RISK ASSESSMENT

How can we support the risk assessment of EPC projects in the proposal stage to better estimate the risk fund?

By:
Mark van Bueren (student number: 1049402)
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Supervised by: Prof. A. Verbraeck (Systems Engineering), Dr. Ir. G. Kolfschoten (Systems Engineering), Dr. Ir. H.G. Mooi (Technology, Strategy & Entrepreneurship) and Ing. W. Berendsen (CB&I Lummus).

COLOFON

Delft University of Technology:
Faculty of Technology, Policy and Management
Department: Multi Actor Systems
Section: Systems Engineering
Jaffalaan 5
2628 BX, Delft
www.tudelft.nl

Professor: Prof. A. Verbraeck

First Attendant: Dr. Ir. G. Kolfschoten

Second Attendant: Dr. Ir. H.G. Mooi (Section: Technology, Strategy & Entrepreneurship)

Chicago Bridge & Iron Company Lummus
Oostduinlaan 75
2596 JJ, The Hague
www.cbi.com

External Attendant: Ing. W. Berendsen
VP & Director of Projects & Construction (of CB&I Lummus, The Hague).

Author: Ing. M. van Bueren
mvanbueren@cbi.com

FOREWORD

After studying mechanical engineering at the Hogeschool of Utrecht I started working at CB&I Lummus in 1998. In the first year I was still missing something with respect to my educational level, which meant that I wanted to know if I was able to complete a study on University level. It was for this reason that I started looking for a University where I could study part time. This resulted in "Technische Bestuurskunde" at the Technical University of Delft, because of the combination between technical and policy aspects, which could be beneficial for the career I had in mind. I started with the study in the year 2000 and continued until 2002. After two years I was not able to combine the study anymore with my work in that period because I was transferred to a construction site. However, in the year 2004 after returning to the Home Office I still wanted to complete this Master.

Currently, I have reached the point of graduating after many years of colleges and studying in the weekends and during the holiday periods. This last part was sometimes not easy for the people at home. But they continued to support me which provide me the necessary pushes to continue. All many thanks for that. I also would like to thank the graduation commission. Especially, Gwendolyn for her continues support and necessary feedback.

Last but not least I would to thank the people within CB&I Lummus who contributed to this Thesis work and off course the people that allowed me to do this study. Hopefully, the results will be used within the CB&I organization as it provides a proper structure to the risk assessment which is necessary to cover up the organization for the negative consequences. Finally, I hope that this Thesis report will provide me the answer to my question, if I am able to finalize a study on University level.

Mark van Bueren

Gouda, June 2009.

PREFACE

Risk management is about understanding a project and making a better decision to manage that project. In some cases it could be decided to reject a project because certain risks can not be absorbed or accepted by one of the actors involved. Because of the crucial decision making process (to continue or reject a project) a proper risk assessment is essential. From a Contractors point of view it is also essential, in case it is decided to continue with a project, to have a sufficient risk fund to cover for the risks identified during the execution of the project. To make a decision regarding the amount of risk fund for a proposal an information system should be in place to substantiate the decision made.

This Thesis work is focused on the analysis of risk assessment within the CB&I Lummus Netherlands (CLN) organization. The purpose is to define those elements which can be improved to create a consistent risk assessment information system. To develop such system the framework of Hevner has been selected to structure the design process. This framework consists of the environment base, knowledge base and information system research. To structure this thesis report the framework of Hevner was used to categorize the chapters.

The first chapter deals with the introduction of the CLN organization. To understand the activities performed by an EPC contractor a project has been selected to describe the different steps. The selected project is a Lump Sum which CLN executed eight years ago in Western Europe. The second chapter defines the research approach and questions for which this research will be conducted for.

The knowledge base which provides the foundations for this research and the methodology are captured in chapter three. The foundations are provided in terms of the project life cycle, cost breakdown structure, contracting structures. These subjects define the technical, commercial and contractual part of an invitation to bid (ITB). This ITB is the basis for evaluating risks of EPC proposals. Definitions of risk & uncertainty will be provided. The methodology is reflected in a seven step risk assessment approach. Both the foundations and methodology will provide the applicable knowledge for this research.

The fourth chapter defines the environment base which captures the people and organization. This means that the practical risk assessment approach within CLN will be investigated by evaluating the CLN procedure and conducting interviews during the case study analysis. Both will be confronted against the methodology found in the knowledge base which will provide the business need or problem.

The fifth, sixth and seventh chapter will describe the information system research. On the basis of the knowledge and environment base, model requirements will be derived and a conceptual model designed. The conceptual model will form the basis to develop an information system.

The information system will be validated on a project which is currently executed by CLN. Sub sequentially, experts will be asked to verify and review the model. The last section is reserved for the overall conclusions, recommendations and elements which need further development before the model can be implemented into the organization.

EXECUTIVE SUMMARY

Chicago bridge & Iron Company (CB&I) Lummus (CLN) is a leading Engineering, Procurement and Construction (EPC) contractor, executing projects in the refinery and petro-chemical industry. Projects can be defined as complex due to the technology, major scope of work resulting in high value Reimbursable and Lump Sum contracts.

Risks are inherent to the execution of large engineering projects. It is essential to verify the risk profiles before a contract is agreed upon. This is necessary to understand and to define resources to cover for the risks identified. It has been realized by the CLN management that the verification of the invitation to bid on their risk profiles is handled inconsistently and based upon assumptions and intuitions. The challenge for this research was therefore; to create an information system which captures the risk assessment process and which would provide a tool to substantiate decisions about the necessary risk fund (in terms of probability and impact).

To be able to learn from the undefined process and to be able to design an information system the framework of Hevner has been selected. The framework is designed around three phases being the environment base, knowledge base and information system research. The knowledge base defines the foundations and methodology for the research, whereas the environment base defines the problem space. A confrontation between both the knowledge and environment base provided the business needs or problem. Requirements for the model are selected, such as a workflow of the risk assessment process within CLN and a conceptual model designed.

On the basis of the conceptual model the information system was developed. The information system consists of a qualitative and quantitative register and has been modeled in Excel. The qualitative risk assessment is based on standardized categories, e.g. does the project fit the strategy, geographical location, client, current workload, contractual requirements, etc. This evaluation will result in a decision to continue or reject a proposal. The quantitative risk assessment consists of a four step approach, being: risk identification, ranking, response planning and risk fund calculation. During the identification risks are described in terms of the event, cause, consequences and categorized to define the nature of the risk element. These risks will be ranked in terms of their estimated (by experts) probability and possible impact (numerical). The outcome of the probability x impact will provide a value on which a selection can be made of high and medium level risks. These risks will then be further analyzed. The correlation between these high and medium level risks must be defined in the correlation matrix (by experts). The response planning will be identified by selecting an initial response strategy. Action and an owner including action (due) dates need to be filled in. The last step is the risk fund calculations. Those risks which need to be included in the risk fund shall be indicated and defined if a risk is continue or discrete. In case of continues risks the impact and probability shall be defined in terms of the minimum, most likely and maximum values. In case of discrete risks a value shall be defined for the probability and risk. To calculate the risk fund the risk model will be loaded in the Excel add on program @risk which will simulate the model. The results, probability and impact are presented cumulative in an S-curve.

It can be concluded that the risk model as designed defines the total risk assessment approach. The model provides a standardized system to identify risk and to calculate the necessary risk fund. It provides sufficient information for the General Management of CLN to substantiate their decisions about the probability and risk fund allocation of a proposal. The risk model will standardize the risk assessment during the proposal stage which will result in consistency over the different proposals. In case of project award the completed risk model can easily be transferred from the proposal team to the project execution team. This should be used for managing the identified risks during project execution. It is therefore, recommended to implement this model into the CLN organization.
Although the model has been verified on completeness and validated by experts, certain aspects need attention before implementing, which are:

- How to implement secondary risks; during the identification of the risk response planning it could be the case that secondary risks are introduced. It should therefore be verified if these secondary risks are higher risk compared to the initial identified risk element. Theories about how to deal with secondary risks are available but do not form part of this research.
- How to incorporate the review of the risk fund related to the budget; the risk fund selected shall be verified against the total cost of the project which relates to bidding strategies.
- How to update the CLN procedures; the risk model and its functionality (including workflow) shall be captured in the CLN procedures. Responsibilities need to be defined and indicated in the procedures. Afterwards training sessions shall be organized to explain the model.
- Incorporate a tool which focus on the decision making process; to analyze several risk simultaneously it needs to be investigated if for example a decision tree would be beneficial.
- Validate the calculation; to be fully sure that the calculations can be trusted by the CLN management, experts need to validate the calculations.
- Analysis of the risk fund, contingency and profit; in case risks do not occur during the project execution the money included for that risk in the risk fund becomes available. It shall be analyzed if this money should be transferred to the contingency or base line profit.
- Relevance of a risk data base; due to limited projects executed by CLN due to the seizes of the projects it could be the case that to less data points are available to set up a risk data base.

It is recommended to analyze these aspects in more detail during the implementation of the model. However, the validation of the calculations should be done on forehand by experts in this field as they need to be trusted and relied upon.

TABLE OF CONTENT

1. INTRODUCTION

This report represents the results of the research about risk assessment. The research is submitted in the fulfillment of the requirements for the degree of "Ingenieur, Ir." (Master of Science, Msc) in "Technische Bestuurskunde" (Systems Engineering, Policy Analysis, and Management) at the Technical University of Delft. It has been executed within Chicago Bridge & Iron Company (CB&I) Lummus, the Netherlands, an Engineering, Procurement and Construction (EPC) contractor.

In this chapter an introduction will be given about the CB&I Lummus organization including an example of the work executed. The importance of risk management during projects will be highlighted and the framework of the research described. Guidance for reading this report will be presented in the last paragraph.

1.1. CB&I Lummus, the Netherlands

CB&I Lummus, the Netherlands (CLN) is a full subsidiary of Chicago Bridge & Iron Company (CB&I). CLN a leading Engineering, Procurement, Construction (EPC) contractor providing in depth technology, project execution (EPC) and project management services in the oil & gas, petroleum refining and petrochemical industries on a worldwide scale. Both Up-stream and Down-stream projects are being executed by CLN. CB&I Lummus is located around the world with offices in; Brno, Cairo, Houston, Bloomfield, Singapore, Saudi Arabia and Wiesbaden. The CB&I Lummus office in the Netherlands is situated in The Hague and employs around 859 people. The world wide Lummus staff consists of approximately 2477 people, the total staff employed by CB&I counts approximately 17.500.

To illustrate the work which is handled within the CLN organization an example is provided of a project executed by CLN in the Netherlands:

CLN entered into a Lump Sum (LS) agreement with the Client for the Engineering, Procurement, and Construction (EPC) of a Propylene Oxide (PO), Styrene Monomer (SM) production plant (POSM) and an Ethyl Benzene (EB) production plant (in total called the plant). The value of the contract was approximately 500 million Euros. POSM is a basic product required to produce plastics. The Plant comprises of units and buildings (collectively known as facilities). There were two kinds of facilities:

- The facilities to process the chemical reactions in order to produce Propylene Oxide, Styrene Monomer (client technology), and Ethyl Benzene (Lummus technology), called Inside Battery Limits (IBL).

- The facilities to support the actual production process and to ship and store the raw materials and products called Outside Battery Limits (OBL). To operate and support these units' utilities such as power, steam, etc. are required called "Utilities".

A unit is composed of the following components: civil work, steel work, equipment, piping and electrical and instrumentation systems. Equipment includes reactors (in which the chemical reactions are processed), storage tanks (in which products are stored), pumps (to transport fluids from the storage tanks to the process units, etc.), compressors (to transport gasses to the process units, reactors) etc. The piping is used to connect the various parts of equipment as well as the units. The electrical and instrumentation systems are required to supply power to the equipment (for example pump electric motors) and to control the various units (by means of an Integrated Control System). Both IBL and OBL facilities comprise units. To facilitate the whole process of project execution of this project CLN executed the following activities, as described below.

1.1.1. Detailed Engineering

In Detailed Engineering, all plant components (equipment, instruments, piping, valves, gaskets, cables, supports, pipe racks, structural steel, pits, paving, ladders, spray nozzles, foundations, bunds, analyzer houses, etc.) were technically specified for the OBL, IBL and required Utilities. All locations and routings were determined and reviewed involving close cooperation between all technical disciplines (process, mechanical, piping, civil/structural, instrumentation and electrical), the client and vendors, to meets all technical, safety, health, environmental, operational and constructability constraints imposed by the client, authorities, licensors, suppliers, vendors and subcontractors.

During this phase a 3 dimensional model (3D model) of the plant was developed which incorporates the majority of the plant components, both above and underground. The 3D model is continuously updated, as more information becomes available, with respect to elevations of equipment, vendor information, accessibility issues, and safe ways, piping routings & supports, location of beams and platforms, cable routings, sewer systems, location of junction boxes and so on.

1.1.2. Procurement

In the procurement phase all plant components (such as equipment, piping, cables, etc.) were bought, based on the technical specifications, using an approved vendor list. Continuous interface with the technical disciplines was required to ensure that all the technical requirements are met, while obtaining the best price and delivery schedule.

1.1.3. Construction

During the construction phase, careful planning and administration was necessary in order to safely construct the plant, under severe schedule pressure, while maintaining the technical integrity of all components to meet operational requirements. In a single unit, a large number of different activities took place simultaneously, like pulling of cables by the cable pulling subcontractor, pressure testing, welding & bolting by the mechanical subcontractor, inspection of internals, insulating by the insulating subcontractor, painting by the painting subcontractor, connecting of control valves & wiring of instruments by the E&I subcontractor, applying of fireproofing by the civil contractor and many more. At the peak of the construction activities approximately 3000 people were working on the construction side, which were provided by several sub-contractors (labor), suppliers (site engineers), CLN (supervisors, engineers, inspectors, direct labor hire), etc. To install all components around 50 cranes were operating on the construction site.

A number of activities were planned for the night or Sundays, for safety reasons or schedule reasons, like X-ray of welds, blowing of lines or placing or removing of scaffolding.

All activities were supervised by CLN supervisors and inspected, using standard check lists / forms on which the subcontractor and the CLN inspector sign for their approval of the work performed, or if the unit was completed. Any defects or incompleteness found can either mean refraining from signing, or adding the item to the punch list, for later resolution and re-inspection.

For a number of activities the signature of the client was required, before the next activity on a unit could be started. The Client used to be closely involved (by means of their operators) in the majority of the inspections, which helps to identify defects as well as to get familiarized with the plant (for the Client operators).

1.1.4. Pre-commissioning, Commissioning, Start-up, Warranty and Close out

The construction phase was followed by pre-commissioning activities which is a pre requisite to turn over the facilities to the client. During pre-commissioning systems are tested, pipe lines flushed and inspected, testing of instruments, etc. After the pre-commissioning activities were completed by CLN the plant was mechanical complete and handed over to the Client. This meant that Care, Custody and Control were taken over by the client which meant that the responsibility was transferred towards the Client. This was the starting point for the commissioning activities, which was performed by the Client. Commissioning comprehends starting up parts of the plant and tests its functionality and make adjustments where necessary. The last phase is the start-up of the plant, which involves testing the plant, analyzing the product and take out incorrect items, which again was performed by the Client.

The CLN warranty/guarantee period started after the Mechanical Completion date. This meant that CLN had to resolve all warranty items up to a period of one year (after the MC date). To close out the project for CLN a close out report was prepared. This was done after the MC date as the majority of the project team members had been de-staffed and only minor persons were still involved in resolving warranty items. The close out report is the last document prepared by CLN for a certain project and contains all relevant information about the project itself including lessons learned.

1.1.5. Plant Magnitude

To create a feeling of the magnitude of the plant, attachment 1 provides the amounts of concrete, steel, cables, equipment, man-hours etc. required to build this plant. The duration of the design (engineering), procurement and construction for this plant was more than three years.

1.2. Risk Assessment within CLN and Research Objective

Demonstrated by the example provided, in paragraph 1.1, it is evident that project execution of large engineering projects (a plant) is complex. It comprehends complex technologies, project execution of more than three years, interaction between several specialism's (technical disciplines and management), suppliers, sub-contractors and the Client, constrains in terms of technical client requirements (standards), omission legislations (of the Country), international standards, etc. Most elements are captured in high value contracts, normally on a Reimbursable or Lump Sum basis. Together with complexity, risks are involved during the execution of a project. According Miller and Lessard (2000); there is no question that Large Engineering Projects are risky.

Project risk has it origins in the uncertainty that is present in all projects (PMBOK Guide, 2004). A distinction can be made between Known and Unknown risks. As presented in figure 1, the Known risks can be identified and can be mitigated or accepted. These risks can be managed throughout the project life cycle. The unknown risks can not be identified and therefore, no strategy can be developed to manage these risks. What can be done is to allocate general risk money against such risks, as well as against any known risks for which it may not be cost-effective or possible to develop a proactive response (PMBOK Guide, 2004) [1].

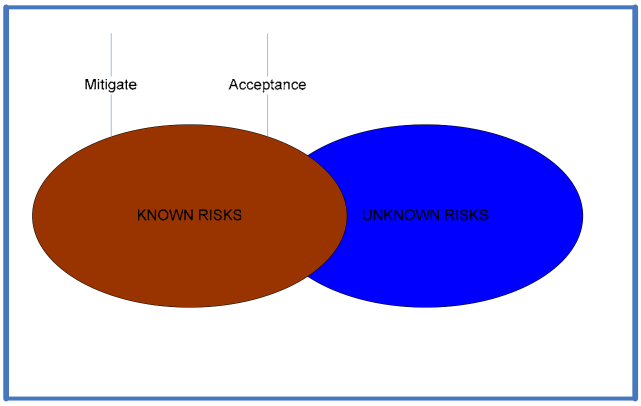


Figure 1: Risks

CLN is aware of the risks involved in large engineering projects and sees the need to evaluate contracts on risk elements before entering into an agreement with a client. This is essential because neglecting risks can lead to significant losses and will have major impact on the organization, as a whole.

During the proposal stage Invitations to Bid (ITB's), which defines the technical, commercial and contractual requirements of a plant from a Client point of view, are assessed on their risk elements (known risks). Probabilities and exposures are identified for these risks. The summation of the {probability} x {exposure} including the cost for "unknown" risks equals the risk fund for the project. This risk assessment is executed by the Business Development Manager (BDM), Proposal Manager (PM) including specialists (if required). A risk register together with the risk fund should be provided to the CLN management. This to be able to make a decision which amount of risk fund will be included in the price. Within this assessment two levels can be defined 1) the project level executing the assessment and 2) the management level making the decisions.

Risk assessment is a particular form of decision making within project management (N.J. Smith et al, 2006). It supports decision makers to make decisions which should be based on

[1] The PMBOK Guide uses the term contingency. Within this Thesis a clear distinction will be made between contingency and risk fund. It is for this reason that the term risk fund is indicated here.

a systematic and consistent risk assessment. It furthermore, should provide a detailed risk register which needs to be managed throughout the project life cycle.

Within the CLN management it has been acknowledged that decisions are not made and based upon a systematic and consistent risk assessment during the proposal stage. The problem is that sometimes risks are accepted or taken into account on one proposal and rejected or not even identified on another. It is essential to understand and to identify "all" risks associated with a proposal and to evaluate the ITB's consistently. In case this is not performed systematically, risks could be missed or no awareness created to focus on risks during project execution. The risk assessment is performed during the proposal stage which means that not all data is available and several assumptions are made. It is still vital to determine appropriate ways of responding to risks as it could hamper project objectives (such as performance, schedule, cost, and quality incentives) or even could result in a loss. Next to the responses the outcome of the risk assessment should provide the required risk fund for the project. This should cover the Contractor for uncertain events during project execution. It is evident in case the risk assessment is not reliable the quantitative reliability of the risk fund (sum of the assessed risks) is negatively affected. This off course has an influence on the decision making process, e.g. deciding on the amount of risk fund required for the project. Therefore, it is necessary to improve the risk assessment process to have "all" relevant risks assessed and a proper risk fund defined.

This research has the objective to provide a systematic insight into risks and its assessment for which an information system will be developed. Herewith, the decision making about the necessary risk fund for a proposal will be substantiated before entering into an agreement[2]. This is done by means of investigating and confronting the risk assessment process from a practical and procedural point of view versus theoretical approaches. The confrontation will define the gap and capture knowledge in which way the risk model can be designed.

1.3. Report Outline

This report is structured around the framework for Information Systems Research as defined by Hevner. It provides a guideline to respond to the research question and the sub-questions which are captured in chapter 2. The research approach (based on Hevner's framework) is described sub sequentially. Basically Hevner's framework defines three bases for research being; the Environment Base, the Knowledge Base and the Information System (IS) research. These three elements provide the structure for this Thesis research and will be applied to structure this report. In chapter 3 the knowledge base will be described. This comprehends the foundations and methodology which will be applied throughout this research. The CLN risk procedure will be confronted against the methodology in chapter 4, the environment base. This includes the case studies investigated to define the practical risk assessment approach within CLN. The knowledge and environment base will result in the model requirements which are described in chapter 5, information system research. On this basis a conceptual model will be designed. Chapter 6 will provide the building of the information system and validated in chapter 7. The last chapter is reserved for the overall conclusions and recommendations including those elements which need further analysis before the model can be implemented within the CLN organization.

[2] For oil & gas, petroleum refining and petrochemical EPC reimbursable and/or Lump Sum projects.

2. RESEARCH APPROACH AND QUESTIONS

In this chapter the problem definition as presented by CLN management is analyzed. This is done by means of a systems diagram, exploring interviews to define the practical challenge and reviewing the literature to define the scientific challenge. This will be the basis for the research motivation including the research question and (sub-) sub-questions. The delineation of this research will be described. The last paragraph represents a chapter indicator based on the framework of Hevner.

2.1. Problem Exploration

The CLN management is responsible to decide for which projects a proposal will be prepared. In case a decision is made, to continue with a proposal, the CLN management has the last responsibility to define the price which includes contingency (and escalation), profit margin and necessary risk fund for a certain proposal. The basis for each proposal is to calculate the cost for engineering hours and materials including allowances, contingency and the profit margin according a standard process (as described in the applicable procedures) which is used consistently over all different proposals. The risk assessment process including the determination of the risk fund has been defined in a procedure. According the CLN management the risk assessment procedure including the determination of the risk fund is not aligned and is not used consistently over the different proposals. This is resulting in different approaches which are followed during the preparation of proposals with different acceptation and selection criteria of risks, e.g. certain risks are taken into account on one proposal and neglected on others. The risk funds are determined by means of the intuition of proposal- and business development-managers, which provides no proper basis for the CLN management to make a decision on the risks and the necessary fund.

To assess the possible risks of a proposal including the corresponding risk fund is important for an organization such as CLN. The core business of CLN is to execute complex projects. This means that profits have to be generated by means of project execution. In case risks are not assessed in a proper manner and no sufficient risk fund is available projects can fail or be delayed, which can have a direct impact on the organizations bottom line.

The CLN management realized that this inconsistent approach can not continue and is in urgent need of an information system to capture the formal risk assessment process and have a tool to substantiate their decisions with respect to risks and the necessary risk fund. This is necessary to be able to protect the company against project risks and possible negative exposure. The tool which should be designed should capture the relevant risks of a proposal and will determine the necessary risk fund by means of standardized calculations.

This problem formulation as presented by CLN management, which is seen as the problem owner, was used as the starting point for the analysis of the current situation. The central problem is the decision making process with respect to risks and its risk fund allocation, which is currently not a consistent process.

To create an inside view of the system a system diagram has been prepared; refer to figure 2. The analysis shows on the left side the input required for the decision making process, which are based on the requirements as captured in the Invitation to Bid (ITB). The ITB needs to be reviewed and analyzed if it fits the organizations strategy. The company strategy represents the market segments, e.g. countries, technology and clients, in which the organization wants to, enhance and maintain its position. If the project falls within the companies' strategy the base cost including contingency[3] needs to be determined and a risk assessment performed to analyze which risks are involved in the particular proposal.

The variables that influence this decision making process are related to the workload within the company. In case the workload is at a minimum the acceptance of more risks may be taken to increase the probability of winning the project. The workload itself is influenced by the market demand. The availability of resources depends on the market situation and on the workload within CLN. In case the market is tight or overheated resources are not easy to recruit. Also in case many people are occupied on different projects within the organization resource availability will be an issue. Off course the other way round, were many resources are available could influence the decision making process as well. The probability of winning depends on the strength of the competitors including the success criteria (for example experience in certain fields) and could have an influence on the CLN strategy and thus on the decision making process. The last variable is the extent that risks are assessed before contracting. It depends on the support and knowledge of the involved experts during the proposal stage and the amount of requirements as indicated in the ITB (by the Client).

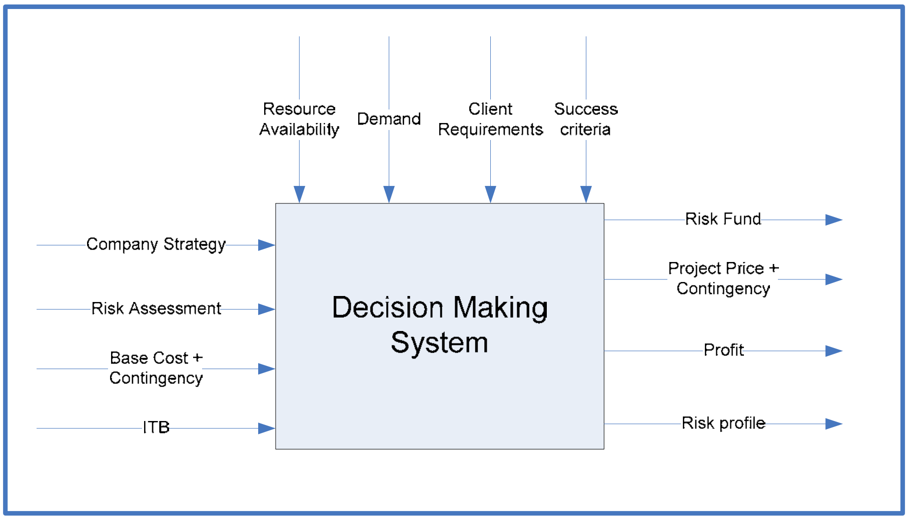


Figure 2: First System diagram

On the right side the results are indicated which are important for CLN management. The result of the risk assessment should be the risk profile including the necessary risk fund. The risk fund is the allocation to cover cost of risk elements for which the probability is moderate or even low. The risk fund shall be sufficient to be able to meet all the project objectives, which are normally related to safety-, schedule-, quality- and cost-performance. Together with the base cost plus contingency, risk fund and profit a decision needs to be made about the final project price. The top of the diagram shows the environmental or

[3] Contingency is an allocation of money to cover "unforeseen" cost. The probability of the unforeseen cost to occur is high (we know we are going to spent contingency but do not yet know wherefore and when).

contextual factors. The decision making process is related to the demand of projects (within the industry). The client requirements can influence the decision to accept a contract in terms of the amount of technical (including environmental), commercial and contractual constrains. Resource availability can be of influence to either a low work load or an overheated engineering market where no resources are available to execute the work. Recourses in this case are related to the CLN resources, suppliers, and sub-contractors. The success criteria (which are known on high level), for example are references of experience in a certain technology which could influence the decision making process.

To define the practical challenge interviews were conducted on project and management level. On project level Proposal Managers and Business Development Managers involved in the proposal stage of several EPC projects, which can be seen as experts in the field of preparing technical proposals and contracts, were interviewed. On management level decision makers were asked to provide input. From these interviews it can be concluded that in particular cases limited analysis was performed of the risk profiles during the proposal phase and before entering into an agreement (contract). In these cases limited financial and managerial responsibilities were defined. It is evident that early identification of risk and uncertainty profiles is essential for successful completion of projects. Furthermore, it was indicated during the interviews that there is no structured methodology for evaluating risks and that this is performed by the proposal team based upon there best knowledge, which means that this differs from proposal to proposal. The decisions made, for the allocation of the risk fund, are therefore, based upon different assumptions and information. The need for a consistent model was found crucial.

Many books, scientific articles and internet pages were found about the subject of risks and its assessment. The process steps which need to be taken in a proper risk assessment for EPC proposals are defined. Several elements out of the literature are relevant to this research and will therefore be used or applied as reference. However, it has been noticed that within the theories found no model or substantiation is given to specific risk elements (within the oil & gas, petroleum refining and petrochemical industry and its projects). It can be concluded that no off-the-shelf information system is available to substantiate the specific risks involved in contracting EPC projects. The contribution (scientific challenge) of this research is therefore, to provide an information system which identifies the risks associated with contracting EPC projects in the oil & gas, petroleum refining and petrochemical industry in a structured way. This to identify and capture relevant risks and provides the substantiation for the risk fund necessary.

2.2. Research Methodology

The research methodology defines the strategy to analyze and recommend on the defined main research question and its (sub-) sub-questions, for which instruments are employed to collect and analyze data. The approach is structured in accordance with the model as provided in figure 3. This model is based on the framework defined by Hevner's and Allan's decision science in information systems research, 1997.

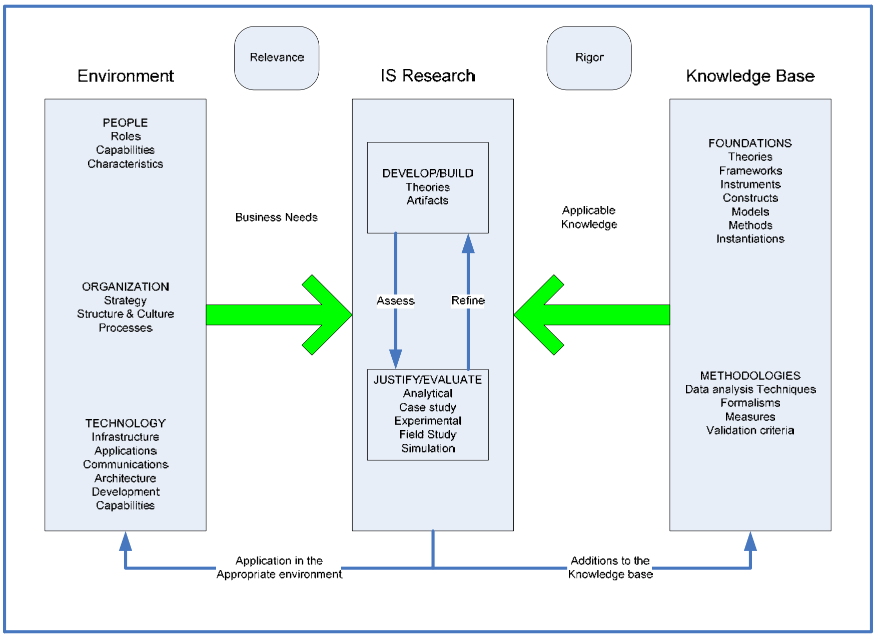


Figure 3: Information Systems Research Framework (Hevner).

2.2.1. Framework

The framework is characterized around two paradigms[4]; behavioral science and design science. The behavioral science paradigm seeks to develop and verify theories that explain or predict phenomena related to the identified business need. It seeks to develop and justify theory (principles and laws) that explain or predict organizational and human phenomena surrounding the analysis, design, implementation, management and use of information systems. The design science paradigm addresses research through the building and evaluation of artifacts designed to meet the identified business need, as indicated by Hevner. It is fundamentally a problem-solving paradigm. The distinction between behavioral and design science is necessary because information system research occurs within the framework of people, organizations, and technology.

The theory of Hevner has been selected to provide guidance on how to solve this problem and thus to search for the solution space (Hevner et al, 1997). For this research the range of the solution space lies within the formal descriptions of procedural and theoretical approaches, and mathematical distributions. Because it was the intention to learn from the undefined process and to be able to design an information system it was decided to make use of the framework, as it combines the learning and design process. Furthermore, it provides distinguished steps, e.g. problem formulation (company objectives) within the environment base, the theoretical framework within the knowledge base, and both coupled to the information system base to develop and create a system. Because knowledge and understanding a design problem are required before building the application seven guidelines have been defined by Hevner. The guidelines are: design as an artifact; problem relevance; design evaluation; research contributions; research rigor; design as an search process;

[4] A paradigm is a set of rules and regulations which defines boundaries and tells us what to do to be successful in solving problems within these boundaries.

communication of the research. Table 1 summarizes the seven guidelines including the application within this research.

Guideline Hevner	**Description Hevner**	**Research Application**
1: Design as an Artifact	The research must produce a viable artifact in the form of a construct, a model, or an instantiation.	The conceptual model and the design of the information system have been captured in chapter 5, information system research and 6.
2: Problem Relevance	The objective of the research is to develop technology based solutions to important and relevant business problems.	The environment base is confronted with the knowledge base which resulted in the business needs, captured in chapter 4.
3: Design Evaluation	The designed artifact must be rigorously demonstrated via well executed evaluation methods.	Verification and validation tools are applied on the information system designed to demonstrate its validity, captured in chapter 7.
4: Research Contributions	The research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.	The overall conclusions and recommendations provide the research contribution including the implication for the CLN organization. This is captured in chapter 8.
5: Research Rigor	The research relies upon the application of rigorous methods in both the construction and evaluation of the designed artifact.	For both the verification and validation rigorous methods are applied and described in chapter 5.
6: Design as a search process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.	The search for a proper and effective artifact is demonstrated by the analysis of the Knowledge and Environment base, captured in chapter 3 and 4.
7: Communication of Research	The research must be presented effectively both to technology-oriented as well as management oriented audiences.	This report is used to substantiate the research and a presentation will be given about the outcomes of the research.

Table 1: Research guidelines and their application

An aspect missing in the theory of Hevner are future changes in the environment such as strategies, market developments, etc. as the theory is structured around one design. Furthermore, related to future changes are the incorporation of lessons learned from previous projects executed, which could influence the possible outcome of the information system. This however, is realized and should be taken into account during the research.

Despite the missing elements it has been decided by the researcher to apply the framework of Hevner and to structure this report accordingly.

2.3. Research Motivation and Questions

Provided by the problem exploration, interviews and literature review it can be concluded that the risk assessment process forms the basis for the decisions made about the relevant risks and the risk fund. During the interviews it was frequently mentioned by the experts that a structured model is not available within the organization. It was mentioned that knowledge is missing in which way risks can be substantiated, which is required to define a proper risk fund. Furthermore, the literature research did not provide an off-the-shelf model to substantiate specific risk elements in contracting EPC projects. Currently, risks are substantiated by means of personal judgment and intuition. For the CLN management it is therefore, difficult to make a proper decision about the assessed risks and the necessary risk fund. As demonstrated by the systems diagram the decision making system is influenced by means of several elements. Analyzing these elements several subjects for investigation and research can be defined to improve the efficiency and effectiveness of the organization and leads to the following subjects:

1. The relation between work load and risk acceptance. Would a higher risk profile be acceptable in case the work load is low and a high impact on the organization is expected?
2. Does the organizational strategy fit the current market situation?
3. Can a structured information system be developed to evaluate risks during the proposal stage?
4. Which crucial risk elements can be defined?
5. How are risks managed throughout the project life cycle, in such away that project objectives are met?
6. How are, lessons learned captured?
7. Which lessons learned could influence risk acceptance criteria?

These items should be investigated further but it has been decided for this research to focus on the risk assessment process and to develop an information system to assess risks systematically, item 3. This has been requested by the CLN management and is an opportunity for the researcher to investigate the subject of risk assessment in detail and develop skills in information system research and design. The developed knowledge can be applied practically in the researcher's current position as senior project engineer. The investigation of the issue is represented in the following research question:

How can we support the risk assessment of EPC projects[5] in the proposal stage to better estimate the risk fund?

The basis for the preparation of a proposal is in most of the cases an Invitation To Bid which describes the technical, commercial and contractual requirements. The technical part of the works will be explained in terms of the project life cycle, the commercial part in the cost break down structure and the contractual part in the most common contract forms.

[5] For oil & gas, petroleum refining and petrochemical EPC reimbursable or Lump Sum projects.

These elements are important to understand the context in which risks can occur within the CLN organization. Furthermore, risk-, uncertainty-definitions and risk assessment approaches (theoretical) will be analyzed to provide a basis for this research. This result in the following (sub-) sub-questions:

- Sub-question 1 (knowledge base); which relevant theoretical factors defines the foundation and methodology of the research and defines the applicable knowledge?

    a. How can the context in which risks occur with respect to EPC projects be defined, what relevant constrains are present?
    b. What are lessons from the literature on risks, uncertainties and assessment approaches and which can be applied?

- Sub-question 2 (environment base); how are risks assessed within the CLN organization, during the proposal stage, from a practical and procedural point of view?

    a. Which procedures are used within the CLN organization and can they be improved?
    b. How can the business needs (problem) be described after the analysis of the practical approach and CLN procedures?

- Sub-question 3 (information system research); what does an information system, to support the risk assessment of EPC projects in the proposal stage, look like?
    a. Which model requirements should be incorporated in the information system?
    b. How to make the information system operational?
    c. Is the information system valid?

- Sub-question 4 (overall conclusions); what can we learn from risk assessment, the framework of Hevner, and the research?

- Sub-question 5 (overall conclusions); did the framework of Hevner provide sufficient guidance in this research?

2.4. Delineation

This research will focus on the risk assessment process during the proposal stage (evaluation of the ITB) and is limited to Downstream (on-shore) oil & gas, petroleum refining and petrochemical EPC projects. The risks assessed will be those which could have a possible negative effect on project objectives. Opportunities will not be further analyzed and in which way these can be exploited. It will address Lump Sum and Reimbursable EPC contracts only which comprehend a scope of work definition until Mechanical Completion (this includes pre-commissioning). The research is executed for the CLN office in The Hague, from a Contractor's point of view. This means that other Lummus offices are not considered. As a last remark a clear distinction will be made between base costs including allowances, contingency and risk fund. This research only addresses the risks falling under the risk fund, e.g. allowances and contingency uncertainties are not considered because these elements are defined as cost and handled separately (within the CLN organization). It must be noted that this Thesis work describes the risk assessment process for which an information system will be designed. This includes the calculations (of the probability and impact of a certain risk) which will not be validated in detail and should therefore, form part of a separate validation check.

2.5. Conclusion

The research consists of a desk research and case study (Verschuren and Doorewaard, 2007). The desk research comprehends a literature review of subjects relevant to understand the framework in which the problem occurs. The case study represents the investigation of four projects for which a proposal have been made and to identify in which way risk assessment is performed within the CLN organization. The risk files for these projects will be compared and analyzed. The strategy followed for both the desk research and case study is qualitative according the terminology of Verschuren and Doorewaard.
The decision is made for an in-depth research, e.g. a small scale research (with respect to risk assessment) which will provide in-depth knowledge, details, complexity and a strong substantiation of the results which will be quantified by means of tables as applicable.
As expressed by Verschuren and Doorewaard is that the process of designing, in this case an information system, is an iterative process. It means that results of the research are continuously analyzed to define consequences of decisions made. Within this research two refine processes have already been described. The first is the diagnostic phase in where the initial problem definition will be verified. The second has been described, by Hevner, during the development of the model, e.g. the interaction of developing the model and verification against its requirements and sub sequentially validating the model.
To structure the report it has been decided to use the Information System Research approach as defined by Hevner. The approach defines different steps which will be indicated in each chapter by means of figure 4 (in the right corner). A green color will be used to indicate the chapters belonging to the environment, knowledge or information research base.

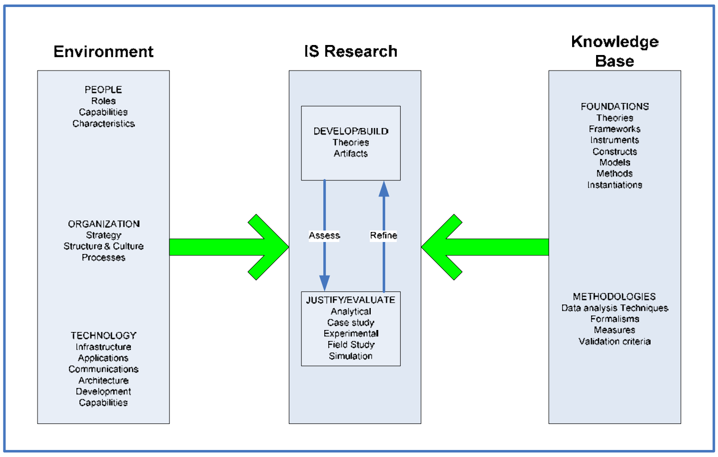
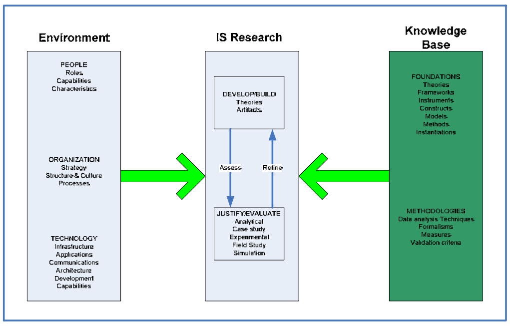


Figure 4: Chapter Indicator

3. KNOWLEDGE BASE



The knowledge base provides the raw materials from and through which information system (IS) research is accomplished. It has been divided into Foundations and Methodologies. The foundational theories are related to the subjects that need evaluation of an invitation to bid, e.g. the technical, commercial and contractual risks. In case of project award the ITB forms the basis for the contract describing all these requirements. The first foundation relates to the technical activities executed by an EPC contractor which will be described in certain phases, which together forms the project life cycle. The second foundation relates to the most common used contract forms. It should be realized that contracts have certain boundaries which will briefly be investigated. The third foundation relates to the commercial part and will be explained by the Cost Breakdown Structure. This includes the allowance for the risk fund which is the central subject of this research. It is for this reason that the last foundation represents the definition of risks and uncertainty. The difference between risk and uncertainty will be investigated and demonstrated.
The methodologies as defined by Hevner provide guidelines used in the: justify/evaluate phase (IS-Research). For this research the methodology is related to risk assessment approaches which will form the basis for the information system. It will be used to define the methodology to review the CLN procedures and practical approach in the environment base. Both the foundation and methodology defines the theoretical framework described as the applicable knowledge (by Hevner). Table 2 summarizes the five research subjects which need to be elaborated on and/or definitions provided.

Subject	F or M	Paragraph
1:Project Life Cycle (PLC)	Foundation 1	3.1
2:Contracting structures and their boundaries	Foundation 2	3.2
3:Project Cost Breakdown Structure (CBS)	Foundation 3	3.3
4:Risk and uncertainty definitions	Foundation 4	3.4
5:Risk assessment approaches (theoretical)	Methodology	3.5

Table 2: Research Subjects

3.1. Foundation 1: Defining the Project Life Cycle (PLC)

The research is structured around the activities involved during the Project Life Cycle (PLC) of EPC projects which define the phases in which risks occur for an EPC Contractor. The PLC will be explained in terms of the different project phases, which are demonstrated by the example provided in chapter 1 and figure 5. Preparing a proposal will start on the basis of an Invitation to Bid (ITB) specifying the technical and environmental requirements of the (production) facility. A proposal will be prepared and submitted to the client for review and further discussions and negotiations (e.g. terms and conditions, price, etc.). In case parties come to an agreement a contract will be signed and started with the Engineering Procurement and Construction (EPC) execution, the contract will be transferred from the proposals team to the EPC project team (in case this is different).

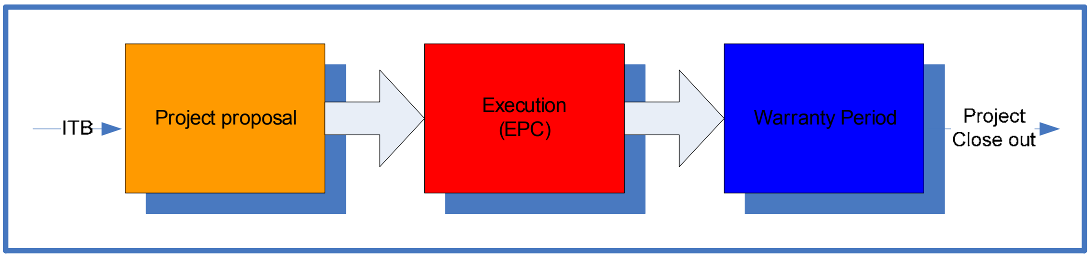


Figure 5: Project Phases

The execution of the project consist normally of three stages being Engineering, Procurement and the Construction of the facility. The engineering comprehends the detailed engineering whereas; the procurement starts with purchasing Goods (e.g. equipment, piping material, etc.) and Services (e.g. labor contracts, soil investigations, etc.). When the engineering has reached a certain percentage of completion and certain Goods and Services are contracted the construction of the facility will start. The construction period ends when the facility has been pre-commissioned and mechanical completed. The phase following EPC and especially the construction is the warranty period (the project team transfer the outstanding issues to the warranty group). Reference is made to chapter 1, in where a real example has been described (the POSM plant).

The warranty period is normally between one and two years. In this period defects found during operation of the facility have to be resolved. In this period the facility will be tested to demonstrate the process performance guarantee given by the Contractor. After the warranty period the project will be closed out.

3.2. Foundation 2: Contracting Structures-General Overview

Contracts exist in many forms and can be classified in many ways, e.g. built up financially or on the basis of the working method. The classification of financially built up contracts can be separated into Lump Sum, Unit Rate and Reimbursable. Contracts that are classified according the working method are: Turnkey, Management Contract, Construction Contract, Call-off Contract, Alliance Contract, etc. Within the CLN organization the main contract forms which are used are:

- Lump Sum (LS)
- Lump Sum Turn Key (LSTK)
- Reimbursable EPC
- Reimbursable Project Management Consultancy

Within CLN several contracts are used on the basis of a LS or Reimbursable basis for:

- License agreements
- Front End Engineering Design (FEED)
- Basic of Design Process (BDEP)
- Full EPC

CLN is specialized in executing Lump Sum and Reimbursable EPC contracts. It is for this reason that the research will focus on these two contract forms only. The particular aspects of the two types of contracts are further detailed in the paragraphs below.

3.2.1. Lump Sum Contracts

In Lump Sum (LS) contracts, Contractors have the full responsibility for the design, Engineering, Procurement and Construction (EPC) of a certain project. In legal terms the contractor is responsible for the actual result and delivery of the complete scope of work, e.g. bearing all uncertainties and risks related to that project. Contractors are often required to accept ridged contractual liabilities wherein the client intends to shift all liabilities for design (including endorsement of designs not prepared by the Contractor), engineering, procurement and construction to the contractor. Clients tend to select the contractor for a particular project based upon bidding procedures whereby pricing of the project is a key factor. The result for the contractor most of the times is a low fixed price (competitive), meaning that the contingencies and risk money for the project are limited.

LS contracts normally have an incentive-penalty scheme related to the schedule of the project. Better earnings can be made by the contractor in case the project is mechanical completed (MC) within the time limits set. This means that the plant is constructed pre-commissioned and in some cases commissioned (the final stage is Ready For Start Up). In case the MC date is missed by the contractor penalties are coming in place for every day the project is delivered later to a certain maximum (ceiling). Risks and uncertainties related to purchase orders, construction contracts, process performance guarantees, etc. are barred by the contractor. This also includes the liability for claims from vendors or sub contractors in relation to delay in engineering and construction activities. Claims itself shall be borne by the project but the time delay is of such an amount which can not be borne by the project (but by the organization itself).

LS contracts can generate major revenue, but have a high risk and uncertainty level. It means that during the proposal stage much effort is required to analyze all relevant aspects of the ITB. It means that the cost for preparing a LS proposal is high. In case things are not going according plan LS contracts can be real financial disasters.

3.2.2. Reimbursable EPC Contracts

In reimbursable contracts the Procurement and often the Construction is undertaken for and on behalf of the Client. The contractor is reimbursed by the Client against man-hour rates for its services. In legal terms these contracts are defined as services contracts wherein the contractual obligation is in principle limited to a best effort obligation to provide the EPC Management services. Normally these types of contracts are set up in such away that the contractor can earn incentives, e.g. meet certain intermittent schedule objectives, meet certain safety objectives, etc. The Client reimburses the Contractor for purchase orders, subcontracts and other cost associated with the project scope of work. The risk of these elements is borne by the Client and not by the Contractor; the level of risk varies per contract. The Contractor has the major advantage that it is paid for all man hours of services provided (in case no ceiling is agreed upon) and that in principle his contractual liability is limited to the loss of the incentives. The maximum financial risk is therefore, in principle equivalent to the incentives.

The risk and uncertainty level of reimbursable contracts are relatively low compared to LS contracts. These risk and uncertainties are pre-agreed in the contract. As the procurement of goods and services is done for and on behalf of the client in principle the contractor has no liability for claims of vendors and sub contractors. Also the contractor has no liability for schedule delays. In general terms reimbursable contracts have little risk on financial disasters, scope definition is of less importance and the proposal costs are low. The opposite however is that it generates little revenue and some markets (Middle East) do not accept contracts on a reimbursable basis.

3.2.3. Risk Sharing Domain

The contract forms as described above (Reimbursable and Lump Sum) have different risk and uncertainty allocation schemes. As presented in attachment 2 the risk and uncertainty profile for the EPC Contractor, in case of reimbursable contracts is low and will increase in case of Lump Sum contracts. For the client the risk and uncertainty allocation scheme runs the opposite way. A client will phase a high risk and uncertainty profile in case of reimbursable contracts and will decrease in case of a Lump Sum contract. It can be decided to allocate all the risks and uncertainties with the Contractor and/or Client. This will be reflected in the hour rates (in case of a reimbursable contract) or in the full price (in case of a lump sum contract). It can also be decided to share the risks and uncertainty, by means of incentives/penalties. In this case the allocation will be assigned to the party willing to accept (portfolio) and able to influence the risks and uncertainties. For example, a ceiling can be agreed upon the total man-hour usage of a contractor in case of a reimbursable contract. An incentive can be provided in case the contractor will meet the set targets. The common risks and uncertainties are related to; Safety, Quality, Schedule, Cost (total Budget) and Productivity (home office man-hours). Normally, the contract form is indicated in the ITB by the client.

Depending on the contract form the risks which need to be covered in the contract are different. Examples are the schedule liabilities in case of LS projects, reimbursable contracts often have no schedule liability. The same applies to claims from sub contractors and vendors which have to be borne by the contractor in case of LS contracts and not in case of reimbursable contracts. Also there should be a focus on those risks which are not part of the contract but could have an impact. For example, a bad performance by the contractor for what ever reason resulting in reputation damage towards that Client which in the end will result in no projects for that particular Client in the future.

3.2.4. Contracting Boundaries (brief exploration)[6]

Contracts define the agreement between two (or more) parties about their responsibility and for what (scope, schedule, cost, quality). A contractual document (contract) is binding on both parties and can be relied upon. But although the responsibilities are binding, some boundaries can be identified which are the exception to this rule. As an example, in case

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[6] Based on interviews held with Lawyers and Contract Administration Engineers

consequential loss is excluded in the contract, for the Contractor. But it can be claimed that the Contractor made a gross negligence, the Contractor can still be held responsible for the consequential losses occurred. The Dutch law has clauses which cover for these circumstances. Within English law these definitions are vague. Therefore, in case projects are executed under English law more emphasize is given to the definitions of these types of circumstances.

Another example which defines contract boundaries is the limit of liability with respect to guarantees. In case a contract is agreed between Contractor and Supplier, the Supplier provides guarantees for the Goods and/or Services provided. In case of damage attributable to the Supplier, this shall be rectified by the Supplier. All work executed by the Contractor (normally spent man-hours) are excluded and are not for the account of the Supplier.

In case of contracting EPC projects the circumstance explained should be taken into account. During the analysis on risks it will be explored if these types of circumstances are taken into account and if provisions are included in the risk fund.

Note that far more emphasize could be given to the subject about the boundaries of contracting, also in relation to the applicable laws.

3.3. Foundation 3: Defining the Project Cost Breakdown Structure (CBS)

All contracts from inception until closure contain risks and uncertainties that may impact the financial revenue, cost and profit ultimately achieved on each project. Monetary allowances must be made for the risks and uncertainties identified on a project. These allowances need to be made during the proposal stage. Within the CLN organization two monetary allowances are recognized, which are Contingency and risk fund, refer to figure 6 (cost breakdown schematic) and together with the base project cost and profit will be further explained.

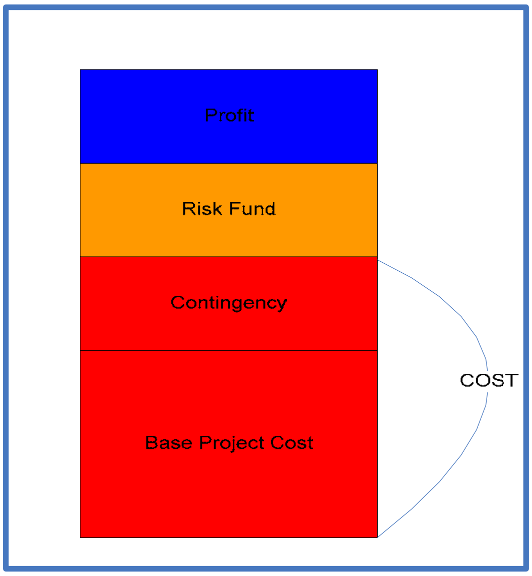


Figure 6: CBS

3.3.1. Base Project Cost and Allowances

The bases for the cost estimate are the requirements as described in the ITB. The scope of work will be verified and reviewed by the responsible lead engineers on the project. The estimator together with the lead engineers will discuss the scope of work and define missing elements. Normally missing elements are added, being allowances for 1) Prices for the scope of work (for example you do not know if all items are taken into account) 2) Quantity related allowances (for example the amount of piping materials required). This is verified against historical data. Data such as piping material per plant surface, meters pipe, instruments/equipment, etc. are available. The estimating group will verify the same projects (meaning same technology, size, etc. if possible). The base costs for a project (100%) is therefore, the base cost including the two allowances. Furthermore, escalation cost will be considered which cover for increasing salaries of CLN personnel every year.

3.3.2. Contingency

The estimating discipline will analyze the risks which are related to contingency. The definition used for contingency within the CLN organization is as follows:

A provision included in the project estimate for items which, by experience, are known to occur but which cannot be quantified at the time the estimate is prepared. It is assessed for variations in: estimated quantities, unit pricing for material, unit pricing for labor, and estimated labor productivity and estimation errors and omissions.

The contingency is determined by means of a Monte Carlo simulation. As an example the piping quantity related to the insulation quantity can be given. In case more piping is required, more insulation is necessary, for which financial security should be provided in terms of contingency. To cover for all relevant aspects related to contingency a model will be made. A contingency run down curve will be the outcome of the Monte Carlo model which represents the overall contingency for the project against time.

Thus contingency clearly relates to the uncertainty present in the details of a cost estimate and is the aggregated amount of money that is needed in addition to the base estimate to provide a given level of confidence that the cost estimate will not be exceeded. In other words it is a provision to allow for overrunning the estimate for a given scope of work. Within the CLN organization contingency is seen as "Cost".

The contingency for a particular project is determined in the proposal stage. In case of project award and execution of the project the contingency must be analyzed, due to uncertainties which may change over time and could have a positive or negative impact on the project.

3.3.3. Risk Fund

The risk fund is a provision for unusual conditions/events that could affect the financial outcome of a project. The risk coverage includes events which are not covered by contingency. It relates to the categories such as contract and agreements, schedule, etc. and should be covered separately. As contingency is seen as cost, the risk fund is something which could occur. Note that in case risks do not occur this could be added to the profit margin, contingency or remain in the risk fund.

3.3.4. Profit

The profit margin is allocated as the last part. A percentage of the contract price will be applied. Adding up all four cost items, base project cost (including allowances), contingency, profit and risk fund will provide the price for a project.

3.4. Foundation 4: Defining Risk and Uncertainty

Before the risk assessment can be explained in further detail the definition of risks and uncertainties needs to be defined (and which definition will be used during this research) as described in the paragraphs below.

3.4.1. Risk Definition

The literature does not provide one generic definition of Risks, as seen by the following definitions, as indicated in table 3.

Author/Book	Risk Definition
J.R. Meredith / Project Management, 2006.	The outcome of any decision depends on two things: (1) what the decision maker does; and (2) what nature does (nature being the set of exogenous factors that interact with the decision maker's course of action to produce an outcome. If the decision maker knows the probability of each and every state of nature and thus of each and every outcome, the decision maker can find the expected value of each alternative course of action he has. The expected value of an action is the sum of the values of each outcome associated with the action times the probability that it will occur. The course of action can be selected associated with the best of these expected outcomes. This is decision making under conditions of risk.
ANSI 99-001-2004 / PMBOK Guide, 2004.	Risk can be defined as: an uncertain event or condition that, if it occurs, has a positive or a negative effect on a project objective. Where project risk is an uncertain event or condition, if it occurs, has a positive or a negative effect on at least one project objective, such as time, cost, scope or quality (PMBOK Guide, 2004). A risk has a cause and, if it occurs a consequence. The consequences of the risk will have an effect on the project cost, schedule, or quality of the work. Project risk includes both threats to the project objectives and opportunities to improve on those activities.
D. Hubbard / How to measure anything, 2007	Risk can be defined as: a state of uncertainty where some of the possibilities involve a loss, catastrophe, or other undesirable outcome. In mathematical terms risk can be described as: Risk = {probability of risk occurring} x {impact of risk occurring} Often, the probability of a negative event is estimated by using the frequency of past similar events or by preparing an event tree. But sometimes it is difficult or even not possible to prepare an event tree and to estimate the probability.
Chapman & Ward / Project Risk Management, 2003	Risk can be defined as: an uncertain event or set of circumstances that, should it occur, will have an effect on the achievement of the projects objectives. Note that this definition defines the upside and unwelcome downside effects of a certain risk.
ISO 17776: 2002	Combination of the probability of an event and the consequences of the event.
APM PRAM guide: 2004	An uncertain event or set of circumstances that, should it occur, will have an effect on the projects time, cost or quality/performance objectives. Refer to the definition of Chapman et al as this is the same definition.
ICE-RAMP: 2005	Risk is a threat (or opportunity) which could affect adversely (or favorable) achievement of the objectives of an investment.
BS: 6079 Part 3: Risk Management: 2002	A combination of the probability, or frequency, of occurrence of a defined threat or opportunity and the magnitude of the consequences of the occurrence.

Table 3: Risk Definitions

Although, there is not one generic definition of risk, it can be concluded that the basic elements are similar, e.g. risk which is uncertain and has an effect on objectives. Therefore, the following definition has been defined:

Risks are the known and "unknown" uncertain factors which could have an influence on project objectives.

To identify a risk element the Event, the Cause and the Consequences of that risk should be analyzed and described in detail, this to be able to prepare a proper response to manage the risk (also refer to the PMBOK guide). Together with the mathematical explanation being: Risk Value = {probability of risk occurring} x {impact of risk occurring}[7] this will be applied throughout the research. The definition emphasizes on the positive and negative aspect of the uncertain event on project objectives, which illustrates the goal of project work, meeting project objectives. Furthermore, the mathematical definition is widely used within the industry.

3.4.2. Uncertainty Definition

For Uncertainty the same applies as for risk, within the literature more than one definition has been found, as summarized in table 4.

Author/Book or Article	Uncertainty Definition
W. Walker / Defining uncertainty, 2003	Uncertainty can be defined as "any departure from the (unachievable) ideal of complete determinism" In mathematical terms; Y is the event if the probability of Y does not equals 1, and then the event Y is uncertain.
Chapman & Ward / Project Risk Management, 2003	In a project context the aspects of uncertainty can be present throughout the project life cycle, but they are particularly evident in the pre-execution phases meaning during the proposal phase, when they contribute to uncertainty in five areas: 1. Variability associated with estimates 2. Uncertainty about the basis of estimates 3. Uncertainty about design and logistics 4. Uncertainty about objectives and priorities 5. Uncertainty about fundamental relationships between project parties. Uncertainty is the lack of certainty involving variability and ambiguity.
J.R. Meredith / Project Management, 2006.	If the decision maker's information is not so complete and the decision maker does not know and cannot collect sufficient data to determine the probability of occurrence for some state of nature, the decision maker cannot find the expected value for each of the alternative actions. This is decision making under conditions of uncertainty. There is no way to solve problems under uncertainty without altering the nature of the problem. One can estimate or guess to assume some probability for each known state of nature and then deal with the problem as if it were one of risk. If the decision maker elects to ignore all states of nature except the one that seems to be most likely, the decision maker then assumes there is one and only possible outcome, which is decision making under conditions of certainty. Finally, the decision maker could assume that an opponent controls the sate of nature and try to use game theory to solve the problem of decision making under conditions of conflict.}

[7] Note: not all risks can be quantified in terms of probability and exposure.

D. Hubbard / How to measure anything, 2007	Uncertainty can be defined as: the lack of complete certainty, that is, the existence of more than one possibility. The "true" outcome/state/result/value is not known. Uncertainty can be measured by means of a set of probabilities assigned to a set of possibilities.
ISO 17776: 2002	No separate definition provided with respect to uncertainty.
APM PRAM guide: 2004	Refer to Chapmen et al as this is the same definition.
ICE-RAMP: 2005	A source of risk derived from a lack of sufficient knowledge about the underlying probabilities of adverse events and/or their consequences.
BS: 6079 Part 3: Risk Management: 2002	No separate definition provided with respect to uncertainty.

Table 4: Uncertainty Definitions

An overlap in all definitions is found by means of the same returning aspects. One of the aspects is the lack of sufficient knowledge or data which means that no probability of occurrence can be identified. Another aspect is variability which results in more than one possibility and in several fields in were uncertainty can be present. To capture these elements in a practical definition which will be applied throughout this research is:

Uncertainties are those factors which can not be quantified in terms of probability of occurrence, due to the existence of more than one possibility and missing data, during the time an assessment is made.

3.4.3. Risk versus Uncertainty

As indicated in the paragraphs above, for uncertain events data can not be collected to determine the probability. In case of Risks the probability can be determined and thus be quantified. Uncertainty can therefore, be restricted to the non quantitative elements and risk to the quantitative elements. Note that uncertain events can change into risks. For example uncertain weather conditions could influence construction activities which could result in the risk of not meeting the applicable project schedules.

3.5. Methodology: Risk Assessment

In the following paragraph the relevant theoretical risk assessment approaches are presented. Risk assessment is the derivation of risk profiles posed by a given situation (Kumamoto and Henley, 1996). It is all about providing decision support; how big is the potential cost related to a specific risk element or a group of risk elements.
Risk assessment is a component of risk management. The focus of this research is on risk assessment and therefore, those elements found in the theories related to risk assessment will be described. This means it will be constrained to risk management planning, risk identification, qualitative and quantitative risk analysis and responses. The outcome will be the methodology applied throughout this research.

3.5.1. Risk Assessment Approaches

A selection of risk assessment approaches has been made. The approaches are screened on the basis of the relation with the execution of large engineering projects, typically

Engineering, Procurement and Construction projects. This resulted in the selection of the approach of the PMBOK Guide (ANSI), ISO, Chapman & Ward, and the theory of J. Meredith, ISO, PRAM, ICE and British Standard. It must be noted that far more theoretical approaches have been developed also specific for project management organizations. However, a selection was made on the basis of the most common used standards within the (petro)-chemical industry. The risk assessment process steps are summarized in table 5 below.

Author/Book	**Risk Assessment Theory**
ANSI 99-001-2004 / PMBOK Guide, 2004.	Risk management planning; the process of deciding how to approach and plan the risk management activities for a project.
	Risk Identification; determining which risks might affect the project and documenting their characteristics.
	Qualitative Risk analysis; the process of assessing the impact and likelihood of identified risks.
	Quantitative Risk analysis; aims to analyze numerically the probability of each risk and its consequences on project objectives, as well the extent of overall project risk.
	Response planning; the process of developing options and determining actions to enhance opportunities and reduce threats to the project's objectives.
Chapman & Ward / Project Risk Management, 2003	Define the project; consolidate relevant existing information about the project at a strategic level.
	Focus the project; define the project scope and provide a strategic plan for the risk management process.
	Structure the issues; complete the structuring of the above mentioned phases.
	Clarify ownership; allocate both financial and managerial responsibilities for issues identified.
	Estimate variability; size the uncertainty that is usefully quantified on a first pass.
	Evaluate implications; asses statistical dependence (dependence not modeled in a causal structure).
	Harness the plans; obtain approval for strategic plans shaped by earlier phases.
J.R. Meredith / Project Management, 2006.	The subject of risk management and its component parts, risk management planning, risk identification, risk assessment, risk, quantification, risk response development and risk monitoring and control are taken from the Project Management Institute (PMBOK guide, 2000) as described. One addition is made which contains the creation and maintenance of a risk management data bank. This data bank should have a permanent record of identified risks, methods used to mitigate or resolve them, and the results of all risk management activities.
ISO17776: 2002	Identification; before risks associated with a particular activity can be assessed, it is first necessary to systematically identify hazards which may affect, or arise from, the particular operation under consideration.
	Evaluate risk against screening criteria; once the hazards have been identified, the risks they present to personnel, environment and the facilities are evaluated. Screening criteria are the targets or standards used to judge the significance of the hazards and effects and together with the results from the risk assessment provide the basis for risk management decision-making.
	Identify risk reduction measures; risk reducing measures are being evaluated.
APM PRAM guide, 2004	The APM PRAM guide defines a five step risk assessment process whit the individual steps: Initiate the process, Identify the risks, Assess the risk, Plan Responses, and Implement the Responses. As an overall indication "manage the process" is provided over the five step process.

ICE-RAMP, 2005	The risk assessment is defined in a four step process. Activity A: Process Launch; A1: Organize and define the RAMP strategy A2: Establish a baseline
	Activity B: Risk Review; B1: Plan and initiate risk review, B2: Identify risks, B3: Evaluate risks, B4: Mitigate risks, B5: Assess residual risks, B6: Plan responses, B7: Communicate strategy and plans.
	Activity C: Risk Management; C1: Implement strategy and plans C2: Control risks
	Activity D: Process close down; D1: Assess investments D2: Review the RAMP process.
BS: 6079 Part 3: Risk Management, 2002	Context: The business and project objectives need to be defined including the business and project boundaries.
	Risk Identification: The sources of risks to be defined. What are the risks? How do they arise? The identified risks to be grouped.
	Risk Analysis: The characteristics of risks to be defined including their classification. The likelihood to be estimated and the potential consequences.
	Risk Evaluation: Set criteria to evaluate the risks. Decide a ranking. Select the high priority risk elements.
	Risk Treatment: Identify options. Evaluate options. Plan the treatment measures. Assess secondary risks. Allocate responsibilities. Implement treatment.

Table 5: Risk Assessment approaches

3.5.2. Risk Assessment Approach Applied

To define the overlap in approaches a selection has been made and summarized in table 6. This selection is based upon the relevance and practicality of evaluating EPC proposals. Furthermore, standards such as the ISO are widely used within the oil and gas industry.

At first instance the theories seems to be comparable, such as: set criteria to analyze risks, identify & analyze risks and define measures to reduce risks. However, after reviewing the theories in more detail a number of differences have been identified. Firstly, the SHAMPU framework does not use the terms Qualitative and Quantitative risk analysis. However, the SHAMPU framework usage the Probability Impact Matrices (PIM's)[8] as a first pass and continues with a selective one-shot numerical follow up. Within the PMBOK theory a distinction between qualitative and quantitative analysis is made and focus on those risks which can have a possible impact on project objectives. This is done to make a first overall risk ranking of the project before entering into a more detailed quantitative risk analysis. The ISO standard describes the process of selecting those risks which can have an impact on personnel, environment and facilities.

[8] A PIM is a matrix which identifies the risks, computation (plausibly pessimistic, very optimistic, and midpoint), and results (plausibly pessimistic, very optimistic, and midpoint). The cost are estimated by means of {probability} x {exposure}.

Chapman & Ward	PMBOK	Meredith	ISO
Define the project	Risk management planning	Equivalent to the PMBOK guide	Screening criteria
Focus the process			
Identify the issue	Risk identification	Equivalent to the PMBOK guide	Identification
Structure the issue			
Clarify ownership			
Estimate variability	Qualitative / Quantitative risk analysis	Equivalent to the PMBOK guide	Evaluate risks
Evaluate implications	Risk response planning	Equivalent to the PMBOK guide	Risk reduction measures
		Risk Data base	

Table 6: Risk Approaches Comparison

The second difference is the timing of the risk response planning. The framework of Chapman & Ward defines that the risk response planning should be performed during the identification phase with important follow-on aspects during the following phases. The PMBOK guide and ISO standard indicates that the response phase should be performed after the quantitative analysis is performed and probabilities and exposure has been identified.

As last difference the PMBOK framework and ISO theory defines an interaction loop during the execution of the project. This means that during project execution risks are being re-evaluated on their criticality and analyzed if "new" or different risks occur. Projects are dynamic; perceptions do change during the project life cycle. It is therefore, essential to revisit the plans made. The SHAMPU framework approach does not explicitly define this interaction loop. The SHAMPU phases defined assumes that risks can be identified, planned (to manage the risks) and implemented, which seems to be a more static approach.

The theory of J.R. Meredith is in-line with the PMBOK guide (2000) with one addition, related to the creation of a risk data base in where critical data is stored required for benchmarking and trend analysis.

Although differences are found it can be concluded that the approaches have a certain overlap. It is for this reason that a selection of relevant steps necessary to properly evaluate EPC proposals is made and therewith to have a complete approach. The selection is based on the analysis of the approaches and reflected against the practical knowledge of the researcher. The risk assessment approach can be defined in seven steps, being:

1. Understand the Project; what are the project scope, schedule, and cost including project objectives and to which quality requirements need to be adhered to? In which contract form these elements are captured? The technical, commercial and contractual requirements shall be understood.

2. Plan the process; identify the process of risk assessment in terms of risk assessment sessions and the people involved, contract type and provide other criteria which could be relevant to the risks identified, e.g. specific project elements.

3. Risk Identification; identify those risks which could have an influence on the project objectives defined. In case the number of risks identified is large, the risk shall be filtered and ranked according their likelihood and consequences. Ranking can be done to evaluate the risks according project objectives, e.g. cost, time, scope and quality and filtered in terms of a numerical scale.

4. Analysis of Risks; 1) Qualitative risk analysis to assess the impact and likelihood of the identified risks. 2) Quantitative risk analysis to analyze numerically the probability of each risk and its consequences on project objectives.

5. Response to risk; determining actions to enhance opportunities and reduce threats to the project objectives.

6. Interaction loop; the theoretical approaches define interaction loops during the execution of projects. This also applies within the risk assessment during the proposal stage. This interaction loop must be defined and taken into account during the assessment itself.

7. Document step 1 through 6; a risk register shall be prepared capturing the steps above and critical data stored in a risk data base.

3.6. Applicable Knowledge

The knowledge base presents the applicable knowledge for the research which has been described in terms of foundations and a methodology. This resulted in the following foundations:

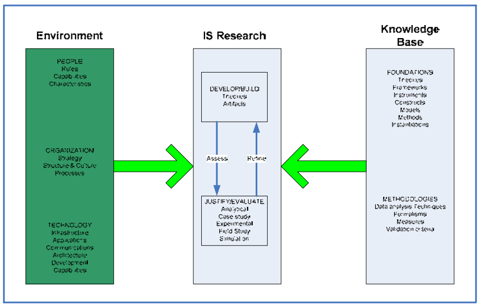
- Technical; the Project Life Cycle; defined the process of building a plant in the proposal, EPC and warranty period phase. The close out of a project defined the last step of a project.
- Commercial; the Cost Breakdown Structure (CBS) was defined in terms of base project cost, contingency, risk fund and profit. Contingency is a provision for uncertain events covering items such as material price increases, increase in quantities of material, etc. and is seen as costs. Risk fund is seen as a provision for unusual conditions/events. In case risks do not occur the money reserved could be added to the base line profit.
- Contractual: the most common contract forms, reimbursable and lump sum were discussed. Contract boundaries were shortly explored and revealed that contract have their limits, for example in terms of gross negligence for which a contractor at all times can be hold responsible for in case it can be substantiated.
- Risk and uncertainty definitions; have been analyzed and for both a definition provided which will be used throughout this research. For risk the following definition was defined: "Risks are the known and "unknown" uncertain factors which could have an influence on project objectives (positive or negative)" and for

uncertainty: "uncertainties are those factors which can not be quantified in terms of probability of occurrence, due to the existence of more than one possibility, during the time an assessment is made".

The methodology was found by means of the evaluation of several theoretical risk assessment approaches. A seven step process was defined which covered the necessary steps for evaluating EPC projects, being: understand the project, plan the process, risk identification, analysis of risks, response to risk, interaction loop and document these steps.

Sub-sub question 1a "how can the context in which risks occur with respect to EPC projects be defined and what relevant constraints are present" have been addressed and answered by means of defining the technical, commercial and contractual aspects of an invitation to bid. The constraints are discussed in terms of contractual boundaries. Sub-sub question 1 b "what are lessons from the literature on risks, uncertainties and assessment approaches and which can be applied" have been addressed by means of the definitions provided about risks and uncertainty. The methodology described represents the assessment approach applied for this research. Herewith, sub question 1 "which relevant theoretical factors define the foundation and methodology of the research and define the applicable knowledge?" has been answered.

4. ENVIRONMENT BASE



The environment defines the problem space (Simon, 1996) in which reside the phenomena of interest. For IS research it is composed of people, organizations and technologies and together they define the business needs or problem. For this research it is understood that within the problem space a large degree of dependencies can be defined. The problem owner, in this case the CLN management, receives data and information from the proposal and business development managers. It is necessary to be aware of interests and objectives of others, who are in some way involved in the problem, affected by the solutions, or have means available that can help solving the problem (Enserink and Koppenjan, 2006). To define which people are involved and have an interest in the problem an actor analysis will be performed. The steps that need to be followed in the execution of an actor analysis are presented by Enserink and Koppenjan in six steps being:

1. Formulation
2. Inventory
3. Exhibiting the formal chart
4. Determining the interests
5. Mapping out the interdependencies between actors
6. Determining the consequences

Business needs are assessed and evaluated within the context of organizational strategies, structure, culture and existing business processes. They are positioned relative to existing technology infrastructure, applications, communication architectures, and development capabilities (Hevner et al, 1997).

To capture the organizational (practical) processes within CLN, case studies will be investigated. Four projects will be selected which have passed the go/no go decision and for which a proposal was made. A selection will be made between Lump Sum and Reimbursable contracts. Based upon the actor analysis interviews will be conducted to retrieve data to analyze the current situation and which improvements with respect to risk assessment are required on project level and management level.

In general case studies are the preferred strategy to pose "how" and "why" questions (Yin, 2003). It links the data which shall be collected (and the conclusions to be drawn) to the initial research question of the study (Yin, 2004). This should result in "practical" requirements for the information system designed.

The approach of case study analysis is based upon the rationale for using multiple sources of evidence, called triangulation (Yin, 2003). The focus for this research is based upon data triangulation. This means that information is collected from multiple sources but aimed at the same fact or phenomenon (Yin, 2003). For this research it means that information is collected and reviewed about:

- The risk registers of the subject proposals.
- The theoretical framework.

- The CLN procedures.
- Research results, internet (scientifically), intranet, etc.

Multiple actors (experts) will be interviewed with different positions, objectives and requirements about the same subject. This would provide and support the case by more than one single source of evidence (Yin, 1982c).

Experts will be interviewed to define the process of risk assessments and providing risk funds for a particular proposal. After the experts have been interviewed the answers will be tested by sending the answers to the experts and requesting them to comment (response >40%). During the interviews relevant documents related to the risk assessment process will be requested for further review and comparison.

It is important to realize that experts could describe the process in partial truth values which lies between "completely true" and "completely false". The reasoning can therefore, be positioned as approximate rather than exact. This is called fuzzy logic which was formalized by Professor L. Zadeh in 1965.

The risk assessment procedure will be reviewed and confronted with the theoretical approaches found, refer to the knowledge base. The relevance of the confrontation is to investigate and judge if the CLN procedures are in line with the theoretical approaches or what can be improved.

Based upon the Knowledge and Environment base (confrontation and case studies) the gap between the current situation and future required situation will be visible (and provides the relevance of the problem). Furthermore, it will provide the business needs according Hevner and evaluation criteria of the information system artifact. Note that technology was found not to be applicable as the information system developed did not needed to be incorporated into an existing system.

4.1. People

To analyze which actors are potential involved in the process and can bring in factors which might have been overlooked an analysis has been performed; refer to attachment 3. The formulation of the problem is taken as a starting point for the analysis. The most important actors with respect to the problem definition are the following:

- Decision Makers; are involved in the decision making process to accept or reject a proposal. They decide on the final total price of a project including the contingency and risk fund which should cover for uncertain events on the project. Their main objective is to make a substantiated decision based on the same criteria for every proposal and takes unique circumstances into account.

- Business Development Manager; is interested in winning the project. The key role is to identify the key risks and to decide how to mitigate them before the senior management's final approval.

- Legal representative; is involved in the evaluation of the ITB on contractual and legal risks involved in the proposal. The risks identified reflect the exposure of the Contractor to liabilities, performance guarantees, warranty periods, etc.

- Proposal Manager; will be selected in case a go decision is made and a proposal needs to be prepared. The objective of the proposal manager is to prepare a proposal execution plan and to define the risk review meetings which are necessary. During the meetings risks are to be identified in detail and qualitatively and quantitatively assessed. The outcome is a risk register and the amount of risk fund necessary.

- Estimating Manager; is responsible for the estimate of the base cost and allowances of the project including the contingency required. The objective is to have a proper definition of the scope of work and materials required for the project to prepare an estimate.

- Planning & Scheduling Manager; is responsible for the review of the proposed schedule. Sometimes a feasibility study is necessary to identify the risks involved in the schedule which could affect schedule objectives.

- Engineering Manager; responsible for all engineering activities, which amongst others is the activity to provide man-hour estimates to the estimating manager to include this in the base cost of the proposal. To identify the man-hours required for the discipline the scope of work needs to be defined. Risks involved within the disciplines should be captured and indicated.

- HSE Manager; is responsible for the risk assessment related to Health, Safety, and Environmental aspects. The objective is to identify health and safety elements for persons which will be located to the host country where the facility will be constructed. For environmental aspects it is relevant that these can be incorporated into the technical design.

4.1.1. Conclusion: Actor Analysis

The consequence of the actor analysis for the problem definition is that some persons are responsible for the risk assessment and some will use the assessment for decision making purposes. In this case the proposal manager is responsible for the preparation of the risk assessment and the decision makers the users. This could lead to certain tension between the persons involved and relates to thrust. Therefore, it should be clearly indicated which persons should be directly involved in the risk assessment process including their responsibility. Herewith, the question arises how transparent the information system should be and if the users thrust the outcomes.

4.2. Organization

The case studies selected are briefly introduced in attachment 4. Due to confidentiality reasons the project names are changed into A through D and locations are named in terms of the region. Actors involved in these projects during the proposal stage have been selected for the interviews. A list with the persons interviewed including a questionnaire used is provided in attachment 5. Furthermore, the risk registers and proposal execution plan (if available) have been reviewed and compared. The outcome of this study is described in terms of the seven step risk assessment process (methodology) as described during the knowledge base. In case relevant quotes were given during the interviews, these have been indicated in italic.

4.2.1. Interviews

The interviews were held to understand the practical approach of risk assessment within the CLN organization. It started with the persons actively involved in the qualitative risk assessment and making the decisions. Within CLN these decisions are made by the Business Development Manager, VP Operations manager and the Legal representative. Secondly, persons involved during the quantitative risk analysis have been selected which are the Proposal Manager which in most cases continued as the Project Manager during project execution and the involved Business Development Manager.
To understand in which manner the estimates including allowances and contingency are prepared and calculated, the estimating manager was interviewed. Also he was involved in approving the estimates for these case studies.
As explained before a major risk for a contractor, especially with a LS contract, is to meet the agreed upon completion schedule. It was for this reason that the scheduling manager was interviewed and to provide inside knowledge of schedule risk analysis.

Sometimes it is necessary to receive inputs from the different engineering disciplines. The Engineering Manager of CLN was therefore requested to explain the direct involvement of the engineering disciplines. The last manager interviewed was the H.S.E. manager responsible for all H.S.E. issues related to the engineering and construction activities of the projects.

In total four projects were selected which means four proposal managers interviewed. The projects selected are representative for the organization in technical terms. Both Lump Sum and Reimbursable contracts have been selected to verify the differences in approaches. After the interviews answers to the questions were described and returned to the person interviewed. Comments (if any) were selected, discussed and taken into account were necessary.

To gain more inside knowledge about contracting and risks, two persons from the contract administration department and the risk expert were consulted and interviewed.

4.2.2. Understand the Project and Plan the Process (step 1 and 2)[9]

For one of the four projects a proposal execution plan was prepared which partially provided guidance in the risk assessment process. It made reference to the applicable risk procedure and defined the risk review meetings, a brief summary of the project and its scope was defined, which project type (LS EPC), etc. However, missing in this document was the criteria (such as schedule or cost driven) to which risks were assessed and resources

[9] For the seven step risk assessment approach selected refer to paragraph 4.6.2.

involved. Ultimately, risks were assessed by the proposal manger and business development manager only. For the other projects no proposal execution plan was prepared, which resulted in limited guidance in the risk assessment process.

…No proposal execution plan was made for this proposal but we should have done so to have more guidance in the risk assessment process…

4.2.3. Risk Identification (step 3)

The risk identification process is based on risk identification sessions. Normally, the proposal manager, legal representative and business development manager organizes these sessions to discuss the risks involved with a proposal. Sometimes discipline specialists are involved to provide particular input on technical issues. The risk elements are captured into a risk register.

…Its important to identify risks but also to understand their causes and possible consequences…

During the review of the risk registers, only risk elements are described and no indication given about the causes and consequences. As captured by one of the experts is that:

…the risk identification process should contain the description of the risk element but also a description of the cause and consequence of that particular risk element….

The risk identification sessions are normally focused on legal and financial issues. The risk registers reviewed showed indeed risk elements related to legal and financial risks. The categories captured in this register are contract liability, guarantees, contract clauses, and payment risk. This means that not "all" relevant risks are captured and taken into account.

…The highest risk level can be found during the construction of a plant and is related to those operational risks which have an effect on the Mechanical Completion (MC) date…

This statement has been captured in figure 7 which represents the Engineering, Procurement and Construction phases (operational). The percentages reflect the total involved cost related to the contract value. It is evident that the highest cost levels are found in the Procurement of materials/services and during the construction of the plant. Risk elements which have a major influence are related to the quality, completeness, delivery times, safety and schedule of drawings, materials & services, and construction activities.

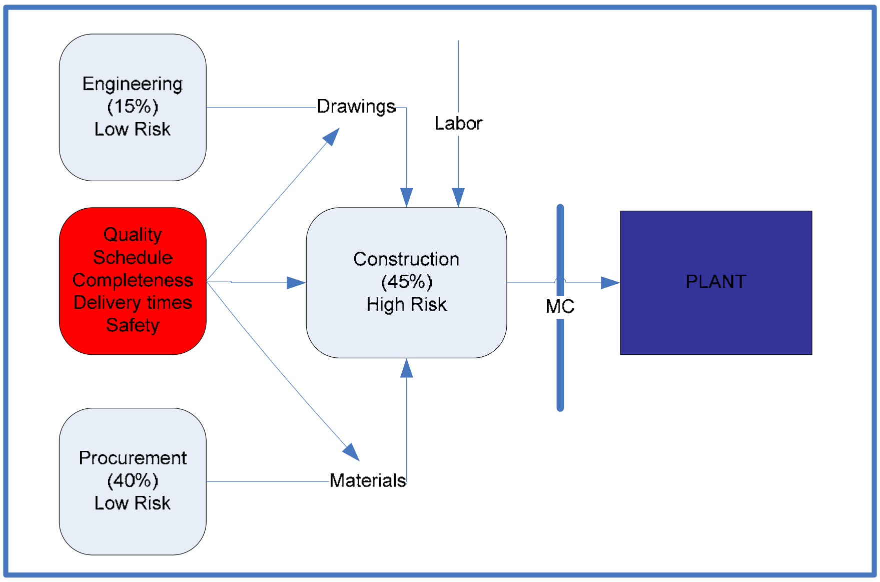


Figure 7: Operational risks

This however is not completely correct as demonstrated by the following:

..The gross of the major risk can be related to operational risks and the schedule but several times it relates to contractual or financial risks…

In several occasions project objectives were not met due to contractual or financial issues. One example given was a project were client payments did not materialize and resulted in project cancelation. The result was a financial loss for CLN as well as for sub-contractors and suppliers. Furthermore, it can be argued that the indication of low risk elements within the Engineering could have a major effect on the construction, especially related to documents necessary to construct the plant. This also applies to the risk of materials delivery which is crucial to have sufficient work front for the sub-contractors on site.

4.2.4. Qualitative Risk Assessment (step 4)

During the interviews it was indicated that for the qualitative risk analysis the same approach was followed (for the different case studies). Supporting material for project risk evaluation described the qualitative analysis and showed a standard approach. However, this analysis was not captured in one overall document showing the complete risk assessment. This means it was not indicated on the documents if a risk identified during the qualitative risk analysis should be transferred to the quantitative risk analysis for further investigation. The process of the qualitative risk analysis can be described in five steps, being:

- Does the project fit within the company's portfolio with respect to technology (products)? For example, pharmaceutical projects are alien to the company and would not be accepted.
- What is the geographical location of the plant and does this fit within our strategy and can the safety of our people be guaranteed? For example work in Iraq would not be accepted.

- Does the Client falls within our strategy? Clear statements are made by our executive management to focus on key clients.
- What is the current (at the time of the proposal) workload? This item is separated in workload for the preparation of the proposal and the workload for project execution.
- Are there any competitors and in which manner can we differentiate from our competitors? A calculation will be made in terms of: {chance a project will continue x winning chance}. There is a relation of course between the outcome of this calculation and the workload. In case the outcome is low and the workload is low it could be decided to continue. In case the work load is high it could be decided to reject the project.

Normally, the qualitative risk analysis is executed by the Business Development Manager and forms the basis for a go / no go decision. Input from the legal representative is essential in this analysis.

..In case clients are not known or known and having unacceptable contractual clauses in the contract a contractual quick scan is made and checked for "no-bid" and "walk-away" conditions….

In case clients, location, technology, etc. do not meet the strategy, a contractual quick scan of the ITB will be made. This to identify conditions which forms the basis for a no-go decision or conditions to stop the project during the proposal stage or negotiations. It provides the Contractor more certainty to reject risky projects.

The final decision to continue or reject an ITB was made by the Business Development Manager, VP Operations and Construction Manager, and the Vice President. In case of the four selected projects the decision was made to continue and to prepare a proposal.

4.2.5. Quantitative Risk Assessment (step 4)

Before the interviews took place the risk registers of the different projects were reviewed and compared. For all four cases the standard CLN check list have been used and prepared.

The risks identified are being discussed on their relevance and if they can be defined as truly risk elements. The relevant risks are captured in the risk register and categorized into high, medium, and low risk with respect to their probability and impact. This is done on the basis of the experience and intuition of the proposals manager, business development manager and legal representative (during the risk sessions).

…No value is given or matrix prepared to define the level of probability and impact of a risk element, this should be improved…

To visualize the level of a risk element a probability and impact matrix could provide a solution (also indicated in the theory found). A value is provided to both the probability and impact (P x I) and plotted into a matrix. This provides directly the risk which should be subject to further analysis. It will remain an expert decision if the probability or impact is high, medium or low.

…After ranking the risk elements, the risk which will be selected as major risks shall be subject to the identification of the correlation between these risk elements…

This step is not taken into account in the current risk register (nor in the CLN procedures). It is crucial to understand the relation between risks. Not only in case of the value calculated by means of a distribution, but also for the management of risks during project execution.

In the current risk register a probability and maximum exposure have been defined. The basis for identifying the maximum exposure was a combination of intuition and experience of the proposal manager and business development manager. In some occasions the maximum exposure was defined through a simple calculation of a certain percentage x the cost to which the risk was related too. For example the risk of additional engineering hours required a percentage of the total engineering hours was taken to define the maximum exposure. The identified probability times the maximum exposure gave the risk money required to cover for this risk element.

The risk fund for the project is defined as the summation of the assessed risk, e.g. {probability} x {impact}. However, it was found that in three of the four cases a percentage of the contract value were taken and used to be spread over the risk elements in the risk register. In one case it was found that the percentage of the contract value was used to verify the summation of the assessed risks and brought in-line with the percentage. Percentages differ over the projects but are limited between 2 and 4 % of the contract value.

.. There is no data base, were we can find risks which occurred on different projects. It means that it is depending on the lessons learned captured by the proposal manager or by the involved persons during the risk assessment sessions…

Risk assessment is performed in isolation and is based on experience and knowledge of the persons involved. Lessons learned from other projects, executed by other persons, are not captured and can not be used for reference purposes or incorporation.

4.2.6. Risk Response (step 5)

The risk register is used to define the responses which are necessary for the identified risks to secure project objectives. The risk registers reviewed showed that certain risks were insured or covered by the contract and for others financial provisions were taken into account. No indication was given about responsibilities to manage the risks or actions required. It is crucial for risk management during the project execution to define responsible resources to manage certain risks or group of risks. It goes without saying that in case actions are required for mitigating the risk these should be clearly identified and described.

4.2.7. Interaction Loop (step 6)

The interaction loop is part of the practical assessment. In case risks change or develop in such away that they should not be part of the risk fund this will be taken into account. For example an identified risk which can be managed though the insurance of that risk, the cost of insurance are to be transferred to the base project cost. In case a risk fund is defined in all cases it shall be reviewed against the contract value and are aware of the competitiveness.

4.2.8. Document Step 1 Through 6 (step 7)

The risks are captured in a risk register per proposal. However, this is a standard register covering limited categories and risk elements. It is essential to have an information system providing both the qualitative risk assessment and quantitative risk assessment. By documenting these steps properly for different proposals, trends can be analyzed and may be anticipated on for future proposals.

4.2.9. Conclusion: Case Studies

The qualitative risk analysis has been consistently applied over the proposals and used to substantiate the decision to continue or reject it. In only one case a proposal execution plan was prepared which gave only limited guidance in the risk assessment process. No criteria had been identified, only that risk assessment sessions were necessary to be planned. There were no risks identified during the qualitative risk analysis which needed to be transferred to the quantitative risk assessment for further investigation. In case the decision was made to continue with a proposal the risk identification process started. A ranking was prepared in terms of intuition about the level of the identified risks. The high and moderate level risks were captured in the risk register, to be able to assess the risks on their probability and impact. However, it was found that standard percentages of the contract value were applied and spread over the standard risk elements in the risk register. Also no correlation between risks was identified.

It can be concluded that the risk assessment process is not structured and consistent. Different percentages are being applied to cover for risks. A top down distribution of the risk fund should be avoided as this does not substantiate the necessary risk fund for the proposal and on which decisions can be made. This was also acknowledged by two proposal managers stating that:

*…. Hopefully the model will provide a systematic approach to make the coupling between the risks identified and the risk fund which needs to be taken into account to cover for the possible risks to occur…*and *…At this stage we estimate the exposure and probability ourselves with no guidance at all…*

4.2.10. Confrontation Between Methodology and CLN Procedures

To verify if the procedures are in line with the theoretical framework and if adjustments are required in the CLN procedures, a confrontation between the theory (methodology; seven step process) and procedure is detailed in the paragraphs below. Reference is made to the implementation of the risk management process during pre-contract phase of work, which is the CLN procedure for risk management during the proposal stage. Within the CLN procedure the risk assessment process has been defined as: a systematic, documented and adequately resourced linkage of processes which follows a standardized cycle. The process involves three discrete steps which are:

- **Identify** the risks in order to avoid surprises
- **Assess/Quantify** the risks using rigorous techniques to ensure reliable prioritization.

- **Respond** to the risks by planning and implementing fully resourced and effective plans with action owners.

<u>Understand the project and Plan the process (steps 1 and 2)</u>

The CLN procedure does not specify the theoretical steps 1 and 2 being understand the project and plan the process explicitly. The understanding of the project is off course the basis for the risk assessment performed within the organization and therefore, will be the starting point (although not explicitly mentioned). The second step, plan the process should however be taken into account. Criteria to which risks are subject too and unique project circumstances should be analyzed and described.

<u>Risk identification (step 3)</u>

The process of risk identification (as per CLN procedure) has been defined as: the scrutiny of the project to highlight any potential opportunities or threats that could impact the results of the project. To identify "all" risks, workshops are arranged. The identification is to be performed systematically with each risk being associated with the following standard categories: External, Technical, Contractual & hand over, Financial, Contracting parties, Organizational & HR, Fabrication, Construction & site works, Scope, Schedule, and HSE.

The PMBOK guide describes the risk identification process as the determination of which risks might affect the project and defines the following risk categories: Technical quality or performance risks (such as reliance on unproven or complex technology), Project management risks (such as poor allocation of time and resources), Organizational risks (such as cost, time, and scope objectives), and External risks (such as shifting legal or regulatory environment). These categories will be subject to a separate analysis to define the relevant categories for CLN. This analysis is captured in the IS research chapter.

All <u>known</u> risks should be identified and classified as to whether they pose a threat to the project. Highlighted is the word known. As indicated in the definition of risks, unknown uncertain factors could also have an influence on project objectives. The indication of unknown risks and uncertainty is missing in the CLN procedure.
Uncertainty can not be quantified in terms of probability of occurrence, refer to the definition provided. Uncertainty is inaccurate and within CLN taken into account in the contingency calculations with respect to the estimates. As an example the bulk take off can be mentioned. This is performed on the basis of the first P&ID's and plot-plan. A bulk take off will be estimated but this is inaccurate due to the information available. Therefore, contingency and allowances will be taken into account for the bulk material take off. Note that Chapman and Ward describe this as the variability associated with estimates and uncertainty about the basis of estimates.
Unknown risks can not be defined as such and can only be captured by means of a financial reservation. This however should be captured in the proposal execution plan and how the proposal manager wants to deal with this. Also the decision makers should be alert to incorporate such a reservation also with respect to competiveness, work load, etc. Therefore, within the risk register only those risk elements will be captured which can be defined as Probability x Impact and could have an influence on project objectives.

Qualitative and Quantitative risk analysis (step 4)

Risk assessment and quantification is the process, according the CLN procedure, of determining the potential impact of the risk and the probability (likelihood) of it occurring. Risks are initially assessed from a qualitative perspective on which a decision is made to continue or reject a proposal. However, no system or process description is provided how risks will be transferred (if necessary) towards the quantitative risk analysis and how this will be documented.

A qualitative risk analysis requires accurate and unbiased data, necessary for the risks to be credible and valid for decision making purposes. It has been indicated in the literature (ANSI) to make use of a Work Breakdown Structure (WBS) or a Risk Breakdown Structure (RBS) to determine areas of the proposal which are the most exposed. A WBS or RBS would provide a structured approach to determine relevant categories which need attention. However this is not captured in the CLN procedures.

Risks are sub sequentially analyzed quantitatively and could have an impact on one of the following areas of the project: H.S.E., Project budget, Project schedule and/or Production efficiency (as indicated in the CLN procedure). This needs to be verified in more detail if these categories capture the most important risk elements of a proposal.
The identified risks will be subject to the determination of the overall magnitude. This is done by means of a five point scale for both the impact and probability of a risk. For the impact a relative scale needs to be applied, e.g. Negligible (VL), Minor (L), Moderate (M), Significant (H) and Extreme (VH). The same scale is used for the probability only percentages are coupled to the relative scale, e.g. VL (5%), L (10%), M (15%), H (22%) and VH (30%). This will provide a ranking of the risks. However, no indication is given which risk elements should be subject to further analysis. Based upon the numerical scale it can be assumed that risks categorized as M until VH are relevant and should be taken into account during further analysis, this due to the desire to avoid high impact threats.

The theory describes a ranking system using a Probability and Impact matrix. The probability and impact is provided on the basis of a numerical scale. Risks can have an impact on the following objectives: cost, time, scope or quality. This will provide a matrix with a color indication of the high, medium and low risks. The benefit of such matrix is the visualization of risks and their level. It can be concluded that within the CLN procedure such a matrix is not incorporated.

It is important to understand risks and their possible correlation on other risks in case of occurrence. According the theory a correlation matrix would provide a clear structure to identify the positive or negative correlations between risks. Note that this aspect is important not only for managing risks but also for simulating the risk model. The correlation between risks has not been described in the CLN procedures.

Response to risk (step 5)

According the CLN procedures a response planning is required, for which four basic methods are defined; Avoid, Transfer, Mitigate and Accept. Risk response actions, depending on the response method, should be described in an action plan (this plan should cover all activities necessary to assure the desired outcome). It shall be ensured that proper mitigation of each risk is identified and to ensure no "double dipping" (provision made in two places). The theories found do not describe an acceptance response. This is an element missing in the theory as it is possible that risks can not be avoided, mitigated or transferred. It has not been described in the procedures that owners and action dates per response are defined, which is essential for managing these risks during project execution.

The coverage for risks has been defined (in the CLN procedures) into two elements being: non-financial actions and financial actions. In case of financial actions are required this shall be included in the estimate as contingency-key risks. Total contingency included in the final price is the total contingency as identified by the estimating department and the total of all key risks. A clear distinction must be made between contingency and risk fund, this because contingency is seen as cost and the risks as uncertain factors which could occur. In case of non-financial actions these shall be identified in terms of the standard responses, e.g. avoid, accept or transfer.

Interaction loop (step 6)

The interaction loop as defined in the CLN procedures is defined as follows: the risk register is reviewed to confirm the relevance of risks identified during the pre-contract phase and to identify any new risks that might have arisen during the final contract agreement and negotiations. It can be concluded that this is in-line with the findings in the theoretical approach.

Document risk assessment (step 7)

The sixth step from the theory found is the requirement to document the risk assessment. Within the CLN procedures this is captured in terms of a risk register. Missing is one overall register capturing the qualitative and quantitative assessment. Furthermore, the incorporation of the risk registers into a data base which could serve to analyze trends and to create a base line for special types of proposals is missing in the procedures. Important in this respect is to capture key decisions about risk acceptance.

4.2.11. Conclusion: Confrontation

Demonstrated by the confrontation step 1 and 2 are missing in the CLN procedure. The familiarization of the project is not indicated but is off course the starting point of the risk assessment. The planning of the risk assessment should be captured in the proposal execution plan and should provide the necessary details for a proper risk assessment.

The process of risk identification (step 3) has been indicated in the CLN procedure including standardized categories of risks, e.g. contractual & hand over, external, contracting parties, etc. These categories shall be further analyzed and a decision made which categories shall be applied. It has been acknowledged that uncertain factors and unknown risks will not be captured in the information system. Only those risk elements which can be defined in terms of probability and impact. Reservations for unknown risks should be identified and incorporated in the quote calculation. Uncertainty was found to be taken into account in the contingency calculations.

Missing is an overall register which captures both the qualitative risk assessment and quantitative risk assessment (step 4). From the theory it became clear that this step is necessary to determine accurate data and to provide a method for prioritizing the identified risks for further actions. Within the theory the qualitative risk assessment is seen and described as a first pass assessment, within CLN it is the first gate to accept or reject a proposal. To capture both assessments in one model it will be transparent. It will provide a structure to transfer risks from the qualitative to the quantitative risk assessment and it is documented properly. Furthermore, missing in the CLN procedure is the determination of the correlation between risks. A correlation matrix should be made as some risks cannot be seen in isolation. It is therefore, important during the calculation of the risk fund to define the dependencies between certain risks. Also during project execution the project manager should be aware of the correlating risks especially when these risks occur.

Missing in the CLN procedures is the indication of unknown risk and uncertainty. Unknown risks shall be captured in terms of a certain percentage which should be verified against the bidding strategy and decided upon by the general management, this will not be captured in the information system designed. Uncertainty is taken into account within the contingency calculations by CLN and therefore, will not be part of the information system designed.

The responses to risk (step 5) and the interaction loop (step 6) have been defined in the CLN procedure. One additional element which needs attention is the word contingency which should be avoided in the CLN risk procedure, as a clear distinction must be made between both risk fund and contingency reservations.

The last step 7 (documenting risks) is partially done by means of a risk register (which forms part of the procedure). Missing is the capturing of risk elements and their responses into a data base which could be used as a reference for other proposals. According J.R. Meredith the data bank[10] should consist of the identified risks, the probabilities and exposure of the identified risks. This detailed information is necessary to bench mark projects and to analyze certain trends in risk results.

4.3. Business Needs

The risk assessment process as found during the knowledge base analysis and acknowledged during the environment base analysis is captured in figure 8.

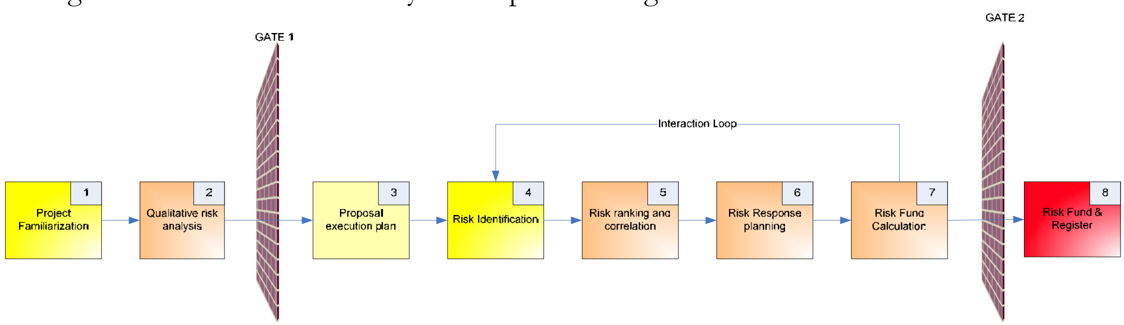


Figure 8: Workflow Risk assessment

[10] The full context of a data bank falls outside the scope of this research.

The gates represent the decision moments in the process starting with the go/no-go decision and ending with the decision about the amount of risk fund required for the project. The first pass risk assessment (defined in the theory) can be seen as the qualitative risk assessment as performed within CLN. Missing however is one overall information system which captures the complete risk assessment, as presented in figure 8. In case Gate 1 has been passed a proposal execution plan should be prepared, which was not done in all cases. Within the theory found risk assessments should be planned and criteria selected. It is desired to prepare a planning for every (EPC) proposal. Missing in the current risk registers is the identification of risks in terms of event, cause and consequences. Ranking of risks is described in the CLN procedures for which standard probabilities have been indicated, but was not applied practically. The correlation between risks is not captured in the risk registers or in the CLN procedures and should be applied as some risks can not be seen in isolation. The response planning was in line with the CLN procedures and the theoretical approach. In case of the risk fund calculation no standard calculation method was provided other than P x I. During the case study research it was found that standard percentages were used and spread over the standard risk elements, which does not provide proper information for decision making purposes, during gate 2. During the decision making process the total risk fund was evaluated by the CLN management and in case not found acceptable discussed and adjusted (interaction). The identified work flow process is in-line with the risk assessment approach (applied) as indicated in paragraph 4.5.2 which is summarized in table 7.

Applied risk assessment approach	**Captured work flow process**
Step 1: Understand the project	Item 1: Project Familiarization
Step 2: Plan the process	Item 3: Proposal Execution Plan
Step 3: Risk identification	Item 4: Risk identification
Step 4: Analysis of risks (qualitative and quantitative)	Item 2: Qualitative risk analysis Item 4, 5, 6: Risk identification, ranking and correlation (quantitative), calculation
Step 5: Response to risk	Item 6: Risk response planning
Step 6: Interaction loop	Interaction loop
Step 7: Document step 1 through 6	Item 8: Risk register

Table 7: Comparison

The CLN risk procedure has been analyzed and improvements identified which provided the answer to sub-sub question 2a. The business needs provided the answer to sub-question 2b "how can the business needs (problem) be described after the analysis of the practical approach and CLN procedures" It resulted in no consistent risk assessment process which describes the necessary steps to define all required information for decision making purposes. No standard risk fund calculations were provided which meant that risk funds were conducted in different ways by means of top down distributions of a percentage of the contract value. Therefore, an information system should be designed which will provide consistent and thrust full information for proper decision making. Both sub-sub questions provided the answer to sub question 2 "how are risks assessed within the CLN organization, during the proposal stage, from a practical and procedural point of view"

4.4. Recommendations

On the basis of the confrontation between the theoretical approaches and the CLN procedures including the case studies, recommendations can be made. The trade off will be described in terms of losing the quality or aspect of one of the two, and in return gaining another quality or aspect. Decisions will be made and highlighted with both the upside and downside of a particular choice. The recommendations are:

The first recommendation is to incorporate the 'gate model" into the CLN procedures.

The process of qualitative and quantitative risk assessment has not been captured in a workflow process. The relation between the qualitative and quantitative analysis can not be ignored and should be aligned to be able to transfer relevant risks between the two. Formalizing such a process would benefit in terms of following the same process on different proposals and educating "new" people who need to follow the same process. The work process is defined in a structured manner and defines firewalls (gates). These gates should be used as an extra quality control before proceeding with a) the risk before deciding to continue with a proposal and b) the quantitative risk assessment resulting in the required risk fund. The downside would be that procedures need to be revised and/or up-dated.

Secondly, a clear distinction needs to be made between risk fund and contingency in the CLN procedures.

The CLN procedure does not make a distinction between contingency and risk fund. As explained before contingency can be seen as cost within the CLN organization. Normally on projects contingency run down curves are being prepared to control the contingency throughout a project. The risk fund on the other hand is being used in case risks happen and for which money is necessary from this fund. In case risks do not occur the risk fund can be transferred to the bottom line profit. By not maintaining a clear distinction between these two aspects confusion is created.

The third recommendation is to incorporate the probability & impact (P&I) matrix and the use of a correlation matrix in the CLN procedures.

The probability & impact matrix makes usage of a color code to identify high, medium and low risks. It is an easy to use model and visualizes all risks in a structured manner. During the risk assessments this matrix does not have much added value as the ranking can take place within the risk register itself. A P&I matrix can however be useful during the execution of a project and in this way control risks and register the shifts (criticality). The information system will be designed for the proposal stage and as such this matrix does not add any value. Therefore, it has been decided not to incorporate the P&I matrix in the design.

The correlation matrix is necessary to identify the relations (positive or negative) between risks. This is important for the calculations made in the risk model and for managing risks during project execution. It must be noted that the identification of the dependencies between risks is subjective. However, experts will be responsible to complete the correlation matrix.

The fourth recommendation is to prepare a Proposal Execution plan for all projects to identify the risk assessment procedure and criteria.

A plan shall be provided which covers the process and criteria for the risk assessment. In this way direction is given to the process. In the plan unique circumstances can be identified which could have an effect on the risk assessment. Within the CLN procedures it has been indicated that for small projects no proposal execution plan is necessary to be prepared. This because it takes to much time (and thus money) to prepare such a document and the benefits is minor. However, also for small projects it can be argued that by preparing a PEP the people involved will think about the risk assessment (and the project strategy) before preparing a proposal. It must be noted that also small projects can fail and have a financial impact on the organization. Therefore, preparing a PEP will be beneficial for all EPC proposals.

The fifth recommendation is to prepare standard categories with respect to the qualitative and quantitative risk analysis.

To create consistency over the different proposals, categories shall be provided. The quantitative risk assessment is performed on the basis of a standard list (standard categories and risk elements). This list comprehends contractual risk elements and is not complete in order to assess "all" risk elements of an EPC project. Therefore, the categories need to be revised to create a consistent risk analysis over the different proposals. The downside is that people will use these categories and will not think out of the box. However, for consistency reasons it is recommended to implement these standard categories.

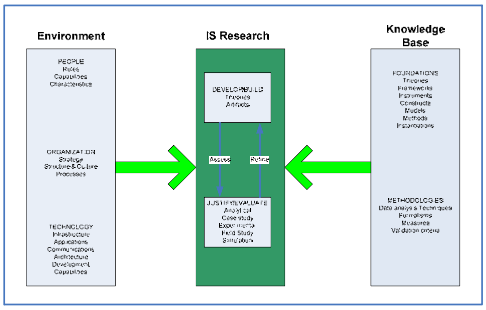
The sixth recommendation is to define a standard method to calculate the probability and impact of risks.

The risk fund was established by means of a percentage of the total contract value. Afterwards this was divided over the standard risk elements and in some cases a probability and exposure was defined. A standard method should be defined to calculate the probability and impact to create consistency over the different proposals. The downside is that a standard distribution will be selected which may not be fully sufficient for all risks identified. However, consistency is an important element in the evaluation and to create this it is necessary to provide a standard calculation method.

The seventh recommendation is to create a risk data base where per proposal risk elements are captured.

Missing in the procedure and expressed during the case studies is a risk data base in where risks, mitigation strategies, probabilities, exposure, etc. are captured. It would be beneficial to use this information as a reference for new proposals and if possible analyze trends. The downside is that projects are not the same and will have different risk profiles and are therewith difficult or can even not be compared. Also it could be misused in terms that people will copy the risks and have comfort that the risk assessment was performed properly. However, a risk data base would still have the advantage that it could be used as a reference for future proposals. Note that the creation of a risk data base falls outside this research.

5. INFORMATION SYSTEM RESEARCH



Information System (IS) research is conducted in two complementary phases. Behavioral science addresses research through the development and justification of theories that explain or predict phenomena related to the identified business need. Design science addresses research through the building and evaluation of artifacts designed to meet the identified business need (Hevner et al 1997). The business needs have been captured by confronting the foundations and methodology during knowledge base with the environment base. Recommendations have been provided from which model requirements will be distilled. On the basis of the model requirements a conceptual model will be prepared and sub sequentially the information system designed and built. The last step is to evaluate the model which is done by mans of a verification and validation test.

5.1. Develop 1: Risk Categories

To create transparency in the risk assessment process high level risk categories with respect to the qualitative and quantitative risk analysis shall be analyzed. This will be done by means of the theories and requirements found during the knowledge and environment base analysis. A systems diagram has been prepared to analyze the system on the basis of an objective tree and causal relation diagram.

5.1.1. Analysis

The first step in defining the risk categories was the review of the risk registers used. After comparison of the registers it could be concluded that the registers could only be partly used to define the categories as the standard registers are related to contractual issues only. It was for this reason that a separate analysis was necessary to determine the different categories. Therefore it was decided to prepare an objective tree, refer to attachment 6 and causal relation diagram, and refer to attachment 7. To understand the cohesion between the aspects found from the objective tree and causal relation diagram with respect to the total system a second system diagram has been made, refer to figure 9. The total system can be separated into six subsystems being: Technical, External, Contractual, Health, Safety, and Environment (HSE), Commercial/Financial, and Organizational, which relates to the quantitative risk analysis. The input for the system is the Invitation to Bid which provides the requirements for the project. The qualitative risk analysis provides the basis for the quantitative risk analysis, as this is the decision to continue or reject a proposal. The qualitative analysis can be separated into the following categories: portfolio, location, client, workload (current), competition, and contractual. The procedures define the processes for the proposal risk assessment.

The technical sub system defines all technical risks associated with the proposal, as an example the completeness of the technical scope of work, proven technology, etc. The international standards provide the technical requirements for equipment, etc. which in all cases are required to be fulfilled on projects together with the Client standards. The Technical sub system provides the basis for the project being the scope of work including the schedule. Therefore, this will influence all other sub systems. The External subsystem defines the risks related to external elements, for example the reliability of the client, country stability (political), etc. The Contractual subsystem defines the contractual risks such as liability, warranty, etc. The Law will influence this subsystem and can not be influenced by the problem owner.

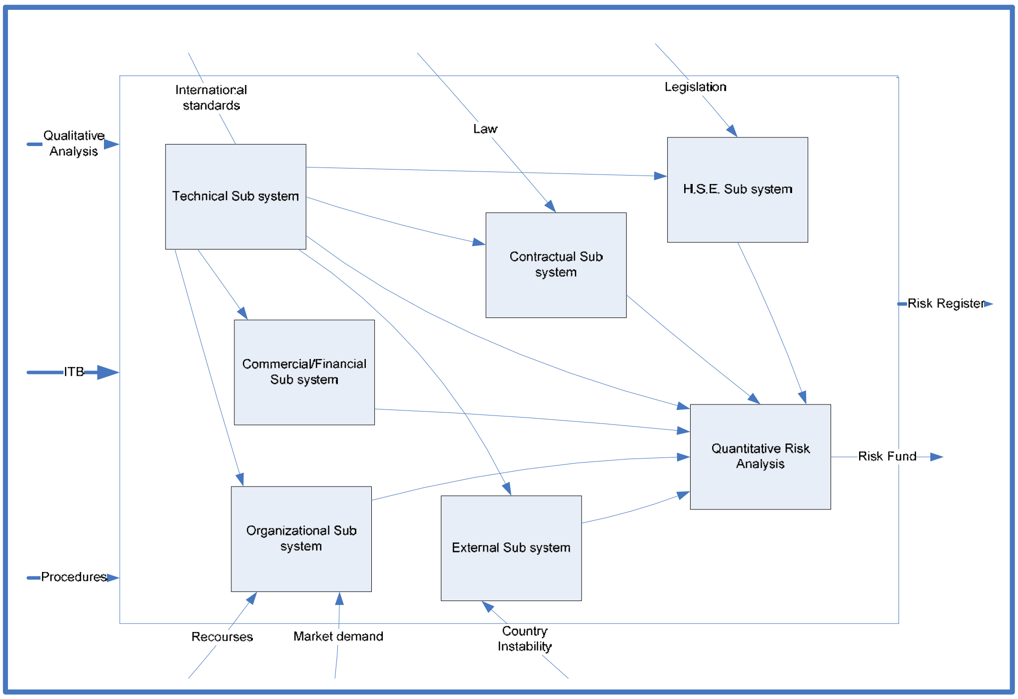


Figure 9: Second Systems Diagram

The HSE subsystem defines the risks related to health, safety, and environment. Legislation provides the requirements in the country for the environmental aspects, such as noise limits, exhaust of gases, etc. Health and safety are related to the work environment of resources during the engineering in the office and during the construction works. Commercial/Financial subsystem defines the risks related to payment conditions, terms and conditions, etc. The last subsystem, Organizational, is related to the availability of resources, skills required to execute the works. The output of these sub-systems is the risk register with "all" risk elements captured including the necessary risk fund. Table 8 summarizes the level 1 risk categories

Category	**Description**
Technical risks	Risks associated with the technical scope of work which forms the basis for the project. This includes the technological risks, risks related to meeting schedules, etc.
External risks	Are related to risks occurring from external actors and can have an influence on meeting project objectives. External actors are Clients, Sub-contractors, Governments, etc.

Contractual risks	That is arising from the contractual clauses of the contract. It relates to guarantees, liabilities, etc.
HSE risks	Are associated to the health and safety of resources working in the engineering office and on the construction site. The environmental risks are related to those where the nature of the project has a major impact on its environment and has a strong objection by the general public.
Commercial/Financial risks	Are related to risks that arise from incomplete scope of work definitions, and have an influence on the project budget. It furthermore, relates to the cash flow of the project.
Organizational risks	Are those risk related to the allocation of available resources including the experience of key project personnel.

Table 8: Risk Categories

5.2. Develop 2: Model Requirements

The development of a risk model is a high risk undertaking for the CLN organization. As described before CLN derive its revenue from these projects. Developing a risk model with incorrect features (requirements) can therefore, have a negative effect on the revenue and even on the market position. It is for this reason that the Collaborative Ethnography Method (CEM) has been selected to analyze and define the requirements for the risk model (Machado, Borges and Gomes, 2006). The CEM provides a systematic and structured approach, which is captured in figure 10. Several methods have been reviewed but CEM has been selected because it specifically fits the domain of risk assessment in which it will be applied. The steps to be taken are transparent and sufficient to identify those requirements necessary for risk evaluation.

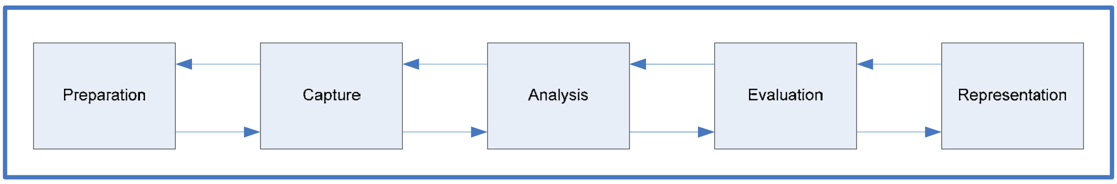


Figure 10: CEM

5.2.1. Preparation

The starting point is to determine what needs to be observed and where to look for: which work settings, key users and choosing which data needed to be collected. These elements have been investigated during the environment base. Part of the analysis was the case studies defining the practical approach and the analysis of the CLN procedures which provided the work setting. The key users were identified by means of an actor analysis. This provided the selection of people which were interviewed. Data which needed to be collected from these interviews were related to the current situation (how did they perform a risk assessment during the proposal stage), was this in-line with the procedures, did they see a need of a risk model, and which requirements did they perceived for such a model. The outcomes of the interviews were verified against the approaches from the theory and the organizational procedures and standards. Furthermore, risk registers, risk funds and proposal execution plans were reviewed and compared. This resulted in the business needs and recommendations provided. On this basis the model requirements are captured.

5.2.2. Capture

The recommendations are used to define the model requirements and are categorized in design- and functional-requirements, which are:

<u>Design Requirements</u>

- The basis of design shall be the work process as captured in figure 8. This means that the model should be separated into a qualitative and quantitative risk register.
- The model should allow for unique project requirements and lessons learned (thus flexibility).
- The model should be transparent and faults intercepted during completion of the risk model.

<u>Functional Requirements</u>

- A proposal execution plan shall be provided for every project indicating the risk assessment process and its criteria.
- The categories (level 1) for the qualitative risk analysis shall be in accordance with the findings as presented in paragraph 4.2.4. The risk categories for the quantitative risk analysis shall be in accordance with the analysis presented in paragraph 5.1.
- Under the risk categories standard risk elements shall be defined and distributions provided (standard calculation method).
- The model shall consist of: risk identification, ranking, correlation, risk response and the calculations necessary to determine the risk fund.

5.2.3. Analysis

The captured requirements will be further analyzed and comments provided to verify if the requirements will be applied during the design of the model.

<u>Design requirements</u>

- The basis for the information system shall be the work process as captured in figure 8.

The work process as derived from the case studies and interviews will be the basis of design (BOD). These steps need to be incorporated to define the different steps necessary to provide a consistent risk assessment process.

- The information system should allow for unique project requirements and lessons learned (thus flexibility).

The risk assessment should be executed from scratch. This means that no standard or default risks will be indicated in the information system. Unique project requirements can therefore, be incorporated during the completion of the information system. With respect to lessons learned, these elements need to be captured during the completion of the model. In the model itself this will not be incorporated but it should be part of the CLN procedure.

- The information system should be transparent and faults intercepted during completion of the risk model.

To implement the information system into the CLN organization the model should be transparent. This means that the calculations behind the model must be understandable. In case of complexity it will be easily rejected or negatively promoted after usage. This is a known phenomenon within the CLN organization and should be avoided. In which way faults are intercepted during the completion of the risk model will be further analyzed.

Functional requirements

- A proposal execution plan shall be provided for every project indicating the risk assessment process and its criteria.

This requirement shall be a pre condition to start with the risk assessment itself. It is necessary to think about the criteria, people involved, dates, etc. Within the model it should be a check box.

- The categories (level 1) for the qualitative risk analysis shall be in accordance with the findings as presented in paragraph 4.2.4.

The qualitative risk analysis will be based upon these findings as presented and discussed during the interviews. A check box needs to be incorporated to identify if a risk need to be transferred to the quantitative risk assessment.

- The categories for the quantitative risk analysis shall be in accordance with the findings as presented in paragraph 5.1.

To group the different risk elements several risk categories have been selected on the basis of the analysis presented. The categorization of risks is important to have a trigger if important elements have been discussed and thought about. Also it helps to identify if risks are not doubled in the register, especially in case if more than 50 risks.

- Under the risk categories standard risk elements (level 2) shall be defined and distributions provided (standard calculation method).

During the research it was found that providing standard risk elements is not feasible. In case standard risks are indicated the probability is high that people will not explore other risks rather than those indicated. Projects are unique in a sense and need grass root risk assessment, to capture most of the unique risks. Therefore, no standard risks will be provided. To provide a standard calculation method, distributions should be provided. Which distributions are relevant during the proposal stage will be further investigated.

- The model shall consist of: risk identification, ranking, correlation, risk response and the calculations necessary to determine the risk fund.

The risks which will be identified shall be described in terms of the event, cause and consequences as defined by the theoretical approaches and missing in the CLN procedures and register. The ranking shall be adjusted in terms of P x I, which will provide a proper selection tool of risks. The correlation between risks will be identified by means of a correlation matrix as defined in the theory. The responses to the selected risks will be performed according the CLN procedure with the addition of the action owner and completion dates.

5.2.4. Evaluation

The data as captured was returned to the people interviewed, to obtain their confirmation and validation. Also the accuracy and completeness were verified. In case of any conflicts or additions this was taken into account and presented as indicated above.

5.2.5. Representation

Based upon the data represented requirements were formulated which forms the basis for the development of the conceptual model and ultimately the risk model itself. Those model requirements which will be taken into account are represented in table 9. The gap between the current practical CLN approach and what is desired. The recommendations including the reference to the practical approach, procedures and theoretical approach will be provided.

Item	Model Requirement	Gap	Recommendation	Reference
1	The basis of design is the work process as captured in figure 7.	Within the current available risk register this work process is missing and not incorporated in one specification.	Incorporate this gate model in one CLN procedure.	Theory; first pass risk assessment and the work process found during the case study interviews.
2	The model should allow for unique project requirements and lessons learned (thus flexibility).	This was not captured in the CLN risk procedure.	A process needs to be described to incorporate these elements.	Practical approach defined during the case studies.

3	The model should be transparent and faults intercepted during completion of the risk model.	Transparency is missing with the current process and register.	The model should be designed as such that it can be trusted. Faults need to be intercepted during the completion of the model by the experts.	Practical approach defined during the interviews of the case study and one of the sub-questions.
4	A proposal execution plan shall be provided for every project indicating the risk assessment process and its criteria.	Not for all proposals a proposal execution plan was prepared.	Prepare a plan for these proposals to provide a guideline for the risk assessment.	Theoretical approaches define plan the process.
5	Categories for the qualitative and quantitative risk assessment shall be provided in the model.	Categories for the qualitative risk assessment are not covered in the CLN procedure or risk register, the quantitative categories are not captured to its full extend in the risk register.	Define standard risk categories (level 1) for both the qualitative and quantitative risk assessment.	Defined during the case studies where it forms the basis of the problem of an inconsistent risk assessment approach within CLN.
6	A standard calculation method shall be provided.	A consistent calculation method is missing which is used for the different proposals.	Incorporate an understandable calculation method and use this for all proposals.	Practically a need for a consistent calculation method is required as indicated during the case studies.
7	The model shall consist of: risk identification, ranking, correlation, risk response and the calculations necessary to determine the risk fund.	A consistent approach on different proposals is missing.	Define a standard risks assessment approach, to make this process consistent within the CLN organization.	Defined during the case studies.

Table 9: Model Requirements

The model requirements will be verified during the conceptual design if all these requirements as presented have been implemented and are taken into account. It was decided due to the complexity to evaluate model requirements 2, 3 and 6 further.

5.3. Develop 3: Design Developments

Design developments need to be made with respect to the calculations of the risk fund (item 6), how lessons learned will be incorporated (item 2) and how faults can be intercepted (item

3) during the completion of the model. Additional the operational requirements will be briefly described.

5.3.1. Risk Fund Calculations

Deterministic Risk Analysis

The calculation of the assessed risks can be performed in a couple of different ways. One way uses single-point estimates, or is deterministic in nature. Using this method, an analyst may assign values for discrete scenarios to see what the outcome might be in each. For example, in a financial model, an analyst commonly examines three different outcomes: worst case, best case, and most likely case, each defined as follows:

- Worst case scenario – All costs are the highest possible value, and sales revenues are the lowest of possible projections. The outcome is losing money.
- Best case scenario – All costs are the lowest possible value, and sales revenues are the highest of possible projections. The outcome is making a lot of money.
- Most likely scenario – Values are chosen in the middle for costs and revenue, and the outcome shows making a moderate amount of money.

There are several problems with this approach:

- It considers only a few discrete outcomes, ignoring hundreds or thousands of others.
- It gives equal weight to each outcome. That is, no attempt is made to assess the likelihood of each outcome.
- Interdependence between inputs, impact of different inputs relative to the outcome, and other nuances are ignored, oversimplifying the model and reducing its accuracy.

Yet despite its drawbacks and inaccuracies, many organizations operate using this type of analysis.

Probabilistic Risk Analysis

A better way to perform the calculation is by using Monte Carlo simulation. Uncertain inputs in a model are represented using ranges of possible values known as probability distributions (@Risk, 2009). By using probability distributions, variables can have different probabilities of different outcomes occurring. Probability distributions are a much more realistic way of describing uncertainty in variables of a risk analysis. Common probability distributions include:

Normal – Or "bell curve." The user simply defines the mean or expected value and a standard deviation to describe the variation about the mean. Values in the middle near the mean are most likely to occur. It is symmetric and describes many natural phenomena such as people's heights. Examples of variables described by normal distributions include inflation rates and energy prices.

Lognormal – Values are positively skewed, not symmetric like a normal distribution. It is used to represent values that don't go below zero but have unlimited positive potential.

Examples of variables described by lognormal distributions include real estate property values, stock prices, and oil reserves.

Uniform – All values have an equal chance of occurring, and the user simply defines the minimum and maximum. Examples of variables that could be uniformly distributed include manufacturing costs or future sales revenues for a new product.

Triangular – The user defines the minimum, most likely, and maximum values. Values around the most likely are more likely to occur. Variables that could be described by a triangular distribution include past sales history per unit and inventory levels.

PERT- The user defines the minimum, most likely, and maximum values, just like the triangular distribution. Values around the most likely are more likely to occur. However values between the most likely and extremes are more likely to occur than the triangular; that is, the extremes are not as emphasized. An example of the use of a PERT distribution is to describe the duration of a task in a project management model.

Discrete – The user defines specific values that may occur and the likelihood of each.

During a Monte Carlo simulation, values are sampled at random from the input probability distributions. Each set of samples is called iteration, and the resulting outcome from that sample is recorded. Monte Carlo simulation does this hundreds or thousands of times, and the result is a probability distribution of possible outcomes. In this way, Monte Carlo simulation provides a much more comprehensive view of what may happen (it tells you not only what could happen, but how likely it is to happen). It is for this reason that the Monte Carlo simulation has been selected by means of @risk.

Within the risk assessment of EPC proposals two types of risks can be identified in terms of discrete or continuous risks. In case of continuous risks the triangular distribution has been selected, because during the proposal stage minimum data is available. In case data is available the triangular distribution will be sufficient as well, refer to the description which includes past history. For discrete risks specific values must be provided. Therefore, the information system should consist of continuous and discrete distributions.

5.3.2. Lessons Learned

The information system should be designed as such that earlier experienced unique risks and recorded lessons learned from previous proposals can be incorporated. To be able to respond to this subject experts were consulted to define a practical approach. It has been stated that during any risk assessment exercise the Best Practices as defined within the CLN organization should be consulted (as a starting point). One of the main reasons for implementing the concept of Best Practices in the CLN organization was to be able to deal with unknown/unfamiliar circumstances. Earlier experienced unique risks and lessons learned should be captured at the appropriate moments which means after the risk has been dealt with. To capture these risks (and lessons learned) a tool which has been developed by CLN will be the most appropriate. The process for this is the CIM process where CIM stands for Continuous Improvement Measure. The unique risk or lessons learned will be described and via a CIM reviewed by the responsible persons. The CIM if relevant will be described as a best practice, procedure or work process. The result will be captured in the Company Management System which can be accessed by the proposal mangers before the risk assessment will start.

5.3.3. Faults Interception

During completion of the model faults should be intercepted. If we assume that technical faults can not occur by means of fool proving the model, for example locking fields which are used for calculations only and identify these by means of a color code. The only faults that can occur are the following:

- The identified risk is not actually a risk

  This can be avoided by testing a perceived risk on one or more criteria. An important criterion is whether it is within the control to avoid the unwanted event. The criteria should be incorporated in the Proposal Execution Plan. During the risk assessment this verification (risk against the set criteria) should be executed directly. This means that risks which are actually not a risk can be deleted directly and with the "agreement" of the participants of the risk assessment.

- The probability has not been correctly assessed

  This can be avoided by a) having the assessment made by (a team of) subject matter experts, or b) using statistics (in case these are available), or both. In case subject experts will estimate the probability it could have the effect of fuzzy logic. However, in case multiple experts will complete the probability about the same subjects, this would provide and support the case by more than one single source of evidence (Yin, 1982c), refer to paragraph 3.1.2. In case of wide spread variations in the estimates, a group session could be arranged to create consensus with the experts. In case of using statistics it should be evaluated that the same risks and probabilities will be compared. Within the CLN organization these statistics have not be captured consistently. Furthermore, in case of EPC projects only two or three will be executed in a time frame of two to three years. This means that there may not be so many data points captured to provide a proper reference.

- The impact has not been correctly assessed

  This can be avoided by a) having the assessment made by (a team of) subject matter experts, or b) using statistics (in case these are available), or c) relating the impact to budgets and estimates (insofar as available), or all three. Items a and b are similar to the items explained under "the probability has not been correctly assessed". In case of item c the impact can be related to the budgets of the different disciplines. However, during the proposal stage the risk assessment will be executed in parallel with the execution of the estimation of the base cost (which will be rolled out to the budgets for the different disciplines). This would mean that the budgets would not be available during the risk assessment and that an estimate needs to be made by the experts.

5.3.4. Operational Requirements

The question arises once the information system is built how it can be made operational. This can be achieved by assigning responsibilities and authorities. For example the project controls department (risk experts) can be made responsible as process owner for providing governance, expertise and facilitation and preparing and maintaining the risk register. The proposal managers which are the users of the process can be made responsible for proposal execution planning and as such calls and lead the risk assessment sessions. To capture these responsibilities, the model and the explanation of the process should be clearly incorporated in the CLN procedure for risk assessment during the proposal stage. Training people in the process and the use of the model would be beneficial.

It must be noted that in case of large amounts of risks identified the management team could decide to discuss only those items with a certain mitigation strategy (such as acceptance) and a certain level of risk, for example high or very high. This depends on the projects and need to be decided on a case to case basis.

5.4. Develop 4: Conceptual Model

On the basis of the model requirements a conceptual model is designed. The starting point is the workflow as captured in figure 7. The workflow can be divided into three phases, which are; phase I the qualitative risk analysis, phase II the quantitative risk analysis and phase III the risk fund calculation.

Phase I

The starting point of the qualitative risk assessment is the familiarization of the invitation to bid. The qualitative risk assessment is based upon the standard categories as applied within the CLN organization. These categories have been plotted in figure 11.

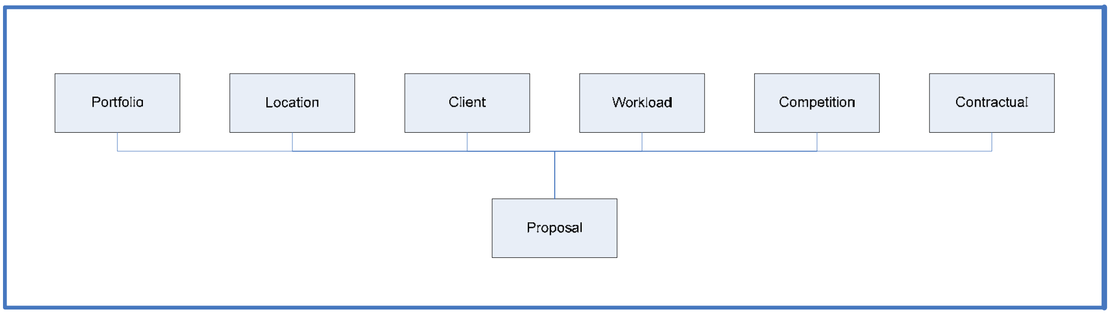


Figure 11: Conceptual model phase I; qualitative risk assessment

In case a decision is taken to continue with a project and to start preparing a proposal a gate is passed and can be started with the second phase. A checkbox will be filled out to identify if an ITB has been rejected or accepted. In case it has been accepted and thus decided to prepare a proposal a checkbox needs to be filled out to verify if a proposal execution plan has been prepared. This should work as a pre-condition before the quantitative risk assessment process may start. Risks which have been identified during the qualitative risk assessment and which need to be transferred to the quantitative risk assessment shall be identified.

Phase II

The quantitative risk assessment consists of the identification, ranking, correlation and response planning, as indicated in figure 12.

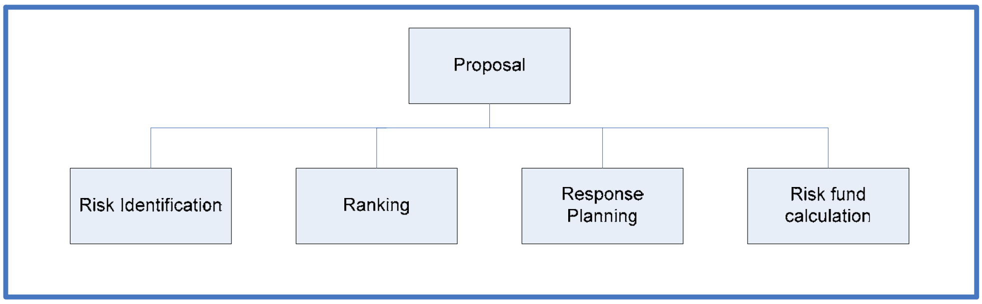


Figure 12: Conceptual model phase II; quantitative risk assessment

It starts with the identification of the first level categories which are to be identified by means of the standard categories, e.g. technical, external, contractual, H.S.E., commercial/financial and organizational. The risk event must be described including its cause and consequences. In case a comprehensive list has been identified the risks shall be subject to a filter (ranking the risks). This will be done by means of identifying the probability and impact (P x I). The high and medium risks which are filtered by this will be further analyzed. The risks which are selected shall be incorporated in the correlation matrix. The correlated risks will be identified which is necessary for the risk calculations as some risks can not be seen in isolation. The response planning shall consist of the initial strategy being; Accept, Avoid, Mitigate or Transfer. The action which needs to be taken will be indicated including the owner of that action. To keep track of the action completion the date and status will need to be filled out including the status of the risk itself.

Phase III

The risk fund calculation is the last part of the quantitative risk assessment. It shall be indicated if a risk needs to be incorporated in the risk fund, which depends on the response strategy. In case risks have to be incorporated into the risk fund it shall be indicated if the risk is continuous or discrete. In case a risk is continuous the minimum, most likely and maximum value of the probability and impact must be provided. In case of a discrete risk a value shall be provided for the probability and impact. After simulating the risk model the probabilities and impacts can be plotted in an S-curve, refer to figure 13, which will be the result of the model.

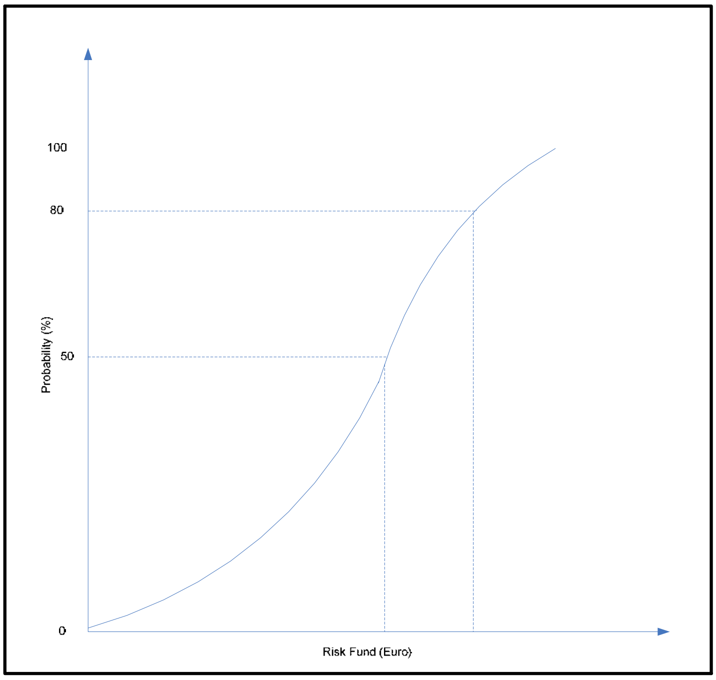


Figure 13: phase III; risk fund

On the basis of the S-curve the decision can be taken and substantiated about the amount of risk fund which should be included into the contract price (and against which probability).

5.5. Justify

The conceptual risk model has been designed on the basis of the workflow. It includes the qualitative and quantitative risk assessment including the risk fund calculations. For both assessments standard categories are provided and structured steps for a complete analysis. In case of the qualitative risk assessment the categories to define if a proposal fits the CLN organizations strategy. In case of the quantitative risk assessment the categories have been defined in terms of technical, external contractual, HSE, commercial/financial and organizational. For both assessments the structured steps are defined in terms of risk identification, ranking, response planning and risk fund calculation.
For this last part, the calculations it has been decided to make use of Monte Carlo simulation. The model will be designed as such that the user defines minimum, most likely and maximum values of probability and impact of a certain continues risk (triangle distribution). This distribution has been selected on the basis that minimum information is available at the time a proposal is being prepared. In case data is available the triangle distribution remains appropriate. Discrete risks shall be defined in terms of the expected value including the likelihood of that risk to happen.

Monte Carlo simulation furthermore, provides a number of advantages, which are:

- Probabilistic Results. Results show not only what could happen, but how likely each outcome is.
- Graphical Results. Because of the data a Monte Carlo simulation generates, it's easy to create graphs of different outcomes and their

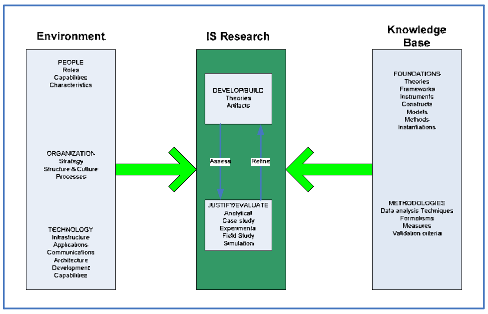
chances of occurrence. This is important for communicating findings to other stakeholders.

- Correlation of Inputs. In Monte Carlo simulation, it's possible to model interdependent relationships between input variables.

The model will be designed on the basis of the conceptual model, in Excel. This will be loaded into @risk to be able to simulate (Monte Carlo) the model and as such to calculate the probability and impact of the selected risks. Both programs have been selected due to the fact that excel is a widely used system which can easily be programmed. @risk is an Excel add program which provides the required buttons for the simulation.

Model requirements have been analyzed and a selection made. This provides the answer to sub-sub question 3a "which model requirements should be incorporated in the information system" The second sub-sub question 3b "how to make the information system operational" has been described by assigning responsibilities within the CLN organization for risk assessments on proposals. By means of the designed conceptual model on the basis of the requirements identified sub question 3 "what does an information system, to support the risk assessment of EPC projects in the proposal stage look like" is partially answered. To be able to fully respond to this sub question the model needs to be build and validated.

6. BUILD



The information system will be developed on the basis of the conceptual design. This means that the model will represent the process of the risk assessment and the incorporation of the design- and functional-requirements. Furthermore, the model will be separated into the following elements:

- Qualitative risk assessment (go/no go decision) including the standard risk categories.

- Quantitative risk assessment including the standard risk categories level 1;
  - Identification: description, cause and consequence
  - Ranking by means of a probability x impact
  - Correlation by means of a correlation matrix
  - Response planning; mitigation strategy, action and owner

- Risk fund calculation (last part of the quantitative assessment)

The model is supposed to be flexible to incorporate unique risk elements for the project and / or capture lessons learned. It is for this reason that it has been decided to prepare the model in excel. In excel it is possible to lock certain fields and allow for adjustments in others (text and value columns). This would be beneficial to have standard calculation columns which can be locked and fields available for adjustments. In case fields are not completed a message can be built in stating that a certain field needs to be completed before the model can be simulated. In this way faults can be intercepted during completion of the model. Furthermore, excel is a widely used program, easy to use and to "program". To calculate the probabilities and impacts (simulation) the excel add-on program @risk has been selected. This program has been selected because @risk adds new functions to Excel for defining probability distributions, simulation and analyzing output results.

6.1. Model Design

The model as developed is captured in attachment 8 and is separated into two worksheets. The first worksheet is the qualitative risk assessment, the second worksheet the quantitative risk assessment.

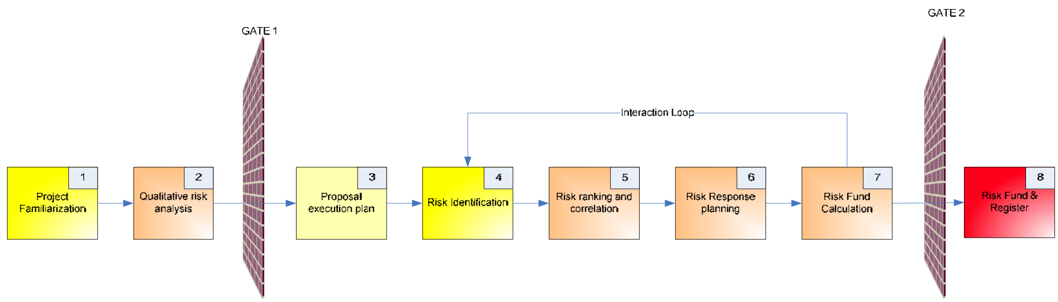


Figure 14: Workflow Risk Assessment

The model will be explained by means of the workflow of the risk assessment as presented in figure 14. The different steps will be explained in terms of people involved, which tools and techniques are available and if sub-steps are necessary.

Step 1; presents the familiarization with the project which is done by reviewing the ITB. It must be understood what kind of facility is required, which feedstock will be used, contract form, location, etc. This exercise needs to be done by the proposal manager and business development manager in detail. The decision makers do need to know on high level what is required. The terms and conditions (T&C's) need to be reviewed by the Legal representative.

Step2; is the qualitative risk assessment which is the first step in the decision making process. To perform this assessment a tool has been designed and is captured in attachment 8, the first worksheet. This assessment is performed, by the decision makers and legal representative on the basis of the standard categories as indicated in the worksheet. Additional elements can off course be included as required. A first pass analysis can be performed with respect to causes, consequences, probabilities and impact. It shall be indicated in the last column if a risk should be transferred to the second worksheet which comprehends the quantitative risk assessment. The last step is to indicate if a decision is taken to continue or reject the proposal. This means that gate 1 has been passed.

Step 3; in case the proposal is accepted by the management of CLN it shall be indicated if a PEP is prepared. The proposal manager is responsible to prepare a PEP which should be a pre-condition to start with the quantitative risk assessment.

Step 4; is the risk identification during the quantitative risk assessment and is captured in worksheet two (attachment 8). A risk identification number needs to be indicated per risk element. The risk identification process has been separated into four elements which need to be completed and consist of:

- Risk Category, level 1
- Risk description, level 2
- Risk Cause
- Risk Consequences

The identification of risks shall be executed by the proposal manager, business development manager and legal representative. However, it should be decided by the proposal manager on a case to case basis if input from engineering disciplines is required.

Step 5; the identification of the risks should be captured and followed by ranking the risks and should be executed by the proposal manager, business development manager and legal representative. The ranking consist of two fields which need to be completed. The first is the probability which needs to be estimated on a scale from 1 to 5 in where, 1 is very low (VL) and 5 is very high (VH). The same scale applies for the expected impact. The probability x impact will provide a value. In the PEP it shall be indicated from which level P x I will be selected for further analysis, for example all risks > 15.

Some risks can not be seen in isolation. Therefore, it is important for accuracy reasons to represent how in reality and when one risk element goes up or down and how the correlated risk element will go up or down accordingly. To capture the correlation between risks a correlation matrix will be applied, refer to attachment 9. The correlation matrix will be incorporated into the Excel risk model.

Step 6; the response planning for the risks assessed shall be identified by: the proposal manager, business development manager and legal representative. The initial response, actions, owner, action due date, action status and risk status shall be filled in. The response planning indicated relates to the initial response strategies: avoid, transfer, mitigate or accept.

Step 7; In case risks need to be included in the risk fund this shall be indicated under the columns risk fund inclusion by the proposal manager, business development manager and legal representative. Within EPC project activities there are risks which can be defined as they occur or they will not occur (discrete), for example bankruptcy of a Seller. In case risks are discrete this shall be indicated in the reserved column (continuous yes/no). When a risk has been identified as discrete an estimate needs to be made about the expected value of the impact and probability. In case a risk is identified as continue the impact and probability need to be estimated by means of determining the minimum, most likely and maximum value and probability (triangle distribution). This is done because normally there is no data available during the proposal stage about budgets as these are being prepared during this stage. A triangle distribution provides than the best solution (also in case budgets per unit are available).

After completing the model, the quantitative risk analysis and the correlation matrix, the values in the model can be simulated[11]. Monte Carlo (@risk) then calculates results over and over, each time using a different set of random values from the probability functions. Depending upon the number of uncertainties and the ranges specified for them, a Monte Carlo simulation could involve thousands or tens of thousands of recalculations before it is complete. Monte Carlo simulation produces distributions of possible outcome values.

Finally, the results of the calculations will be shown in the applicable columns and presented graphically in an S-curve (cumulative), providing the probability and impact. This will be the graph used by the decision makers to decide which probability, for a particular project, they want to accept and the corresponding risk fund value and therewith, will substantiate their decisions.

The interaction loop is defined to provide feedback about changes in the identified risks and / or new risks during the proposal stage including risks which might have arisen during the final contract agreement and negotiations.

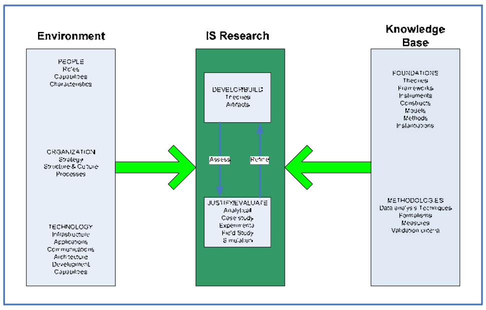
Step 8; represents a gate which is passed and the agreed upon risk fund (by the decision makers) based upon the accepted risk register for the proposal. This risk fund shall be incorporated into the contract price.

[11] Within Excel the model has been programmed and taken into account if risks are continuous or discrete. In case of continuous risks the correlation between risks is incorporated in the calculations which will be used during the simulation.

6.2. Conclusion

The model has been designed according the design and functional requirements as analyzed during the knowledge and environment base. The qualitative risk assessment including the standard risk categories have been incorporated into the model. The quantitative risk assessment as incorporated into the model consists of: risk identification, ranking, correlation and the response planning. An interaction loop is foreseen and must be taken into account during the assessments, e.g. in case risks change during the proposal stage and during negotiations this shall be changed in the risk model. The last step is the risk fund calculation by means of a standardized calculation method, e.g. continuous risks (triangle distribution) and discrete risks. The model has been programmed in Excel in close corporation of the CLN risk expert and will be simulated (Monte Carlo) by means of the add-on program @risk. This provides the answer to sub-question 3: "what does an information system, to support the risk assessment of EPC projects in the proposal stage, look like?" However, the risk model shall be verified and validated which is captured in chapter 7.

7. EVALUATE



After the designing phase the model will be verified and validated. The verification of the model is done to check the consistency. The validation is done to check the suitability of the model. It must be checked if no mistakes are made within the model itself and if the design requirements are incorporated. To verify the risk model the direct structure test has been selected. To validate the model a proposal will be selected on which the risk model will be applied. This will be done by performing a risk assessment session to investigate all relevant risks. These risks will be incorporated in the model for further analysis. A group of experts, which are involved in the proposal, will be requested to complete the model. This means that the experts will rank the risks and provide the estimated probabilities and impact. As explained before, it is important to understand that experts can wrongly indicate these values or leave out certain important aspects in their estimation (fuzzy logic). To support the judgment of experts[12], as described by Yin, 1982c multiple experts' judgment can be viewed as increasing the sample size and therewith making it acceptable to make judgments on the outcome. Furthermore, it is difficult to use actual data as not all risks are taken into account or not assessed in the same way on different proposals.

After completing the risk model the group of experts will be requested to complete a questionnaire about the model. This questionnaire will be prepared, on the basis of the Delphi methodology (Linstone and Murray, 2002). This is done to explore the reliability, quality of the model and which elements need further investigation before the model can be implemented in the CLN organization.

7.1. Verification

The model will be verified on its consistency and structure before the validation process will start. To provide structure in this verification process the direct structure test (Van Daalen and W. Thissen, 2001) has been selected. This test consists of the following:

- Structure and parameter check; the structure and parameters should be consistent with the knowledge of the system as described.
- Boundary adequacy of the structure; verification of the delineation of the model. It must determine if all relevant concepts are considered and taken into account in the model.
- Empirical structure confirmation; the test is required to compare the information of the system with the structure of the model.
- Empirical parameter confirmation; the test is required to compare the parameters with the knowledge of reality (part of validation).
- Face validation; persons which have knowledge of the system will judge the structure of the model related to the structure of the real system (part of validation).

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12 Expert judgment can be defined as the degree of belief, based on knowledge and experience that an expert makes in responding to certain questions about a subject (Clemen & Winkler, 1999).

7.1.1. Structure and Parameter Check

The model has been designed in accordance with the process found during the case studies and interviews held. The risk assessment process has been captured in terms of a qualitative risk assessment which relates to the selection of proposals. The quantitative risk assessment follows the qualitative assessment in case a decision is made to continue with the project and to prepare a proposal. The parameters for the qualitative risk assessment have been selected during the case studies and its interviews held. These parameters have been verified with the experts and were found comprehensive. The parameters for the quantitative risk assessment, e.g. identification, ranking, response planning and risk fund calculation have been selected after the analysis of the seven step risk assessment approach confronted against the case studies and CLN procedure. It can therefore, be concluded that the structure including the parameters of the model are inline with the real system and the approach defined. Table 10 summarizes the model requirements including its verification.

Item	Model Requirement	Verification
1	The basis of design is the work process as captured in figure 8.	The gate model has been incorporated in the design, check boxes provided and the identified steps modeled.
2	The model should allow for unique project requirements and lessons learned (thus flexibility).	The model is designed in excel providing the necessary flexibility.
3	The model should be transparent and faults intercepted during completion of the risk model.	In excel certain fields can be locked which prevents faults of completing the model; this can also be achieved by means of pop-up boxes requesting certain information. The model as prepared is transparent due to the structure of the model.
4	A proposal execution plan shall be provided for every project indicating the risk assessment process and its criteria.	A check box is included in the model (qualitative analysis) and should function as a pre-condition before the quantitative assessment may start.
5	Categories for the qualitative and quantitative risk assessment shall be provided in the model.	For both standard categories were analyzed and incorporated into the qualitative and quantitative risk assessment.
6	A standard calculation method shall be provided.	Risks are separated into continuous and discrete risks. In case of continuous risks the probability and impact shall be provided by means of a triangle distribution. In case of discrete risks a value for the probability and impact shall be provided. The simulation is done by means of the Excel add-on program @risk.
7	The model shall consist of: risk identification, ranking, correlation, risk response and the calculations necessary to determine the risk fund.	These steps are taken into account in both the qualitative and quantitative risk assessment.

Table 10: Verification of incorporated model requirements.

7.1.2. Boundary Adequacy of the Structure

The delineation of the Thesis work and the model design are presented in paragraph 2.3. The model was confronted with this delineation. It was noted that the following is missing in the delineation. As defined before uncertainties are captured practically in the contingency. It was therefore decided to only capture risk elements into the risk register which can be defined in terms of P x I. In case of unknown risks it shall be decided on a case to case basis to incorporate a certain provision for these types of risks. The delineation has been adjusted accordingly.

7.1.3. Empirical Structure Confirmation

The model has been verified against the current risk registers. As no complete risk model was available within the organization, this was the only information which could be used. The structure of the risk register did not showed the qualitative risk assessment. The quantitative risk assessment was however, captured in the risk registers. The focus was more on contractual elements rather than compromising the full scope of risks relevant to the proposal. It must be noted that the risk model as designed comprehends more details than available. The conclusion is that the model describes the real process in far more detail.

7.1.4. Empirical Parameter Confirmation

The empirical parameter confirmation test is done to compare parameters with knowledge from the real system and the model. This test is done on a conceptual basis. This means that parameters should be in-line with elements out of the real system. During the validation of the model this will be analyzed.

7.1.5. Face Validation

Persons which have knowledge of the system and are familiar with risk assessment within the CLN organization will be requested to validate the model. During this validation process the persons were requested to judge if the structure of the model represents the structure of the real system. The structure of the model should be in-line with the real system to gather enough confidence in the model, necessary to properly implement the model into the CLN organization. The validation process is further described in the paragraph below.

7.2. Validation

The model has been validated by applying the model for a life project. To understand the project and its objectives a brief description will be provided about the project and its scope of work. To complete the model a risk review meeting will be scheduled which will be facilitated by the Total Quality Management (TQM) expert. The outcomes of the risk review meeting will be implemented in the model and further analyzed by the CLN Proposal Manager, Risk Expert and TQM expert. Finally, a questionnaire will be prepared and submitted to the experts that completed the model to verify the quality of the model, if the results of the model can be trusted and elements which need to be further developed before the model can be implemented into the organization.

7.2.1. Brief Description of the Project

In June 2008 CLN was awarded on an early work agreement for the detailed engineering of a natural gas buffer plant in Europe; refer to the attached 3D-model in attachment 10. The early work agreement was based on a reimbursable basis. The project consists of two parts being: the Gas Technical Installation and the Cavern Pads. Caverns are holes created in the salt layer in the earth at a depth between 1000 and 1500 meters. The caverns will have a cross cut of approximately 50 to 60 meters. The geometric volume will be around 500.000 cubic meters. The caverns will be filled with natural gas. Due to the stones in the earth layer (above the caverns) the gas can not escape the caverns in any way and makes this a safe storage place.
After some months working on this early work agreement the client requested CLN to convert the outstanding works into a Lump Sum agreement. For this reason it has been decided by the project management team to perform a risk assessment. The following paragraphs describe the outcome of the meeting including the results of the questions asked to the experts by means of a questionnaire.

7.2.2. Risk Assessment

<u>Qualitative</u>

The project already started on the basis of an early work program. The qualitative risk assessment was therefore already executed. This qualitative assessment was never described and it was not known to which extend the assessment was held. It was decided due to the fact that the decision was already made to continue with the proposal and project not to complete the qualitative risk assessment. The focus of the validation was therefore, on the quantitative risk assessment only. It must be noted that the qualitative risk assessment and its categories were subject to expert review and found complete.

A Proposal Execution Plan was prepared in the sense of a description of the requirements of the risk assessment and a date for the risk assessment meeting. For the meeting people from different disciplines were invited from CLN as well from the Client. The results are described below.

<u>Quantitative</u>

The risk assessment meeting was performed with the project management team of CLN and the Client including the lead engineers of the different disciplines; refer to the attached list of participants (attachment 11). The starting point of the meeting was an explanation of the risk review objective, to list all relevant risks (input for the risk register). It was requested to identify SMART (Specific Measurable Aligned Realistic Timely) objectives. However, no SMART objectives were presented nor requested by the facilitator. The process of the risk assessment was explained which started to define objectives for the different disciplines derived from the overall project objectives. Afterwards risks where assessed by all disciplines (note that four tables were created with two or three disciplines present per table). The risks assessed were listed on a white board and presented. A level in terms of high, medium or low was indicated per risk element (but not completed for all risks identified).

Model Input

The risks as presented during the risk assessment meeting are incorporated in the model, refer to attachment 12. The PM, Risk expert and TQM expert have been requested to complete the model further, which meant:

1. Categorize the risks;
2. Indicate the Cause and Consequences of the risks;
3. Identify the probability and impact in terms of Very High to Very Low;
4. Provide the risk response for the selected high risks;
5. Identify if the risks should be incorporated in the risk fund and if the risk is continue.
6. Identify the correlation between risks;
7. Estimate the minimum, most likely and maximum value of the impact and probability for the continuous risks;
8. Estimate the value of the impact and probability of discrete risks.

During the completion of the risk model by the experts within CLN the following was commented on:

..The impact can be determined when you have some inside knowledge of the risk element and cost structure of the project. The estimation of the probability however, is somewhat more different. I would suggest to couple the minimum, most likely and maximum probability directly to a value of respectively, 0- 10%, 10-15%, and 15-22% (in line with the values given in the CLN procedure).....

This would assume the same probability for every risk which is not realistic. Risks can have higher probabilities than the 22% indicated. It is also not necessary to constrain this into these values as the system in @risk will run the model approx. 10.000 times and will calculate an average value for the probability (and impact).

During the completion of the model it was noted that the correlation between risks is relevant because certain risks cannot be seen in isolation. For example the risk of a delay in piping may result in a risk of not meeting the overall project schedule due to the fact that piping is per definition on the critical path. It means that these two risks are correlated and thus needs to be coupled in the model. A rule of thumb exist within the industry that in case you do not know the value of the correlation between risks take 0.7. Note that this value has not been analyzed or investigated further, if it is correct.

..To define the minimum, most likely and maximum impact of a risk it is necessary to know and understand the budget of the different disciplines. In this case when a risk is related to a discipline it is easier to define the values for the risk. Herewith it is more substantiated rather than estimating a value….

As mentioned before normally the budgets are not available during the proposal stage. However, in this particular case the budgets were available and therefore, could be provided for estimating purposes. This means that the estimated man hours, estimated Purchase Order values, and Construction estimate for the works were made available. Afterwards the expert completed the model.

During this assessment it has been decided to continue with those risks elements > 15 (refer to the ranking in the model). This was based on the fact to select only the high risk elements. This of course may differ per proposal and should be decided upon during the assessment and indicated in the proposal execution plan.

The simulation of the model resulted and has been plotted into an S-curve as presented in attachment 13. Note that the values indicated during the risk assessment for the project are rough estimates. However, the risk assessment simulation resulted in a risk fund of 2.5% of the contract value at a probability of 80% (standard percentage within CLN). This is inline with the 2-4% as used during the proposals of the case study. This might be a coincidence and should be analyzed by comparing multiple proposals where this risk model has been applied. Note that the S-curve as shown is not a perfect curve which can be explained due to the discrete risks in the model. In approximately 1 out 5 times a value for the discrete risks are taken into account which is incorporated in the S-curve. The simulated risks are reflected in the risk model (attachment 12) which is static. Therefore, most of the discrete values are not shown.

7.3. Expert Panel

Experts completed the risk model on an individual basis. To explore the reliability of the risk model and its underlying risk assessment process the experts were requested to complete a questionnaire, refer to attachment 14. The Delphi method has been selected as a reference and to structure this process of questioning. It provides a systematic approach to collect and distilling knowledge from these experts about the subject. The result of the Delphi method should be to create consensus of the experts about the risk model and its risk assessment process and all their comments. The goal of this questionnaire is therefore, to:

1. Clarify the quality, feasibility and transparency of the risk model.
2. Can the results of the model be trusted and substantiate the decision making process.
3. Implementation requirements
4. Define which elements need to be further explored or analyzed before the model can be implemented (or during/after implementation).

The process consisted of two rounds. The first round represented the completion of the questionnaire to which all experts responded to. After compiling all answers, the compilation was submitted to the experts for their last comments. The outcomes of this process including results are presented in the following paragraphs.

7.3.1. Quality of the Model

On average the experts agreed that the results and effectiveness of the model are reliable. Especially, the inclusion of the differences between causes and consequences was indicated as a strong point of the model. The calculations as incorporated in the model were found less transparent and should have a proper explanation in for example a procedure in where the model will be explained. According the experts the model represents the full scope of risk assessment, during the proposal stage, within the CLN organization.

7.3.2. Results of the Model

The experts rated the outcomes of the model to substantiate the decision making process as high. It furthermore forces people to apply a structured approach to assess risks during the proposal stage. The calculations of the model need to be explained in more detail and should form part of a training session. Furthermore, the calculations should be validated properly.

7.3.3. Implementation Requirements

The ease of implementation within the CLN organization was rated high. Off course guidelines how to use the model and proper definitions of responsibilities is essential before the model is implemented. It should be formalized in the Company Management System on all levels, which means management and departments.

7.3.4. Further Requirements

The experts presented certain aspects in the questionnaire which need further analysis before the model can be implemented in the CLN organization. This resulted in the following subjects:

- How to implement secondary risks into the model;
  An initial risk strategy will be indicated in the model. However, this strategy shall be verified if the strategy itself has no risk or higher risk compared to the initial risk element ("is het middel niet erger dan de kwaal?"). Note that within the theory several solutions are provided of how to deal with secondary risks. However, theories how to cope with secondary risks are available but do not form part of this research.

- Review of risk fund, contingency, profit;
  In case a risk which has been included in the risk fund does not occur the provisions for this risk are coming available. The question arises if this provision should be directed to the base line profit (in case not used to cover other risks) or should it first be directed to the contingency or remains in the risk fund itself.

- How to incorporate the review of the risk fund related to the budget of the project;
  Risks should be evaluated if the provisions should be taken into account in the risk fund or if the provisions should be bared in the budget. Furthermore, the overall risk fund should be verified against bidding strategies, e.g. are we in competition, etc. and project budget (which is a management decision).

- Relevance of a risk data base;
  CLN is executing approximately 3 major EPC projects in 2 -3 years. This may not provide enough data points to set-up and maintain a risk data base. It might be better to incorporate risks (as indicated) in the CLN management system.

- Update procedures;
  The model and its functionality should be incorporated in CLN's procedures. This to be sure the model will be used consistently over the different proposals. Responsibilities should be defined in terms of people that will complete the risk model and the users

(decision makers). The procedures need to be explained together with the functionality of the risk model in training sessions.

➢ Incorporate a tool which would increase the focus on the decision making process; The tool could be for example a decision tree. This would be beneficial to analyze several risks simultaneously.

➢ Verify and validate the calculations and perform a sensitivity analysis.
The calculations need to be verified and validated, by an independent third party, to be sure that the outcomes are realistic and can be trusted for the decision makers. A sensitivity analysis should be part of the validation process.

7.4. Follow-up

Sometimes projects are cost driven or schedule driven which is defined by the Client. This can have an effect or an influence on the risks, their acceptance or response planning. If a project is cost driven or schedule driven must be made clear before the qualitative and quantitative risk assessment starts. It should be captured in the proposal execution plan and explained to all people involved. It could be that other elements are relevant to this subject and therefore, follow up on this item is required.

This Thesis work is structured around lump sum or reimbursable EPC projects which in nature are complex engineering projects. However, in case of relative small projects it is not feasible, also due to time constraints, to prepare a full assessment as explained in this report. For that reason it is recommended to prepare a so called light version of the risk model designed. This light version of the model should be developed as such that a quick scan of high level risks is possible. The down side of such system is that the creation of standard risk elements will have the affect that only those risks will be identified which could lead to missed items. Follow up on this subject is necessary.

7.5. Conclusion

To answer sub-sub question 3c: "is the information system valid?" the risk model has been verified and validated. After the verification it can be concluded that the model requirements as defined were incorporated in the model. The delineation has been adjusted with respect to uncertainties, only those elements which can be defined in terms of P x I will be taken into account in the risk model. With respect to unknown risks this shall be captured in the CLN procedure and decided upon on a case to case basis.

The validation of the information system was achieved by applying the risk model on a real life project and an expert panel was consulted to review and complete the model. The outcome of the application of the information system on the proposal was that a lot of risks were duplicated due to different teams working on the same subject. These were filtered and the model adjusted accordingly. The standard categories (level 1) helped to delete duplicated risks. The risk fund was calculated and represented in an S-curve. This curve was not perfect due to the discrete risks incorporated. It must be noted that the risk fund value was 2.5% (P80) of the contract value. This figure is inline with the values applied as indicated during the case study analysis. The value of 2-4% should be analyzed by means of several completed assessments.

Critical comments have been provided by the experts and discussed by means of the completion of the model and by completing a questionnaire. These comments have been taken into account and incorporated. Elements which need further investigation before the model can be implemented have been identified.

The overall conclusion about the outcome of the expert panel analysis is that the risk model provides a structured approach to perform the risk assessment during the proposal stage. It furthermore, provides proper substantiation of decisions which needs to be made during the finalization of the proposal.

Demonstrated by the outcomes is that the model satisfies the specified verification and validation criteria. Only the calculations itself need to be verified and validated by independent experts before implementing the risk model into the CLN organization.

As a last remark follow-up actions were identified with respect to the creation of a light version of the model, which is necessary for relatively small proposals for which no extensive risk assessment will take place. Also the criteria if a proposal is schedule or cost driven should be clearly identified. How this affects the decision making process related to risks should be further investigated but does not form part of this research.

Herewith, sub questions 1 through 3 have been answered and resulted in a valid information system which is based upon a substantiated research. The response to the remaining sub questions 4 and 5 are captured in the overall conclusions in chapter 8.

8. OVERALL CONCLUSIONS AND RECOMMENDATIONS

8.1. Overall Conclusions

This Thesis research has described the building process of an information system that facilities the risk assessments approach within the CLN organization. During the research and especially the interviews it became clear that within CLN the risk assessment approach is not consistently used during the proposal stage. To improve this, a research and design of an information system was performed. Because it was the intention to learn from the undefined total process and to be able to design an information system it was decided to make use of the framework of Hevner, to structure the process of information system research. The framework consists of the knowledge base, environment base and information research, which was also used to structure the report.

The knowledge base provided the raw materials from and through which information system research is accomplishes and was separated into foundations and methodology. To respond to sub question 1 "which relevant theoretical factors defines the foundation and methodology of the research and defines the applicable knowledge", the following foundations were defined:

- Project life cycle, defined in terms of proposal phase, EPC execution phase, the warranty period and ends with the close out of the project. This to define the phases in which risks occur for an EPC Contractor (technical).
- Contracting structures, defined by means of the common used contracts, which are reimbursable and lump sum. In case of a lump sum contract the EPC contractor will take the highest risk, in case of reimbursable the highest risk will be taken by the client. Although these contracts are binding still there are boundaries in both contract forms, for example gross negligence for which at all times a contractor can be held liable (contractual).
- Project cost break down, is separated into base project cost, contingency, risk money (fund) and profit. A clear distinction must be made between contingency and risk fund. Contingency presents the uncertainty in estimates taken into account allowances for prices and quantity. The risk fund presents coverage for unusual conditions that could influence the financial outcome of a project (financial).
- Risk and uncertainty definitions, this resulted after analysis of theoretical definitions into the risk definition of: "risks are the known 'unknown' uncertain factors which could have an influence on project objectives" and uncertainty: "are those factors which can not be quantified in terms of probability of occurrence, due to the existence of more than one possibility, during the time an assessment is made". Both definitions were necessary to analyze the subject.

Several risk assessment approaches were analyzed and captured in a seven step approach which defined the methodology. The seven step approach consists of the following steps:

1. Understand the project. The technical, commercial and contractual requirements shall be understood.
2. Plan the process. The process if the risk assessment shall be planned and selection criteria provided.

3. Risk identification. Those risks which could have an influence on project objectives shall be identified.
4. Analysis of risks. The analysis of risks is separated into a qualitative and quantitative risk assessment which follows the risk identification.
5. Response to risks. Provide actions to enhance opportunities and reduce threats to the project objectives.
6. Interaction loop. During the risk assessment of the proposal stage interaction is necessary to identify any changes in risks.
7. Document step 1 through 6. A risk register shall be prepared capturing the steps above and critical data stored in a risk data base.

The applicable knowledge for this research was therewith captured and used throughout the research. The methodology was applied in the environment base to analyze and evaluate the CLN procedures and case studies.

The environment base defined the problem space (Simon, 1996) in which reside the phenomena of interest and was separated into people, organizations and technology. This meant for the research that the organization structure (case studies and interviews) and its procedures were analyzed, which was done by means of the methodology. Table 11 summarizes the most important conclusions for both the case studies and CLN procedures.

Seven step process	**Case studies and Interviews**	**CLN Procedures**
Step 1: Understand the project	Familiarization of the technical, commercial and contractual requirements was done.	Familiarization is not indicated however it is the starting point
Step 2: Plan the process	In case of one proposal a PEP was prepared.	Has not been indicated and should be made part of the procedure.
Step 3: Risk identification	A standard list was used which covered contractual items.	No overall register of the qualitative and quantitative risk assessment is provided.
Step 4: Analysis of risk	Percentages of the contract value were distributed over the standard risk elements.	No identification of the correlation between risks is captured.
Step 5:Response to risk	No identification of responsibilities and due dates shown.	Four basic risk responses are captured being: avoid, transfer, mitigate and accept.
Step 6: Interaction loop	Part of the practical assessment.	This is defined in terms of: "the risk register is reviewed to confirm the relevance of risks identified during the pre-contract phase and to identify any new risks".
Step 7: Document step 1 through 6	The standard risk register were applied and completed.	No overall register of the qualitative and quantitative risk assessment is provided.
Unknown risk and Uncertainty	Missing is the indication of unknown risks and uncertainty. Uncertainty can not be defined in terms of P x I. Within CLN uncertainty is taken into account in the contingency part. For unknown risk it must be decided to incorporate a certain percentage in the risk fund. This shall be captured in the PEP and agreed upon by the General management. Both unknown risks and uncertainty will therefore not be included in the designed information system.	

Table 11: Conclusions Case studies and CLN procedures

During the analysis it became clear that a consistent process for risk assessment is missing. No overall tool is available which captures both the qualitative and quantitative risk analysis. Furthermore, no standardized risk fund calculations are foreseen. This results in inconsistent decision making with respect to acceptance or reject ion of certain risks and the necessary risk fund, which provided the business needs. A structured risk assessment process has been captured by means of a gate model presented in figure 15.

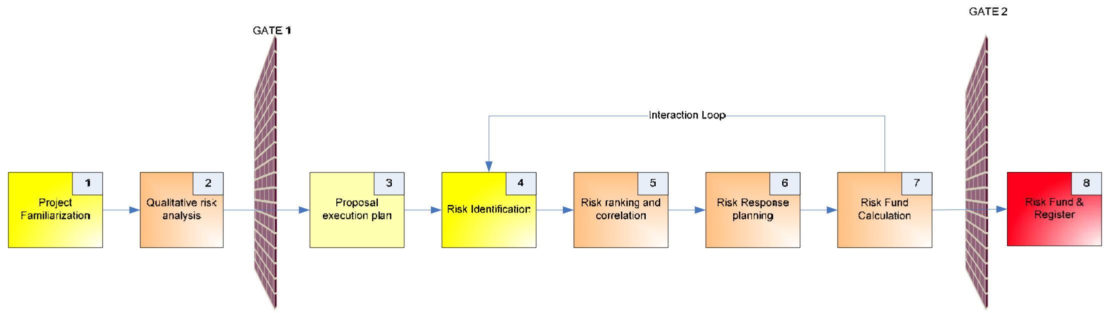

Figure 15: Workflow Risk Assessment

This provided the answer to sub question 2 "how are risks assessed within the CLN organization, during the proposal stage, from a practical and procedural point of view. Furthermore, it has been recommended to incorporate this gate model in the design of the information system, as a basis of design. Furthermore, a standard method to calculate the probability and impact of risks which defines the risk fund was recommended to be developed.

The information system research describes the process of development / justifies and builds / evaluate. Risk categories were defined; model requirements analyzed and design choices made. All were captured in a conceptual model and justified. On the basis of the conceptual model the risk model was designed and sub sequentially evaluated. A proposal was selected and experts asked to complete the model. The completed model was simulated and the results captured in a cumulative S-curve, providing the probability and impact value. An expert panel was requested to answer several questions related to the completion of the model. Herewith it was demonstrated that the process and model are functional and the S-curve including the risk register can be used to substantiate the decision making process, which was the response to sub-question 3.

With this Thesis research it has been demonstrated that to be able to support the risk assessment of EPC projects in the proposal stage to better estimate the risk fund (main research question) a consistent risk model is essential. Proposals are made by different proposal managers and involving different actors. It is then necessary to have a tool which provides guidance of how to assess risk. Also to better estimate the risk fund a proper risk assessment and standard calculations are needed and forms the basis for a substantiated risk fund. It can be concluded that without a standardized risk assessment process the organization will not be able to evaluate the invitations to bid on a similar basis.

8.2. Implications

To answer sub question 4 "what can we learn from risk assessment, the framework of Hevner and the research?" implications for the organization and the use of Hevner are provided.

The implication for the organization is related to the inconsistent use of risk assessments on different proposals which is resulting in acceptance of risks on one proposal and rejection on another. A structural process was missing as identified during the interviews held. As defined in the theory different steps are relevant in this process and should be taken for properly understanding risks. The risk model as designed provides a record of all relevant steps to identify the risks. It starts with the review of the ITB on a qualitative basis which is used to decide to continue with a proposal or reject it. Risks identified during the qualitative risk assessment can be transferred to the quantitative risk assessment for further investigation (in case a decision to continue has been made). The quantitative risk assessment provides a proper basis to identify other risks which are relevant to meet project objectives. After ranking the risks the model will calculate the probability and impact. The probability and impact of the several risks will be plotted into an S-curve. On the basis of the S-curve a substantiated decision can be made by the CLN management which probability and risk fund is acceptable. The implication for the organization is therefore, a structured risk assessment process with a detailed tool, e.g. the risk model, which will provide a consistent risk assessment process once implemented. This will improve the effectiveness and efficiency of the organization related to risk assessment.

The implication of the use of Hevner was a structured process of information system research. It is divided into two paradigms being behavioral science and design science. The behavioral science paradigm informed us of the people and organization and had an impact on the design decisions made, especially the found workflow (gate model). The design science paradigm addresses the research through building and evaluating the artifact. Proper evaluation methods are to be applied. It is up to the researcher to select these evaluation methods for which Hevner provides five types of design evaluation methods, i.e. case studies, functional testing, etc. Both case study analysis and functional testing of the model have been applied. Additional it was decided by the researcher to apply the Collaborative Ethnography Method (CEM) to evaluate the model requirements in a structured manner. This was found necessary to have a proper analysis about the basis of design. Sub question 5 "did the framework of Hevner provide sufficient guidance in this research?" is herewith confirmed.

Stated by Hevner is that in both design science and behavioral science, rigor is derived from the effective use of the knowledge base-theoretical foundations and research methodologies. It can be argued that to derive rigor it is essential to confront the knowledge base and environment base. Also to define the true business needs (problem). Within this research a seven step risk assessment approach (methodology) has been defined during the knowledge base. This methodology was applied during the environment base to analyze the practical approach within CLN and their procedures, which provided the business needs.

As a last remark on the framework of Hevner is the incorporation of lessons learned. Within the CLN organization it is important to incorporate lessons from other proposals and projects and not to make the same mistakes or have the same failures. This process should be captured in the design of an artifact and has not been explicitly incorporated in the theory presented by Hevner. However, overall the framework of Hevner forces you to define a proper theoretical basis and analyze the environment in which the problem is defined. Both provide input in the design phase to develop the artifact. With the addition of the confrontation between the knowledge- and environment-base it was found very useful to structure the process including outlining this report. This provided the answer to sub question 5 “did the framework of Hevner provide sufficient guidance in this research”

8.3. Recommendations

The risk model as designed has the ability to improve the risk assessment during the proposal stage due to the structure of the model representing both the qualitative and quantitative risk assessment. It provides sufficient information to the General Management of CLN to substantiate their decisions about the probability and risk fund allocation of a proposal. It is therefore, recommended to implement this in the CLN organization. However, it must be noted that certain aspects need further investigation before the model can be implemented, which are:

- How to implement secondary risks; during the identification of the risk response planning it could be the case that secondary risks are introduced. It should therefore be verified if these secondary risks are higher risk compared to the initial identified risk element. Note that within the literature secondary risks and how to handle these have been described.
- How to incorporate the review of the risk fund related to the budget; the risk fund selected shall be verified against the total cost of the project which relates to bidding strategies.
- How to update the CLN procedures; the risk model and its functionality (including workflow) shall be captured in the CLN procedures. Responsibilities need to be defined and indicated in the procedures. Afterwards training sessions shall be organized to explain the model.
- Incorporate a tool which focus on the decision making process; to analyze several risk simultaneously it needs to be investigated if for example a decision tree would be beneficial.
- Verify and validate the calculation by an independent third party (expert); to be fully sure that the calculations can be trusted by the CLN management, experts need to validate the calculations.
- Analysis of the risk fund, contingency and profit; in case risks do not occur during the project execution the money included for that risk in the risk fund becomes available. It shall be analyzed if this money should be transferred to the contingency or base line profit.
- Relevance of a risk data base; due to limited projects executed by CLN due to the seizes of the projects it could be the case that to less data points are available to set up a risk data base.

It is recommended to investigate all of these aspects when the model is implemented with the exception of the validation of the calculations by experts.

The model should be used in the long term for supporting the risk monitoring process during project execution. Risks captured in the model should be analyzed with for example ten other proposals to verify if risks are rated simultaneously. This process of monitoring and verification should be executed and outcomes incorporated into the model. However, this can be executed after the risk model has been implemented in the organization.

As the research has been executed for lump sum and reimbursable EPC projects which per definition are large and complex engineering projects. It could be argued that for smaller proposals this risk model as designed is to complex and will take to much time to complete. It is the researcher's opinion that in case of smaller proposals a light version of this system should be designed. The basis would remain the same only high level risks could be indentified. The down side is that standard high level risks will be defined which could result in not overseeing all relevant risks.

A relevant aspect found was that there is sometimes a focus on cost and sometimes on schedule. This might influence the risks and risk response. If a project is cost driven or schedule driven it should be clearly identified in the proposal execution plan. It is recommended that people involved in the risk assessment process should be made aware of the focus which can be achieved by means of presenting the PEP.

Several subjects have been identified under paragraph 2.3 which are a result of the problem exploration using the system diagram to capture the "full" system. These subjects reflect certain problem areas which could be interesting for CLN to investigate to improve the efficiency and effectiveness of the CLN organization. Some of these subjects have been answered by this research, which are:

1. Can a structured artifact be designed to evaluate risks during the proposal stage? A risk model was designed and substantiated by means of this research.
2. How are, lessons learned captured? The subject of lessons learned is captured in this report and a method to make use of an existing management system introduced.

For further investigation the following subjects are relevant:

3. The relation between work load and risk acceptance. Would a higher risk profile be acceptable in case the work load is low and a high impact on the organization is expected?
4. Does the organizational strategy fit the current market situation? Is it necessary to adjust the strategy in the current market situation and should the organization focus on "new" business, e.g. wind energy, etc?
5. Which crucial risk elements can be defined? In case a decision is made to implement the risk model it is desired to create a light model for smaller proposals. High level risk elements should then be defined.
6. How are risks managed throughout the project life cycle, in such away that project objectives are met? In case the project is awarded it is important to understand and may be improve the management of identified risks.

7. Which lessons learned could influence risk acceptance criteria? In case risks occurred on previous projects it could affect the acceptance of certain risks on new proposals.

It is recommend to investigate these subjects as they can contribute to improve the understanding and management of risks. It is however up to the CLN management to decide if a research in these fields should be performed.

8.4. Reflection

My major personal learning objective was to investigate whether an information system could be designed to improve the effectiveness and efficiency of the organization with respect to risk assessment during the proposal stage. The initial problem definition as indicated by the CLN management was used as the starting point for this research. An in depth verification of this problem definition was performed by means of case studies and interviews with actors involved in risk assessments. The information gathered made it possible to design a gate model and represented the required workflow. Sub-sequentially model requirements could be derived from the interviews held and the confrontation between the CLN procedures and a seven step theoretical approach of risk assessment. I have highlighted the model requirements including their constraints. On this basis I designed a conceptual model and the risk model. The research as presented in this report confirms that this information system in general can improve the effectiveness and efficiency by means of a consistent risk assessment approach.

The subject of risk assessment is complex in terms of the amount of ideas and approaches found in the literature. Also to keep focus on the main research question was sometimes not easy. This resulted in a lot of interaction loops during the research and in many text parts which were deleted from this report. This can partially be contributed that the research was conducted part time, which resulted in an un-continued process. This is something that I would do differently the next time. But despite the difficulties faced it was an interesting project which increased my knowledge base in terms of risk assessment, the application of Hevner and the many discussions about the research itself. With high expectations I will be following the decision making process to implement this risk model into the organization. In case a decision is made to implement this I will attempt to contribute as best as I can to make the implementation a success.

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GLOSSERY OF TERMS

BDEP	Basic of Design Process
BOD	Basis Of Design
CB&I	Chicago Bridge and Iron Company N.V.
CIM	Continuous Improvement Measure
CLN	CB&I Lummus Netherlands
EPC	Engineering, Procurement and Construction
FEED	Front End Engineering and Design
HSE	Health, Safety, and Environment
I	Impact
LD	Liquidated Damages
ITB	Invitation To Bid
LS	Lump Sum
LSTK	Lump Sum Turn Key
OBS	Organizational Breakdown Structure
P	Probability
PEP	Proposal Execution Plan
PLC	Project Life Cycle
RAM	Responsibility Assignment Matrix
R and R	Rest and Relaxation
T&C	Terms and Conditions
WBS	Work Breakdown Structure

ATTACHMENTS

1. Plant Magnitude

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2. Risk Sharing Domain

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3. Actor Analysis

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5. List of interviewed people and questionnaire

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6. Objective Tree

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7. Second Causal Relation Diagram

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8. Risk Model

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9. Correlation matrix

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10. 3D-model gas plant

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11. List of participants risk review meeting

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12. Risk model completed (quantitative and correlation matrix)

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13. S-Curve

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14. Questionnaire

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