCM can mitigate those risks, as this is not within the scope of this research. Moreover, researching that would be a whole new study which requires much time and effort to correctly analyze that topic Nevertheless, I would like to warn the management of RCM to specifically look at their personnel (in terms of experience) and at the gross margin of that project when enrolling for a B class project. These risks have significant impact on the project during the realization phase. A low gross margin can be seen as a buffer between a successful project and a failure (break-even project or unprofitable project) and as most risks result in increased costs, it is better to have a bigger buffer (i.e. higher gross margin) to absorb these NCCs.

8. Limitations and Future Research

This research was conducted from a sample size of 17 projects, where the distribution in terms of project types was not equal. The research would be more accurate if there were more projects and the distribution among the project types were proportionally equal, e.g. a total of 30 projects with 10 S, 10 C and 10 B projects. Furthermore, this research only contained project types as an independent variable, meaning that the dependent variable (risk indicators) is only determined by a project type. I would suggest investigating the relationships between macro/micro risks indicators and, for instance, the answers to the questions asked in the LoA classification tool. The answers to each question can be considered as a project characteristic. Then, micro risk indicators can be related to project characteristics, making it a more sophisticated way of predicting project risk events.

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10. Definitions

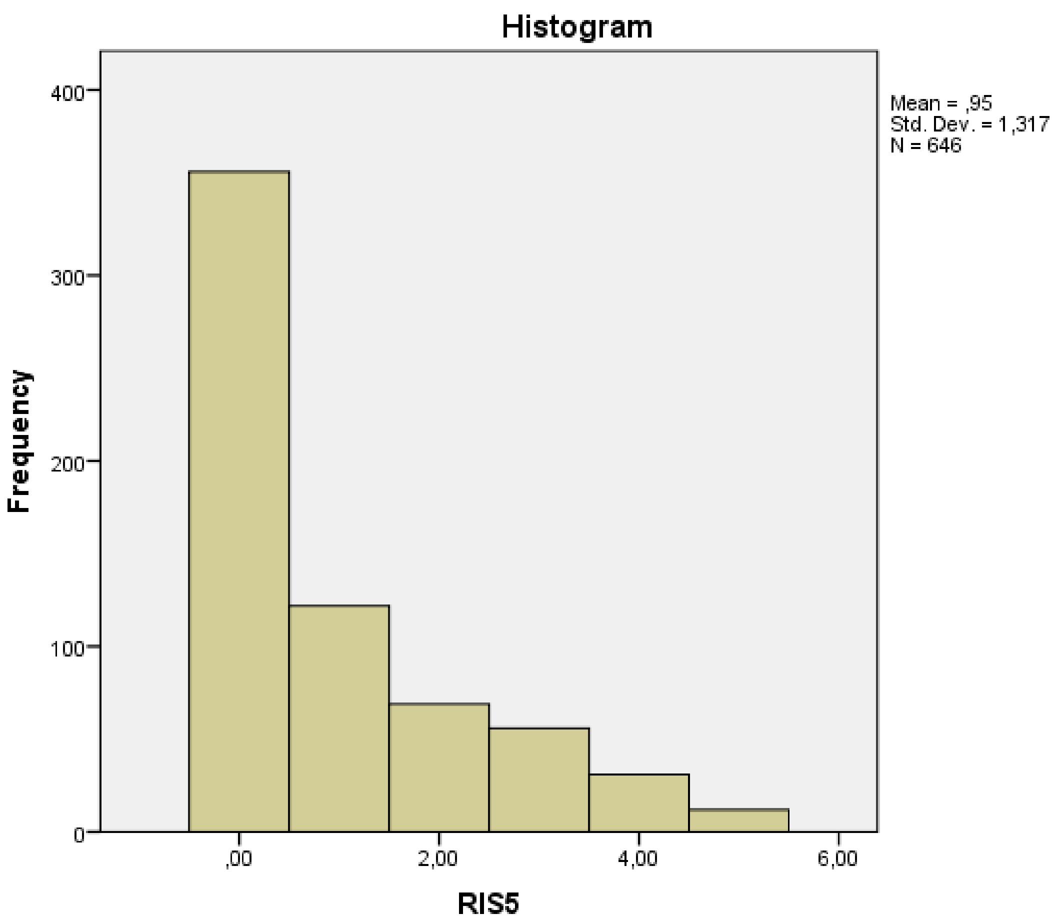
AC score	The Anti-Corruption score is a grade in Siemens' classification tool for classifying project risk. Each country has its own AC score and projects that are executed in that country receive the corresponding AC score.
ACRA	The Anti-Corruption Risk Assessment is a questionnaire in Siemens' classification tool for classifying project risk. The questionnaire contains questions regarding corruption and focusses on the client, sub-contractors and partners of that project.
BRC	The Business Risk Classification is a questionnaire in Siemens' classification tool for classifying project risk. The questionnaire contains questions regarding project risks and contains questions regarding Legal and Contractual risks, Technical risks and Financial risks.
Chi-square test	The Chi-square test is a statistical test that assumes, under the null hypothesis, that there is no association between the row and column classification. The Chi-square distribution is applicable for this statistical test and along with its only parameter, degrees of freedom, and the corresponding Chi-square statistic X^2, the P-value of a data set can be determined. We can reject the null hypothesis when P-value < α.
Correlation coefficient	The correlation coefficient is a value between two variables which tells the correlation between the two. The values of the correlation coefficient lie between -1 and 1. Where -1 means a perfect negative correlation (e.g. when x increase by .2, y decrease by .2) and 1 means a perfect positive correlation (e.g. when x increase by .2, y increase by .2). Absolute values between: 0 and .2 indicate a very weak correlation, .2 and .4 indicate a weak correlation, .4 and .6 indicate a moderately strong correlation, .6 and .8 indicate a strong correlation and values between .8 and 1 indicate a very strong correlation.
H_0	The null hypothesis (H_0) for correlation tests and chi-square tests are always that there is *no association* between the two variables. Whenever the P-value is smaller than the pre-set α, we can reject the null hypothesis and accept the alternative hypothesis.
H_a	The alternative hypothesis (H_a) for correlation tests and chi-square tests are always that there *is an association* between the two variables.
Interval values	These values can be seen as values where the difference between two values is meaningful, e.g. the variable temperature has interval values.
Kendall's tau-b rank correlation	A correlation test that measures the correlation between the rankings of two quantities of the same objects.
Macro risk indicator	This report contains six risks areas or macro risk indicators. These areas of risks can be divided into: Contractual and Legal risks (CON), Technical risks (TEC), Quality risks (QUA), Cost risks (COS), Project team & management risks (PTM) and Sub-contractor risks (SUB).
Micro risk indicator	Micro risk indicators go one level deeper when it comes to risks compared to macro risk indicators. This research contains 38 risks that are divided into the six areas of risks (macro risk indicators).
NCC	Non-Conformance Costs or NCC are costs which are found to deviate from the calculated order costs over the whole period of the project, including the warranty period.
Nominal values	Variables that can be seen as groups or categories are considered to be nominal values, e.g. ZIP-codes and gender.
Ordinal values	Variables that can be seen as rankings are considered to be ordinal values e.g. the rating of movies.
PM@Siemens	PM@Siemens is Siemens' general project management process that is a standard for all Siemens parties worldwide. It is a guideline that sets a uniform project management system. Note that this is not a process that tells the project manager exactly what to do.
P-value	A value that can be found for specific statistical test that represents the probability of the statistical value. The P-value is the probability that from a future set of data the test statistic will be the same or larger than the test statistic in current data. A small P-value suggests that there is a small possibility that the test statistic will be the same or larger.
PRM	Project Risk Management is the process of risk management for projects.
Ratio values	Values that have the same properties as interval values, but also have a clear definition of zero, e.g. temperature expressed in degrees of Kelvin.
RCM	Road and City Mobility (RCM) is a business unit of Siemens' division Mobility. As the name suggest, this business unit focusses on the delivery of infrastructure solutions for road and city projects.
RIP	A Risk impact Point is the point that a risk indicator receives on a scale of 0 till 5, where 0 represents no impact and 5 means significant impact. In this research, RIPs can be seen as interval values.
RISs	A Risk impact Scale is the scale in which a risk indicator is in. The scale goes from 0 till 5, where 0 represents no impact and 5 means significant impact. In this research RISs can be seen as nominal values.
Siemens' LoA Tool	A Tool that Siemens uses for purposes to limit the Level of Authorities (LoA). Based on different questionnaires, a project receives a classification and a risk classification.
Spearman's correlation	A correlation test that measures the correlation between two nominal values.
α	Alpha is a boundary of accepting an hypothesis or rejecting it. In statistics an alpha of .05 (or 5%) is regularly used.

Appendices

1. SPSS Output of RIS Histogram

RIS5

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	,00	356	55,1	55,1	55,1
	1,00	122	18,9	18,9	74,0
	2,00	69	10,7	10,7	84,7
	3,00	56	8,7	8,7	93,3
	4,00	31	4,8	4,8	98,1
	5,00	12	1,9	1,9	100,0
	Total	646	100,0	100,0	



2. *SPSS Output of Chi-square test for section 6.1 Shenhar and Bonen*

RIS * Project Crosstabulation

			Project			Total
			B2	C2	D3	
RIS	,00	Count	280	46	30	356
		Expected Count	188,5	104,7	62,8	356,0
	1,00	Count	41	57	24	122
		Expected Count	64,6	35,9	21,5	122,0
	2,00	Count	16	33	20	69
		Expected Count	36,5	20,3	12,2	69,0
	3,00	Count	5	35	16	56
		Expected Count	29,6	16,5	9,9	56,0
	4,00	Count	0	19	24	43
		Expected Count	22,8	12,6	7,6	43,0
Total		Count	342	190	114	646
		Expected Count	342,0	190,0	114,0	646,0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	246,935[a]	8	,000
Likelihood Ratio	269,004	8	,000
Linear-by-Linear Association	183,059	1	,000
N of Valid Cases	646		

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 7,59.

3. SPSS Output of Chi-square test for section 6.1 Shenhar and Bonen

RIS * Project Crosstabulation

			Project		Total
			C2	D3	
RIS	,00	Count	46	30	76
		Expected Count	47,5	28,5	76,0
	1,00	Count	57	24	81
		Expected Count	50,6	30,4	81,0
	2,00	Count	33	20	53
		Expected Count	33,1	19,9	53,0
	3,00	Count	35	16	51
		Expected Count	31,9	19,1	51,0
	4,00	Count	19	24	43
		Expected Count	26,9	16,1	43,0
Total		Count	190	114	304
		Expected Count	190,0	114,0	304,0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	9,239[a]	4	,055
Likelihood Ratio	9,090	4	,059
Linear-by-Linear Association	1,885	1	,170
N of Valid Cases	304		

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 16,13.

4. Chi-square test for section 6.1 Siemens LoA Class

RIS * LOA Crosstabulation

			LOA			Total
			S	C	B	
RIS	,00	Count	175	123	58	356
		Expected Count	125,6	125,6	104,7	356,0
	1,00	Count	30	51	41	122
		Expected Count	43,1	43,1	35,9	122,0
	2,00	Count	11	27	31	69
		Expected Count	24,4	24,4	20,3	69,0
	3,00	Count	5	16	35	56
		Expected Count	19,8	19,8	16,5	56,0
	4,00	Count	7	11	25	43
		Expected Count	15,2	15,2	12,6	43,0
Total		Count	228	228	190	646
		Expected Count	228,0	228,0	190,0	646,0

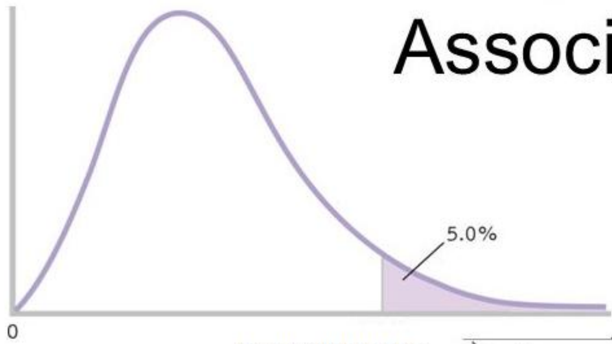
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	109,899[a]	8	,000
Likelihood Ratio	111,482	8	,000
Linear-by-Linear Association	92,611	1	,000
N of Valid Cases	646		

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 12,65.

5. Chi-square table

The Chi-Square Test for Association



9.488 (df=4), 15.507 (df=8)

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

df \ p	0.995	0.975	0.9	0.5	0.1	0.05	0.025	0.01	0.005	df
1	.000	.000	0.016	0.455	2.706	3.841	5.024	6.635	7.879	1
2	0.010	0.051	0.211	1.386	4.605	5.991	7.378	9.210	10.597	2
3	0.072	0.216	0.584	2.366	6.251	7.815	9.348	11.345	12.838	3
4	0.207	0.484	1.064	3.357	7.779	9.488	11.143	13.277	14.860	4
5	0.412	0.831	1.610	4.351	9.236	11.070	12.832	15.086	16.750	5
6	0.676	1.237	2.204	5.348	10.645	12.592	14.449	16.812	18.548	6
7	0.989	1.690	2.833	6.346	12.017	14.067	16.013	18.475	20.278	7
8	1.344	2.180	3.490	7.344	13.362	15.507	17.535	20.090	21.955	8
9	1.735	2.700	4.168	8.343	14.684	16.919	19.023	21.666	23.589	9
10	2.156	3.247	4.865	9.342	15.987	18.307	20.483	23.209	25.188	10
11	2.603	3.816	5.578	10.341	17.275	19.675	21.920	24.725	26.757	11
12	3.074	4.404	6.304	11.340	18.549	21.026	23.337	26.217	28.300	12
13	3.565	5.009	7.042	12.340	19.812	22.362	24.736	27.688	29.819	13
14	4.075	5.629	7.790	13.339	21.064	23.685	26.119	29.141	31.319	14
15	4.601	6.262	8.547	14.339	22.307	24.996	27.488	30.578	32.801	15

6. *Correlation matrix Shanhar and Bonen and RIS*

Correlations

			Project	RIS5
Spearman's rho	Project	Correlation Coefficient	1,000	,574**
		Sig. (2-tailed)	.	,000
		N	646	646
	RIS5	Correlation Coefficient	,574**	1,000
		Sig. (2-tailed)	,000	.
		N	646	646

**. Correlation is significant at the 0.01 level (2-tailed).

With Project: C2 and D3

Correlations

			Project	RIS5
Spearman's rho	Project	Correlation Coefficient	1,000	,068
		Sig. (2-tailed)	.	,239
		N	304	304
	RIS5	Correlation Coefficient	,068	1,000
		Sig. (2-tailed)	,239	.
		N	304	304

7. *Correlation matrix LoA class and RIS*

Correlations

			RIS5	LOA
Spearman's rho	RIS5	Correlation Coefficient	1,000	,394**
		Sig. (2-tailed)	.	,000
		N	646	646
	LOA	Correlation Coefficient	,394**	1,000
		Sig. (2-tailed)	,000	.
		N	646	646

**. Correlation is significant at the 0.01 level (2-tailed).

8. Micro Risk Indicators and their ranking

	Project type			LoA class		
Micro risk indicators	B2	C2	D3	B	C	S
Delay in solving contractual issues [CON-1]	9	3	7	9	3	13
Unfavorable contractual payments [CON-2]	5	12	26	16	24	4
Delay regarding customer's review time for documents [CON-3]	5	16	13	13	9	10
Change order negotiation [CON-4]	1	4	4	2	3	3
Significant penalties related to milestones [CON-5]	24	21	31	26	24	27
Compliance: permits, jurisdiction, insurance etc. [CON-6]	19	23	26	29	13	27
Infinite liability [CON-7]	24	37	34	36	33	27
Delay in solving technical disputes [TEC-1]	3	2	4	5	1	1
Tight planning [TEC-2]	2	1	1	1	2	1
Unclear design specifications and requirements [TEC-3]	4	6	2	4	5	10
Amendment of national standards [TEC-4]	24	33	20	20	30	27
Insufficient design time [TEC-5]	9	16	13	11	10	21
Design mistakes [TEC-6]	19	16	9	20	7	21
Design variations [TEC-7]	7	16	9	20	7	7
Lack of experienced designers [TEC-8]	24	8	9	5	17	16
Delay in approving design drawings [TEC-9]	12	23	20	16	13	27
Poor "as maintained" input information of client's current systems [TEC-10]	12	10	15	11	13	16
Use of inappropriate equipment and systems [QUA-1]	24	6	15	9	33	7
Inexperienced personnel [QUA-2]	9	8	15	15	17	4
Insufficient supervision and system testing [QUA-3]	24	35	26	33	24	21
Damage during installation [QUA-4]	24	37	34	36	33	27
Current installations do not meet requirements [QUA-5]	24	23	34	36	24	16
End-user demands differ from contract requirements [QUA-6]	19	5	4	13	6	10
Low gross margin set in tender price [COS-1]	24	12	9	3	33	21
Material price escalation [COS-2]	12	27	34	33	17	21
Labor price escalation [COS-3]	12	27	31	31	17	21
Lack of communication within project team [PTM-1]	19	16	15	16	17	13
Change of key personnel [PTM-2]	8	12	2	5	10	6
Poor prioritizing by (functional) manager [PTM-3]	19	21	25	20	30	13
Missing team spirit [PTM-4]	24	27	15	29	10	27
Missing standard procedures [PTM-5]	12	10	26	16	13	16
Lost of knowledge during the transfer from the salesteam to the realisationteam [PTM-6]	12	27	31	26	33	16
Shortage of personnel [PTM-7]	12	12	8	5	30	7
Capability of sub-contractor [SUB-1]	24	33	20	26	24	27
Cost disputes with sub-contractor [SUB-2]	24	23	20	20	17	27
Penalties imposed by sub-contractors [SUB-3]	24	35	34	33	33	27
Insufficient communication with sub-contractor [SUB-4]	24	27	26	31	17	27
Compliance of sub-contractor's contractual requirements	24	27	20	20	24	27

9. *Micro Risk Indicators and their RIPs*

	Project type			LoA class		
Micro risk indicators	B2	C2	D3	B	C	S
Delay in solving contractual issues [CON-1]	3	16	10	12	14	3
Unfavorable contractual payments [CON-2]	6	9	3	8	3	7
Delay regarding customer's review time for documents [CON-3]	6	8	7	10	7	4
Change order negotiation [CON-4]	13	14	11	16	14	8
Significant penalties related to milestones [CON-5]	0	7	2	6	3	0
Compliance: permits, jurisdiction, insurance etc. [CON-6]	1	6	3	5	5	0
Infinite liability [CON-7]	0	2	0	1	1	0
Delay in solving technical disputes [TEC-1]	9	18	11	13	16	9
Tight planning [TEC-2]	10	19	14	19	15	9
Unclear design specifications and requirements [TEC-3]	7	12	12	14	13	4
Amendment of national standards [TEC-4]	0	4	5	7	2	0
Insufficient design time [TEC-5]	3	8	7	11	6	1
Design mistakes [TEC-6]	1	8	8	7	9	1
Design variations [TEC-7]	5	8	8	7	9	5
Lack of experienced designers [TEC-8]	0	11	8	13	4	2
Delay in approving design drawings [TEC-9]	2	6	5	8	5	0
Poor "as maintained" input information of client's current systems [TEC-10]	2	10	6	11	5	2
Use of inappropriate equipment and systems [QUA-1]	0	12	6	12	1	5
Inexperienced personnel [QUA-2]	3	11	6	9	4	7
Insufficient supervision and system testing [QUA-3]	0	3	3	2	3	1
Damage during installation [QUA-4]	0	2	0	1	1	0
Current installations do not meet requirements [QUA-5]	0	6	0	1	3	2
End-user demands differ from contract requirements [QUA-6]	1	13	11	10	11	4
Low gross margin set in tender price [COS-1]	0	9	8	15	1	1
Material price escalation [COS-2]	2	5	0	2	4	1
Labor price escalation [COS-3]	2	5	2	4	4	1
Lack of communication within project team [PTM-1]	1	8	6	8	4	3
Change of key personnel [PTM-2]	4	9	12	13	6	6
Poor prioritizing by (functional) manager [PTM-3]	1	7	4	7	2	3
Missing team spirit [PTM-4]	0	5	6	5	6	0
Missing standard procedures [PTM-5]	2	10	3	8	5	2
Lost of knowledge during the transfer from the salesteam to the realisationteam [PTM-6]	2	5	2	6	1	2
Shortage of personnel [PTM-7]	2	9	9	13	2	5
Capability of sub-contractor [SUB-1]	0	4	5	6	3	0
Cost disputes with sub-contractor [SUB-2]	0	6	5	7	4	0
Penalties imposed by sub-contractors [SUB-3]	0	3	0	2	1	0
Insufficient communication with sub-contractor [SUB-4]	0	5	3	4	4	0
Compliance of sub-contractor's contractual requirements	0	5	5	7	3	0