THE FUNCTIONING OF HEEREMA MARINE CONTRACTORS' PROJECT RISK MANAGEMENT & THE USEFULNESS OF QUANTITATIVE RISK ANALYSIS

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THESIS INFORMATION

MASTER THESIS

Title:	The Functioning of Heerema Marine Contractors' Project Risk Management Method & the Usefulness of Quantitative Risk Analysis
Graduation date:	19th of August, 2011
Version:	Public

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"The word 'risk' derives from the early Italian 'risicare', which means 'to dare.' In this sense, risk is a choice rather than a fate. The actions we dare to take, which depend on how free we are to make choices, are what the story of risk is all about."

Peter L. Bernstein

ACKNOWLEDGEMENTS

In the last six months I have performed my master thesis at Heerema Marine Contractors. This thesis project has been the last step towards the completion of the Master Management of Technology (MoT) at the Delft University of Technology. In those six months, I really have enjoyed the research done.

The thesis wouldn't have been possible with such an interesting case as presented by Heerema Marine Contractors. Therefore, I would like to thank all people that have contributed to the thesis' results. In special I want to thank Carol Granneman, who was my day-to-day supervisor at Heerema Marine Contractors. Carol has provided a lot of insight information of the company and contributed to research strategy. I also would like to thank Peter de Bree, whom has given me the opportunity to start the master thesis at Heerema Marine Contractors in February 2011.

I also would like to thank my graduation committee at the Delft University of Technology. Their guidance has, among others, resulted in a research methodology guiding towards the results and findings of the research. Therefore, I want to thank Herman Mooi and Jos Vrancken for their day-to-day guidance and their valuable input and comments. I also want to thank Alexander Verbraeck who has given valuable input during the official meetings with the graduation committee.

Martijn van Dongen

Leiden, August 2011

MANAGEMENT SUMMARY

THE RESEARCH PROBLEM

Heerema Marine Contractor's (HMC) former Project Risk Management (PRM) method was until recently supported by a specialized risk team. The risk team facilitated the PRM activities, i.e. risk assessment workshops and review moments during the projects. The risk team also performed a quantitative risk analysis on all projects. Such an analysis provides insight into the project risk, i.e. the combined effect of the identified risk events.

The Board of Directors abandoned the risk team after three years of service. The abandonment was associated with two adjustments: (a) the project manager received the full responsibility for all PRM activities and (b) the quantitative risk analysis disappeared. Since then there has been an ongoing discussion about the Board of Directors' decision to abandon the risk team. This raises the research questions *'Which aspects of HMC's current project risk management method show room for improvement?'* and *'What is the usefulness of quantitative risk analysis in HMC's project risk management?'*

THE RESEARCH METHODOLOGY USED

The research that has been conducted is divided into two parts: (a) an extensive literature research and (b) a single-case multiple-source study. The literature research will present the PRM theory with elaborate insight into qualitative and quantitative risk analysis. The case study will provide insight into HMC's PRM procedure ('SOLL') and HMC's PRM practice ('IST'). A comparison between these three elements has been done, as shown in the figure.

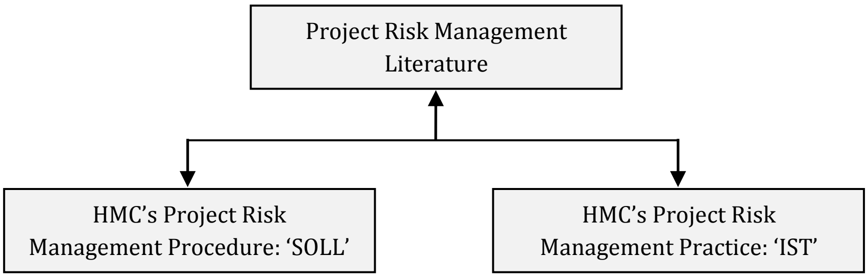

Figure: Research Triangle

Additionally a distinction is made between HMC's former and current PRM method. The entire current PRM procedure and practice are reviewed. HMC's former PRM is reviewed regarding the elements that are different from the current PRM practice, i.e. the risk team's facilitating role and the quantitative risk analysis.

The literature research is done by using scientific knowledge, published journals and books in the field of PRM. For the case study, (a) documentation of HMC has been used, (b) eighteen interviews with project managers and other personnel related to PRM have been performed, (c) three risk assessment workshops have been attended, and (d) ten risk register surveys have been completed, providing insight into HMC's qualitative risk analysis tool as it is currently used in practice.

RESULTS & FINDINGS

HMC's project managers have a positive attitude towards the PRM, i.e. they confirm its importance. Nevertheless, the comparison between HMC's PRM procedure ('SOLL') and practice ('IST') has indicated that the PRM process is not properly executed. This is due to the project manager's high workload besides the PRM activities, and partly to a lack of discipline.

There is also a big difference between HMC's PRM procedure and practice in the method of reporting the project's risk events to the upper management. HMC's PRM procedure requires one to report the ten highest scored risk events in the monthly Progress Status Report (PSR). In practice, the method of reporting is used very differently by individual project managers. It varies from reporting only those risk events in which money is involved, i.e. the ones that have already had a financial impact, to reporting all identified risk events. Because of this, there is no complete and uniform overview of all the projects. However, even if all project managers report the top ten highest scored risk events a complete and uniform overview will still be missing; the project managers' perception may differ so much that a risk event could be in the top ten for one manager and clearly not in the top ten for another, as proven by the risk register survey.

HMC's current qualitative risk analysis tool may lead to confusion, based on the comparison between HMC's PRM procedure and practice with the PRM literature. The likelihood and impact scales in HMC's Risk Evaluation Matrix (REM) are inaccurate, which may result in unrealistic risk assessments. Furthermore, some of the subjectivities and biases associated with qualitative risk analysis tools (Capen, 1976), (Hubbard, 2009), (Simon, 2003) are confirmed to be present based on the risk register survey results, i.e. (a) the problem of perception, (b) overconfidence of people, and (c) the bias of scoring a low likelihood intuitively with a high impact.

The risk register survey also indicates that HMC's project documenting method may cause confusion. The risk events' effect on the project objectives – indicated by (-), (+), or (±) – may be perceived differently among the PRM participants. This confirms that it is important to describe the risk event as precisely as possible to overcome misunderstandings (Isaac, 1995).

The response planning, and a part of the risk assessment workshop in HMC's PRM practice is more in line with the PRM literature than with HMC's PRM procedure. The procedure requires to identify the response strategies during the risk assessment workshop (Bree, 2010), while in HMC's PRM practice this is done after the workshop in consultation with the project manager and the risk owner. This is a confirmation of the PRM literature's approach (Hillson & Simon, 2007). Regarding the response planning, HMC's PRM procedure only presents the strategies that reduce the likelihood and/or impact of a threat and improves the likelihood and/or impact of an opportunity (Bree, 2010). The interview results show that more types of strategies are used in HMC's PRM practice that are similar to the strategies as presented by Hillson & Simon (Hillson & Simon, 2007).

The first difference between HMC's former and current PRM method was the risk team's facilitating role. The facilitating role, which provided substantive guidance and training to the PRM participants, is missed by the majority of the project managers that were interviewed. Furthermore, the risk team had an objective view on all projects, as confirmed in the PRM literature (Keizer, Halman, & Song, 2002), and maintained a uniform PRM method. It is not surprising that several project managers consider HMC's former PRM method, exclusively referring to the facilitating role, better than the current PRM method. This is confirmed by a project manager who is satisfied with the fact that a former risk team member is currently facilitating the PRM activities on his running project.

The second difference between HMC's former PRM method and the current PRM method was the presence of a quantitative risk analysis method. The MC simulation provided insight into the risk events' combined effect, and, by using the MC method interactively, the effect of the response strategies on the project outcome. However, the MC simulations' results were not widely used. This is so because they (a) weren't trusted, (b) were not understood and/or (c) didn't provide more insight into the project's risk events in comparison to the qualitative risk analysis. This attitude towards the MC method isn't outlandish. Galway (Galway, 2004) and Hubbard (Hubbard, 2009) have indicated that, in general, there is a lot of misunderstanding towards the quantitative risk analysis. The project managers that used the MC's estimations used it as an awareness, i.e. to check if it was equal to what was expected. Also, these project managers indicated no real surprises based on the analyses. However, a few project managers would consider using the MC simulation when working on HMC's more complex and difficult projects.

HMC's former MC method's quality was questionable: this is so because (a) there often wasn't a truthful division between threats and opportunities, (b) the correlations between risk events were not taken into account sufficiently, and (c) the method used was not tested based on previous finished projects.

Conclusions & Recommendations

Regarding the first research question it are in the first place the time issues, and partly the lack of discipline that show room for improvement for the PRM method. The risk team in HMC's former PRM method eliminated those concerns. Therefore, it is recommended to appoint a risk champion on *short term*. This will improve HMC's PRM method since the risk champion will (a) facilitate the PRM activities, (b) have an objective view on all projects, (c) provide substantive guidance, (d) train the PRM participants, and (e) develop a higher quality PRM practice over time.

Secondly, the risk analysis that is done in the PSR is a powerful tool that could be used more efficiently. When the reporting is done more consistently a complete and uniform overview of all projects will be provided. Therefore, another *short term* recommendation is to take in account all important risk events in the newly introduced semi-quantitative risk analysis. All risk events are reported with a single valued probability of occurrence and a singled valued financial impact, which results in a single valued project risk estimation. This makes the semi-quantitative risk analysis more detailed than a qualitative method and less detailed than a quantitative method.

Thirdly, other methods, tools and techniques in HMC's PRM procedure show room for improvement as well, which results in several *short term* recommendations. This, among other things, includes (a) an improved qualitative risk analysis tool that eliminates the confusion, (b) the metalanguage as presented in the PRM literature to overcome confusion in the risk events' descriptions (Hillson & Simon, 2007), (c) a slightly different format for the risk assessment workshop, and (d) a supplement of response strategies to complete the response planning format (Hillson & Simon, 2007).

Concerning the second research question, it can be concluded that a quantitative risk analysis tool isn't useful for HMC's PRM method at this moment. This mainly because of the misunderstandings regarding the MC method, but also because of the fact that (a) the MC method didn't provide additional information, and (b) the improvement that is possible concerning the semi-quantitative risk analysis. However, the fact that (a) several project managers would consider a quantitative risk analysis when working on a more complex, difficult and/or new project, and (b) HMC's core business is turning towards those more complex projects, induces the recommendation to consider a quantitative risk analysis method for HMC's PRM on the *long term*. This provides more insight into the combined effect of the project's risk events in benefit of the response planning. Before re-introducing the MC method, HMC should deal with two difficulties: (a) the misunderstandings about the method, and (b) ensuring a higher quality method than the method that was used in the past.

ABBREVIATIONS

APM	Association for Project Management
ATOM	Active Threat and Opportunity Management
CoG	Centre of Gravity
CSF	Critical Success Factor
EPIC	Engineering, Procurement, Installation and Commissioning
EPRD	Engineering, Procurement, Removal and Demolition
HAZID	Hazard Identification and Assessment
HAZOP	Hazardous Operability study
HMC	Heerema Marine Contractors
HSE	Health Safety and Environment
MC	Monte Carlo
P-I	Probability and Impact
PMBoK	Project Management Body of Knowledge (PMI)
PMI	Project Management Institute
PVOR	Possible Variation Order Request
PRAM	Project Risk Analysis and Management (APM)
PRM	Project Risk Management
PSR	Progress Status Report
QESH	Quality, Environment, Safety and Health
RBS	Risk Breakdown Structure
REM	Risk Evaluation Matrix
S&BD	Sales & Business Development
SSCV	Semi-Submersible Crane Vessel
T&I	Transport & Installation
VMT	Vessel Management Team
VOR	Variation Order Request
WBS	Work Breakdown Structure
QESH	Quality, Safety, Environment and Health

LIST OF IMPORTANT DEFINITIONS

Exposure	According to HMC a risk event is an *exposure* when it *negatively* effects the project objectives (Bree, 2010).
Opportunity	According to HMC and to the literature a risk event is an *opportunity* when it *positively* effects the project objectives (APM, 2004), (Bree, 2010), (Hillson & Simon, 2007).
Project Risk	The accumulation of all identified risk events and additional sources of uncertainty which has impact on the entire project (APM, 2004).
Project Risk Management (PRM)	PRM is the controlled process of understanding and managing risk events and the accumulated project risk. This is done by identifying, analyzing, planning, mitigating, monitoring and controlling the risk events. Properly executed PRM will increase the likelihood that the project meets its objectives with respect to time, cost, quality and scope (APM, 2004), (Cooper & Chapman, 1987), (Hillson & Simon, 2007), (Hubbard, 2009), (Norris, Perry, & Simon, 2000), (PMI, 2008).
Qualitative Risk Analysis	Prioritizing the identified risk events based on the probability of occurrence and magnitude of impact indicated by the use of *ordinal scales* (Hillson & Simon, 2007).
Quantitative Risk Analysis	An estimation of the project risk, i.e. the combined effect of the risk events, based on the identified risk events' probability of occurrence and magnitude of impact done by a (*computerized*) normalized simulation of the risk events' *ranges and distributions* (Hillson & Simon, 2007).
Response Strategy	A strategy to determine what should be done with an identified risk event, this leading to specific actions (Hillson & Simon, 2007).
Risk Champion	A PRM specialist who guides the people involved in the PRM through the entire PRM process (AIRMIC, ALARM, IRM, 2002), (Hillson & Simon, 2007).
Risk Event	An uncertain event or set of circumstances that, should it occur, will have an effect on achievement of one or more project objectives both as threat and as opportunity (APM, 2004).
Risk Owner	Appointed by the project manager, if applicable in consultation with the risk champion, as the person best managing the identified risk event (Hillson & Simon, 2007).
Risk Team	A team existing of several risk champions. HMC's former PRM method made use of a risk team. The team facilitated the PRM activities and performed quantitative risk analysis.
Semi-Quantitative Risk Analysis	An estimation of the project risk, i.e. the combined effect of the risk events, for HMC's projects based on the identified risk events' probability of occurrence and magnitude of impact done by a calculation of the risk events' *single-values*.
Threat	According to the literature a risk event is a *threat* when it *negatively* effects the project objectives (APM, 2004), (Hillson & Simon, 2007).

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CHAPTER 1: INTRODUCTION

1.1. HEEREMA MARINE CONTRACTORS

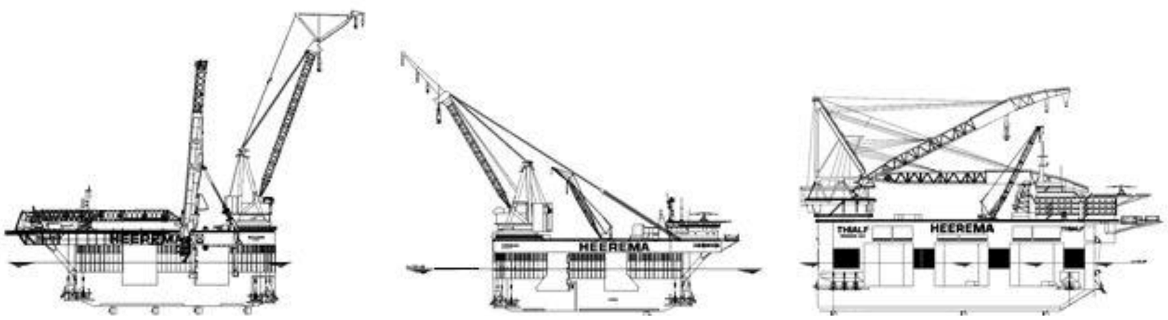
Heerema Group designs, constructs, transports, installs and removes offshore facilities for the global oil and gas industry. The group is divided into two separate companies, Heerema Fabrication Group (HFG) and Heerema Marine Contractors (HMC). HFG fabricates offshore structures whereas HMC is involved in the transportation, installation and removal of offshore facilities. Besides activities on the North Sea, HMC is currently also working on complex offshore facilities in e.g. Houston, Mexico City, Lagos, Luanda, Singapore and Perth (Heerema Marine Contractors, 2010). With 2000 employees worldwide and an annual turnover of EURO 1.2 billion HMC is one of the world's leading companies in the offshore industry.

HMC is specialized in fixed structures, complex infrastructures and floating facilities placed in shallow water, deep-water and ultra-deep-water (Heerema Marine Contractors, 2010). The projects can be classified in three different types: Transport & Installation (T&I), Engineering, Procurement, Installation and Commissioning (EPIC), and Engineering, Procurement, Removal and Demolition (EPRD).

The T&I type of project is the most experienced core business of HMC. An example of a conventional T&I is the installation of a fixed platform where the base, the jacket, is placed on the seabed and the upper part, the topside, is placed on the jacket. HMC also has experience with other, more complex, T&I jobs all over the world.

The project type EPIC is relatively new for HMC. The EPICs are much more complex than the T&I jobs. The preliminary phases before installation, i.e. the engineering and procurement, are within HMC's responsibility. So, an EPIC has much more interfaces compared to a T&I job, which has a higher risk and lower margins. In 2008 the first large EPIC started in Angola, Block 31, which is a Risers and Production Flowlines contract for a large oil exploration firm. Block 31's billion dollar contract is HMC's largest contract in history.

HMC started in 1985 with the removal of relatively simple fixed platforms. Later, the removal jobs became more complex because of heavier and larger fixed platforms. In an EPRD project the topside is removed first, and then the jacket is removed. Since the platforms to be removed are obsolete, there is lot of uncertainty concerning the platform's condition, e.g. the presence of asbestos or structural weaknesses. The EPRD projects mostly take place in the North Sea.



Balder Hermod Thialf

Figure 1.1: HMC's SSCVs

The project execution is done using HMC's equipment. In 1978, HMC took the first Semi-Submersible Crane Vessel (SSCV) into service which made it possible to work in more adverse weather. Currently, HMC is the owner of three of the five semi-submersible vessels that exist worldwide. The Balder and Hermod have the capability lifting 8.100 tons and the Thialf, the largest SSCV ever built, is capable of lifting 14.200 tons. To provide an indication of the vessel costs: the SSCVs do have high fixed cost and relatively small variable costs, this causing high financial consequences when the SSCV is delayed and/or is stationary.

Two tugs, the Retriever and the Husky, are also owned by HMC. Besides, HMC is building a new vessel called the Aegir. The Aegir is a specialized Deep Water Construction Vessel with which HMC will execute complex infrastructure and pipeline projects in ultra-deep water.

The project management of HMC is complex. On average the planning of a project takes two to three years after which the execution, i.e. the T&I of the offshore facility, is done in several days up to several months. Since the vessel costs are so high, the risk events causing delay during the execution phase offshore are of high impact. Furthermore, HMC undertakes more EPIC and EPRD projects, which also generates high-impact risk events in engineering and procurement.

1.2. RESEARCH PROBLEM

Project management is becoming more important every day, because of the projects' increasing complexity (Ahn, Zwikael, & Bednarek, 2009), (Baccarini, 1996). Besides the complexity the project size, the speed of construction, the location of the project and the degree of unfamiliarity with the client play a role in project management (Perry, 1986). To overcome project failure the analysis and management of risks is of high importance for those characteristics (Royer, 2000).

A risk can be identified as 'risk event' and be combined in the 'project risk'. In the Association of Project Management's (APM) Body of Knowledge a risk event is defined as 'an uncertain event or set of circumstances that, should it occur, will have an effect on achievement of one or more project objectives.' A risk event can cover a threat as well as an opportunity. APM defines the project risk as the 'exposure of stakeholders to the consequences of variation in outcome'. The project risk consists of an accumulation of risk events and additional sources of uncertainty which impacts the entire project (APM, 2006).

Risk events are ranked by the usage of qualitative techniques, e.g. by using checklists or during brainstorm sessions, which enables prioritization for further consideration. Additionally a quantitative risk analysis can be performed to identify the combined effect of risk events on the overall project outcome. Examples of quantitative techniques are Monte Carlo (MC) simulations, decision trees, sensitivity analysis, and influence diagrams (APM, 2004), (Hillson & Simon, 2007), (PMI, 2008), (Milosevic, 2003). In project management the MC method is the commonly used technique. The MC method is a computerized model which analyses the combined effect of the identified risk events; an indication of the project risk is estimated (Hillson & Simon, 2007).

Besides the identification and assessment of risk events, risks are also mitigated and reported in project risk management (PRM). The purpose of PRM is to increase the likelihood of project success with respect to cost, time, scope and performance (APM, 2006).

The PRM within HMC was until recently supported by a specialized risk team. The former Board of Directors saw a change in the company's risk profile at the time HMC was tendering a large EPIC in Nigeria, a new type of project at that time. In September 2006 the team started to identify HMC's risk profile on corporate level. Project risk analyses were of high importance since about 80% of HMC's risk is in its projects.

The risk team facilitated risk meetings at the start of each project to identify risk events and to do a first qualitative risk analysis. Combined with additional specific risk event information, this was used as input for a quantitative risk analysis. The MC simulation results provided the project manager with a visual on the combined effect of the identified risk events. In cooperation with the project manager, the risk team updated the risk analysis each month to each quarter.

The new Board of Directors abandoned the risk team in September 2009. The Board came to the conclusion that the risk team was time consuming and costly. Besides, several project managers had an aversion to the MC simulation. After the shutdown the risk team's facilitating role and the quantitative risk analysis disappeared. The project manager received the full responsibility for the PRM again.

HMC's current PRM procedure results in a seven column wide risk register (Appendix A.1). Among other things the cause, effect and consequence of the identified risk events are pointed out. Also, both the mitigation action for the risk treatment and the responsible person/group are presented. The risk events are prioritized by the combined likelihood and impact score by using HMC's qualitative risk assessment tool: the Risk Evaluation Matrix (REM) (Appendix A.2).

There is an ongoing discussion about the Board of Directors' decision to abandon the risk team. With the abandonment the risk team's facilitating role and the PRM expertise disappeared. Currently, the project manager is responsible for the PRM in the project phase. This raises the question: 'Is there room for improvement in HMC's current PRM method?' Besides, the abandonment also did disappear the quantitative risk analysis. Currently, no analysis of the combined effect of the identified risk events, i.e. the project risk, is performed. The question that arises is: 'What exactly is superior about the quantitative risk analysis?'

Therefore, the theoretical objectives (Velde, Jansen, & Anderson, 2008) of the research are to define if there is room for improvement in HMC's current PRM method and to define the usefulness of quantitative risk analysis for HMC's PRM. The practical objective (Velde, Jansen, & Anderson, 2008) will be a recommendation how to modify HMC's current PRM procedure and a recommendation for HMC to implement or not implement a quantitative risk analysis method on project level.

1.3. Research Questions

This thesis will answer the main research questions. The path towards those answers is based on the answers to the research sub-questions, each of which is presented in a separate chapter.

1.3.1. Main Research Questions

The main research questions are as follows:

'Which aspects of HMC's current project risk management method show room for improvement?'

'What is the usefulness of quantitative risk analysis in HMC's project risk management?'

1.3.2. Research Sub-Questions

1) a) 'What is the project risk management theory?' (Descriptive research question (Velde, Jansen, & Anderson, 2008)).
   b) 'How is qualitative and quantitative risk analysis used in theory and in practice?' (Descriptive research question (Velde, Jansen, & Anderson, 2008)).
2) 'What is HMC's current project risk management procedure?' (Explorative research question (Velde, Jansen, & Anderson, 2008)).
3) a) 'How does HMC's current project risk management practice differ from HMC's current project risk management procedure?' (Explorative research question (Velde, Jansen, & Anderson, 2008)).
   b) 'How does HMC's former project risk management practice, with risk team and quantitative risk analysis, differ from HMC's current project risk management practice?' (Explorative research question (Velde, Jansen, & Anderson, 2008)).
4) a) 'How do HMC's current project risk management procedure and practice differ from the project risk management according to the literature?' (Explorative research question (Velde, Jansen, & Anderson, 2008)).
   b) 'How does HMC's former project risk management practice differ from the project risk management according to the literature?' (Explorative research question (Velde, Jansen, & Anderson, 2008)).

1.4. Methodology

Several steps of the PRM process, including the risk event identification and qualitative risk analysis, serve as input for the quantitative risk analysis (Hillson & Simon, 2007). To enjoy the advantages of quantitative risk analysis the afore mentioned steps should be done correctly. Therefore, HMC's PRM procedure ('SOLL'), HMC's PRM practice ('IST') and the PRM literature are compared to each other. Hence, the research will be based on the triangle as shown in figure 1.2.

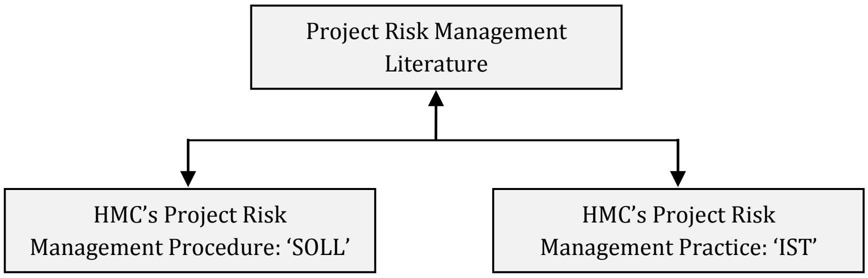


Figure 1.2: Research Triangle

The thesis will be an explorative research (Baarda, 2007), (Yin, 2003). It will consist of two parts: an extensive literature research, the upper rectangle in the triangle, and a single-case multiple-source study focused on the lower rectangles in the research triangle. Before discussing the research procedures, the research framework is presented.

1.4.1. *Research Framework*

Figure 1.3 presents the research framework of this thesis. The framework is based on the literature of Verschuren and Doorewaard (Verschuren & Doorewaard, 2010). The research objects with the corresponding relations are indicated. Also the associated chapter, research sub-question (SQ) and main research questions (MRQs) are shown.

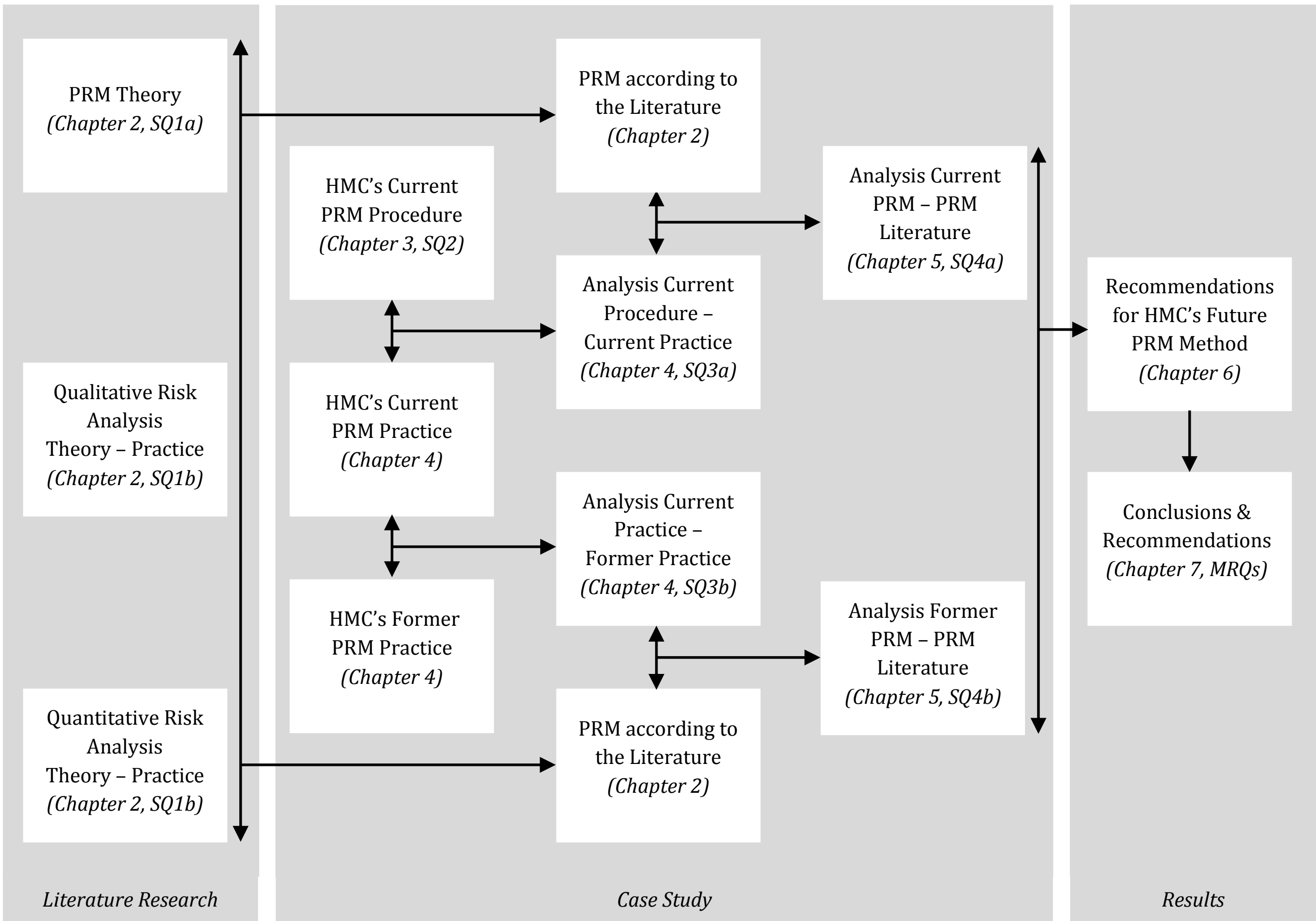


Figure 1.3: Research Framework

1.4.2. *Literature Research*

The literature research is used to become familiar with the PRM theory and the current state of qualitative and quantitative risk analysis in practice. The purpose is to use existing information to answer the first sub-questions. For the literature research scientific knowledge, published scientific journals and books are used, where necessary and/or possible professional knowledge is used additionally.

1.4.3. *Case Study*

The inquiry within HMC will be done to answer the remaining sub-questions. It will be an explorative case study. Opting for a case study is clear when you look at its definition by Yin (Yin, 2003): "A case study is an empirical inquiry that (a) investigates a contemporary phenomenon within its real-life context especially when (b) the boundaries between phenomenon and context are not clearly evident." That is to say, the boundaries between real-life PRM with qualitative and/or quantitative data analysis and the PRM as described in theory.

A distinction is made between HMC's PRM procedure ('SOLL') and the execution of HMC PRM practice ('IST') to investigate relationship between HMC's current PRM procedure and practice. The presence of the former risk team with the additional quantitative risk analysis will be studied as well. This is done by comparing HMC's former PRM practice with HMC's current PRM practice.

A single-case multiple-source study is done to answer the explorative research sub-questions. The case study design is elaborated on in Chapter 2.6 and Appendix B. The following procedures are applied:

1) *Documentation*: the PRM procedures as well as reports/risk registers provided by HMC are used as background information. In the case of HMC, those documents are stable and precise. The sources will be selected and reported in an unbiased fashion (Yin, 2003).
2) *Interviews*: semi-structured interviews (Wengraf, 2004) with HMC's project managers and other PRM relevant personnel are used to answer the last three sub-questions. The interview questions, categorized using the research framework, are presented in Appendix B. In the case of HMC it is important to be aware that the interviewee is not prejudiced and that the reproduction of the interview is complete and correct (Yin, 2003).
3) *Direct observation*: risk assessment meetings in the project phase are attended to compare the practice with the procedure. It is used as an additional source to verify the interview results. Where possible multiple meetings are attended to prevent a biased view on the meetings (Yin, 2003).
4) *Survey*: the project managers are asked to fill out an unfinished risk register of two different projects: (a) a relatively simple T&I project and (b) a more difficult engineering and installation project. The answers of the surveys are used to research the consistency between the project managers' ranking of the risk events' likelihood and impact. Furthermore, it is used to research the project managers' perception of the effect the risk events could have on the project objectives. The survey format is shown in Appendix B.

1.4.4. *Validity of Case Study*

The validity of the case study is defined by the construct validity and the internal and external validity.

1) *Construct validity*: the construct validity mainly depends on the selection of the documentation and the interviewees. It is important to select objectively, therefore multiple projects and project managers are used for the gathering of data (Tellis, 1997), (Yin, 2003).
2) *Internal validity*: during a case study it is necessary to draw a conclusion when an event cannot be directly observed. It is possible that such a conclusion is incorrect, that not all the rival explanations and possibilities have been considered, or that the evidence was not convergent (Tellis, 1997), (Yin, 2003). If there are doubts about this, additional sources are used to verify the conclusion.
3) *External validity*: since it is a single-case study, a statistical generalization is not possible. However, the case study can be analytically generalized. The analytical generalization is not automatic, results do have to be tested to replicate the findings in one or more other case studies (Tellis, 1997), (Yin, 2003). Where an analytical generalization is possible, it is not possible to replicate the findings in other case studies because of time shortage.

4) *Reliability*: for the reliability of the study it is important to minimize the biases and errors within the project. If another investigator conducts the same case study, he or she should come up with the same results (Tellis, 1997), (Yin, 2003). To overcome unreliable notions, the procedures followed during the case study are documented and can be found in the Appendices (Appendix B, C, D, E).

CHAPTER 2: PROJECT RISK MANAGEMENT IN LITERATURE

Before answering the explorative question '*How is qualitative and quantitative risk analysis used in theory and in practice?*' it is important to introduce the practice of PRM. This is done by answering the question *'What is the project risk management theory?'*

Firstly the definition of risk has to be defined. In fact there is lot of discussion about the exact meaning of risk. Where APM's definition of risk is argued by Douglas W. Hubbard (Hubbard, 2009), HMC uses a comparable definition as in APM's Body of Knowledge (APM, 2006).

When opening a dictionary, risk is defined in terms of threat, chance of loss, harm, injury, etc. Not one mentions the possibility of positive outcomes (Hubbard, 2009). Nevertheless, APM's definition, as well as the majority of official project management standards and guidelines (Hillson & Simon, 2007), includes that a risk can influence the project objectives in both a positive and a negative way.

A 'risk event' is defined as 'an uncertain event or set of circumstances that, should it occur, will have an effect on achievement of one or more project objectives' both as threat and as opportunity. The higher level of 'project risk' consists of an accumulation of all identified risk events and additional sources of uncertainty which has impact on the entire project (APM, 2004), (Hillson & Simon, 2007). For this study APM's definition of risk will be used to overcome disagreement with the majority of project management standards and HMC's definition of risk. HMC's definition for risk is 'an event or circumstance which, if it occurs, could affect the expected outcome both in terms of opportunity or exposure' (Bree, 2010).

In addition the difference between uncertainty and risk needs some further explanation. Where uncertainty is the lack of total certainty, e.g. regarding tomorrow's weather, a risk is a state of uncertainty with respect to possible threat or opportunity, e.g. a possible project delay because of tomorrow's weather (Hubbard, 2009).

Uncertainty can be divided into three parts as shown in figure 2.1: total certainty, uncertainty and total uncertainty. The knowns, the events for which complete information is available, are entirely predictable and therefore are no risk events. Neither do the unknowable or unidentifiable events, known as the unknown unknowns, fall under the definition of a risk event since there is no information. The known unknowns are linked to the definition 'risk event'. A future risk event arises from uncertainty that has a definite cause and affects the project objectives. It can be measured and quantified in terms of a future likelihood and impact (Milosevic, 2003), (PMI, 2008).

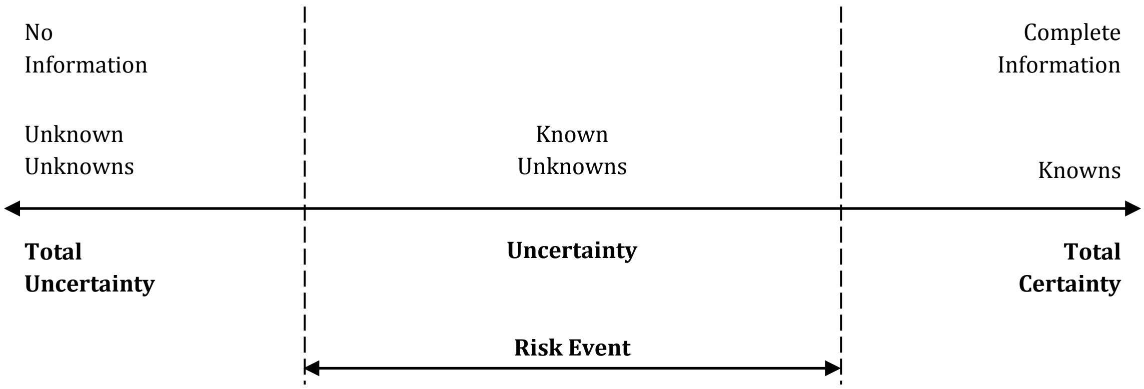


Figure 2.1: Relation between Risk and Uncertainty (Milosevic, 2003)

Now that the term 'risk' and its side terms are known it is possible to introduce the term 'Project Risk Management' (PRM). PRM is the controlled process of understanding and managing risk events and the accumulated project risk. This is done by identifying, analyzing, planning, mitigating, monitoring and controlling the risk events. Properly executed PRM will increase the likelihood that the project meets its objectives with respect to time, cost, quality and scope (APM, 2004), (Cooper & Chapman, 1987), (Hillson & Simon, 2007), (Hubbard, 2009), (Norris, Perry, & Simon, 2000), (PMI, 2008).

The remainder of this chapter will introduce the steps necessary for proper PRM and how those steps are worked out in practice. Afterwards the qualitative risk analysis will be compared to the additional use of quantitative risk analysis. But first the necessary characteristics needed to make PRM work are presented.

2.1. Making PRM Work

PRM is of high importance to overcome project failure (Royer, 2000). Knowing that a single event can cause the failure of an entire system it is important that the PRM practices are effective. Insufficient PRM can become a common mode failure for the total project, i.e. numerous project components fail because of incorrect risk management (Hubbard, 2009). According to Hubbard (Hubbard, 2009) risk management fails for at least one of the following three reasons:

1) *The failure to measure and validate methods as a whole or in part*: verifiable evidence of the efficiency of risk assessment and mitigation activities are often missing, especially for the softer methods. It is dangerous not to know the PRM's own risk. Therefore it should be positively proven that it works (Hubbard, 2009).
2) *The use of components that are known not to work*: there are several errors and biases concerning various PRM elements. The research that demonstrates humans misperceive and underestimate risks should be considered since a lot of PRM methods rely on human judgment (Capen, 1976), (Hubbard, 2009). Additional inaccuracies exist because of the naive use of historical data or subjective scales (Hubbard, 2009).
3) *The lack of use of components that are known to work*: risk management methods of which evidence exists that it works are not used in most PRM processes (Hubbard, 2009).

The failure of risk management is not just related to the processes and tools used. After large process, tools and training investments, it is still possible that a company fails to obtain the benefits of PRM. It is important to invest in the organizational culture as well, i.e. show that PRM works and is worth the investment (Hillson & Murray-Webster, 2004), (Murray-Webster & Simon, 2006).

To make PRM work Hillson and Simon present the four Critical Success Factors (CSFs). When all CSFs are present, the probability of successful PRM is highly increased (Hillson & Simon, 2007). The CSFs are as follows:

1) *A supportive organization*: it is important to invest in the PRM culture within the company. PRM objectives should be defined and communicated to the stakeholders. Time should be scheduled and required resources should be available to perform PRM.
2) *Competent people*: participants should be continually trained in the PRM process and activities. If the training is done effectively a shared PRM understanding will be created. Besides, effective training also convinces the participant of the PRM's benefits.
3) *Appropriate methods, tools, and techniques*: firstly the level of PRM implementation has to be chosen. Subsequently the necessary infrastructure can be acquired. It is important that there is not too little support since this will negatively affect the efficiency, and, on the other hand, not too much bureaucracy with an overload of PRM infrastructure.
4) *A simple to use, scalable, and documented process*: this ensures that PRM activities are known for each project. It provides a standard of PRM activities for each unique project.

2.2. The PRM Process

There are several national, international and professional risk management standards. It is important to use the standards that match the research topic best. Raz and Hillson (Raz & Hillson, 2005) compared the major standards. Based on this comparison, the Project Risk Analysis and Management (PRAM) guide of the Association for Project Management (APM) (APM, 2004) and the Project Management Body of Knowledge (PMBoK) guide of the Project Management Institute (PMI) (PMI, 2008) fit the research topic best. Both standards have their scope on project level and have a broad risk definition; threats as well as opportunities are taken into account. Hence, the treatment of positive and negative 'risk' is also presented. Both standards describe the main steps for planning, identification, assessment, treatment and control.

For the PRM discussion the Active Threat and Opportunity Management (ATOM) (Hillson & Simon, 2007) methodology is used. This methodology provides a practical illustration of how to perform PRM in a real project instead of a theoretical framework. The major standards, including PMBoK and PRAM, are consistent with the ATOM methodology. Besides the ATOM methodology, the PMBoK, PRAM and other additional sources are used for the discussion. The ATOM process, figure 2.2, will be the guideline to explain the separate steps.

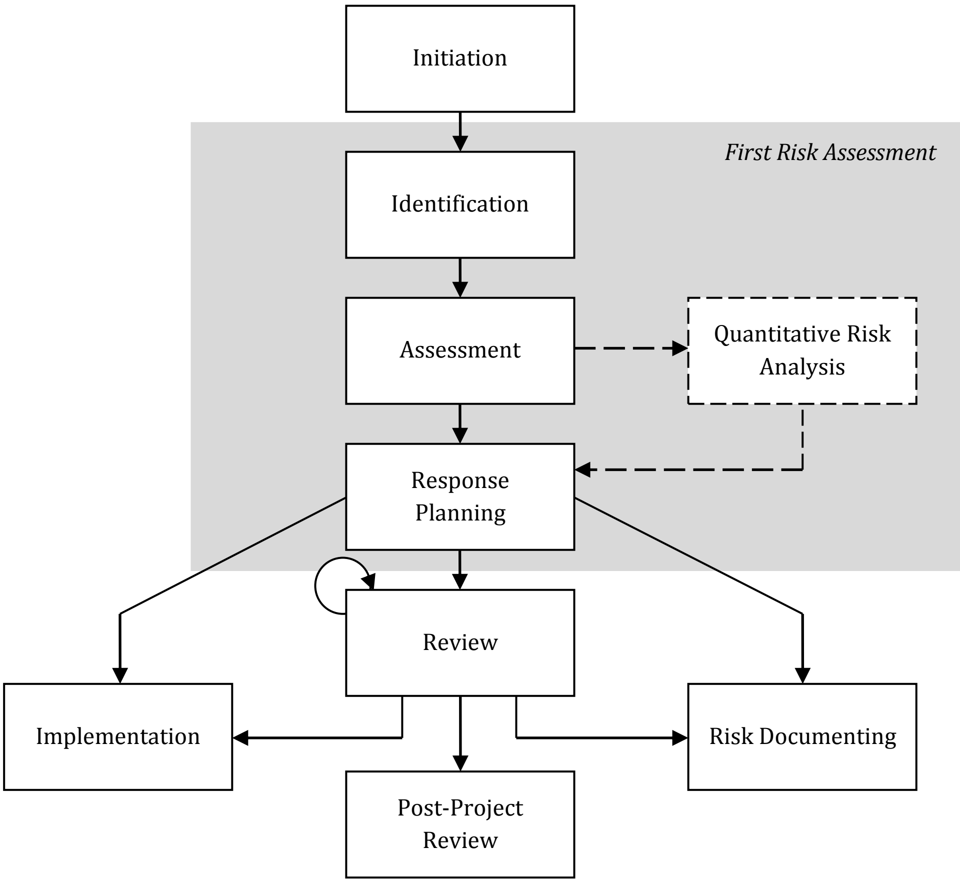


Figure 2.2: The steps in the ATOM process (Hillson & Simon, 2007)

2.2.1. *Initiation*

The main purpose of the initiation phase is to define a PRM plan for the project. The project size, project objectives and stakeholder list serve as input to set the activities to be done and the tools to be used. It is important that the key stakeholders and team members play a role in defining the plan.

Developing a specific PRM plan is advisable because each project is unique. Where one project is relatively large and complex, the second project could be a routine execution, both types need a different PRM level. Besides, a proper and well defined planning increases the chance of success in the next steps.

2.2.2. *Identification*

In the identification phase the risk events are defined. This step is of high importance in the PRM process; an unidentified risk event (an *unknown unknown*) cannot be assessed or treated.

There are over 40 different kinds of techniques for risk event identification (Raz & Hillson, 2005). Several techniques can be used consecutively for one project. The most commonly used techniques are:

1) *Brainstorming*: an approach that can be called 'pondering' where an individual or a small group starts from scratch to identify sources and/or responses (Chapman & Ward, 2003).

2) *Assumptions and constraints analysis*: the validity of the identified assumptions and constraints is tested: e.g. it may or may not be false based on experience (Hillson & Simon, 2007).
3) *Checklists*: using a checklist that guarantees that previous or standard risk events of comparable projects are considered (Hillson & Simon, 2007).
4) *Interviews*: consultation of experienced experts can provide risk event information relevant for the project (Kendrick, 2003).

2.2.3. *ASSESSMENT*

The purpose of the assessment step is to prioritize all identified risk events from most urgent to least urgent. The assessment can be done qualitatively and additionally quantitatively. Here a first introduction of qualitative and quantitative risk analysis is provided. A more elaborate discussion is presented from Chapter 2.4 to Chapter 2.5.

1) *Qualitative techniques*: the risk events are prioritized based on the probability of occurrence (high/low or in percentage) and the magnitude of impact (high/low). The impact can be related to time, cost, quality and/or scope. The scaling is done using qualitative tools and techniques, e.g. a probability and impact matrix. Additionally the risk events can be categorized by sources of risk in a Risk Breakdown Structure (RBS) or related to the project Work Breakdown Structure (WBS) (Hillson & Simon, 2007), (Lester, 2007).
2) *Quantitative techniques*: the qualitative risk analysis is the foundation of the quantitative risk analysis. With quantitative assessment the combined effect of the risk events is expressed using mathematical techniques. This can be done manually, e.g. with decision tree diagrams, or computerized, e.g. with MC simulations. The output gives an indication of the project risk related to time and/or cost.

2.2.4. *RESPONSE PLANNING*

Besides the identification the risk treatment and response planning is also of high importance; in this step the preparation is made to minimize the threats and maximize the opportunities. The response strategies are prioritized in table 2.1.

Priority	*Threat Strategy*	*Opportunity Strategy*
1	Avoid	Exploit
2	Transfer	Share
3	Reduce	Enhance
4	Accept	

Table 2.1: Prioritized possible response strategies (Hillson & Simon, 2007)

1) *Avoid*: changing the project plan to eliminate the risk event's probability and/or impact.
2) *Transfer*: transferring the threat to a third party, i.e. the risk is not eliminated but the responsibility for the risk event management shifted.
3) *Reduce*: a mitigation to reduce the threat's probability and/or impact. This to the point where the risk event is on an acceptable level.
4) *Exploit*: changing the project plan to guarantee the opportunity will definitely occur.
5) *Share*: sharing the opportunity with a third party, i.e. benefit the project by allocating the ownership to a party best able to get the opportunity.
6) *Enhance*: a mitigation to enhance the opportunity's probability and/or impact.
7) *Accept*: this is a passive or active response; passive if it is decided to take the risk as it occurs or active when a contingency reserve (time, money and/ or resources) is included to handle the risk. A contingency reserve requires two actions; firstly the planning before the risk event occurs and secondly the action at the moment or just after the risk event occurs. It is important to decide on a trigger point for the second action upfront (Isaac, 1995), (Kendrick, 2003), (Milosevic, 2003).

Subsequently, the residual risk events and secondary risk events, the risks of the response strategies, should be defined/identified. Also the risk events' post-response probability and impact score should be identified when the response planning is known.

2.2.5. First Risk Assessment Workshop & Interview

The identification, assessment and response planning steps can be done during a first risk assessment: a workshop for the first two steps and interviews for the third step.

The workshop, facilitated by a risk champion or another specialist, should best be attended by the project manager, project sponsor, key stakeholders and important project team members. The more participants the better: the ideal number is ten to sixteen. In case of a large group, subgroups should be formed during the activities. To attain an effective workshop, it should last for one to three days. During the workshop the risk events are identified and scaled on probability and impact. Grouping the risk events as first categorization, e.g. based on the WBS or RBS, is done as well (Hillson & Simon, 2007).

It is also important to assign a risk owner for each identified risk event. The risk owner should be the one that is the best in managing the identified risk event. There are three important points concerning risk ownership:

1) It is crucial that the risk owner is an individual.
2) It has to be avoided that the person that identified the risk event automatically becomes the risk owner.
3) The project manager or risk expert should only take the responsibility if they are beyond doubt the best candidate for managing the risk event.

After the workshop the risk champion should start interviewing the risk owners individually: the response planning step. An appropriate response strategy, the actions needed to implement the strategy, the post-response probability and impact scores, and possible secondary risk events are identified in cooperation with the risk owner (Hillson & Simon, 2007).

2.2.6. Risk Documenting

The identified risk events are updated in a risk register describing all the risk event's characteristics. It is important to update the risk register on a continuous basis during the PRM process.

The purpose of documenting the PRM steps is to ensure the identified risk events are understood by everybody within the project. When documenting the identified risk events it is essential to describe the characteristics appropriately. This can be done best by using metalanguage: *'As a result of <definite cause>, <uncertain event> may occur, which would lead to <effect on objective(s)>'* (Hillson & Simon, 2007). The more specific the description the less likely it is that the risk event will be misinterpreted. Isaac demonstrated that the estimation of the likelihood and impact was easier with lengthier, more detailed, descriptions (Isaac, 1995).

There is general consensus that a risk register should at least contain the description of the risk events, preferably in metalanguage, the probability and impact score, and the response strategies (Patterson & Neailey, 2002). It is advisable to additionally present the initiation plan, the risk owners, and the risk status in the risk register.

2.2.7. Implementation

The previous steps have resulted in a risk event report, but the agreed actions are not yet implemented. The actions are performed during the continuous process of implementation. Besides the performance of the agreed actions, additional secondary and newly emerged risk events are identified. The risk event status is updated in the risk register. This can be done using ATOM's eight risk events statuses as shown in figure 2.3.

2.2.8. Review

Performing PRM steps so far doesn't ensure the risk events are managed effectively. It is important to have risk event review momentum during the project to ensure positive project returns (Arrow, 2008). This can be a minor or a major review depending on the project size and/or complexity.

During a minor review only the highest prioritized risk events are discussed. The identification of new risk events and the probability and impact score updates are done by the people directly involved with PRM. During the major review the total workshop is redone with the previously documented risk report as input. The same people are present and the same tools and techniques are used to have another total view on the PRM.

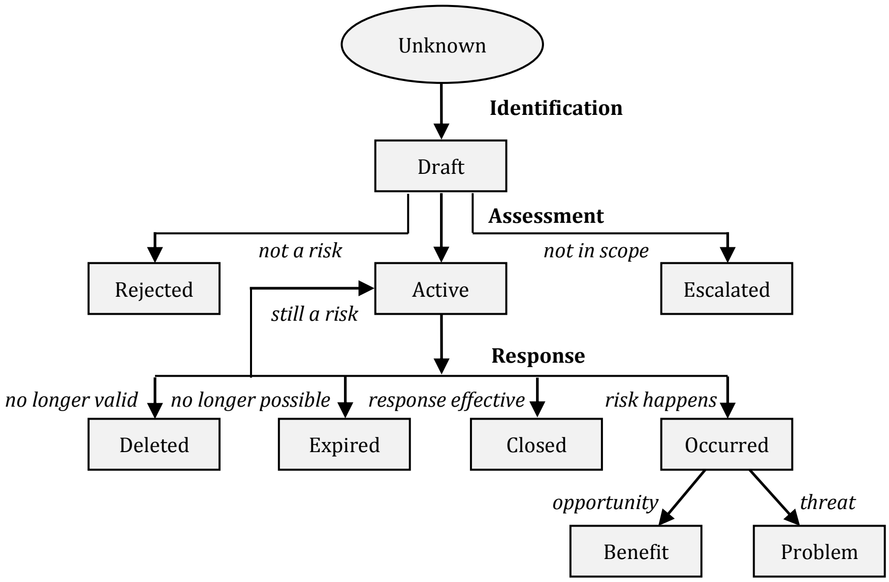


Figure 2.3: Risk status values and their relations (Hillson & Simon, 2007)

2.2.9. Post-Project Review

Besides the purpose of finishing a project successfully, there is also an additional secondary aim; the contribution to the organizational experience. To include such experiences into new projects, it is important to identify the 'lessons learned'. If done correctly the company's body of knowledge will benefit future projects (Hillson & Simon, 2007).

2.2.10. Risk Champion

It's possible to appoint a 'risk champion', also called a 'risk facilitator', who guides the people involved in the PRM through the entire PRM process. This will include the facilitation of the risk assessment workshops, review moments and interviews with risk owners. The risk facilitator will also have a coaching and advising role towards the people involved in the PRM process. (AIRMIC, ALARM, IRM, 2002), (Hillson & Simon, 2007). Hence, a risk champion goes beyond organizing the PRM activities. It is a PRM specialist operating independently and unbiasedly with the project manager and project team (Keizer, Halman, & Song, 2002).

2.3. Qualitative Risk Analysis

An introduction to qualitative and quantitative risk analysis has already been presented in the previous sub-chapter. This sub-chapter and the following two sub-chapters will provide a deeper understanding of the two different types of risk analysis.

The purpose of qualitative risk analysis is to define which risk events are most urgent and should be treated first (Hillson & Simon, 2007). The prioritization is done by two steps: the *risk analysis* and the *risk evaluation.* In the risk analysis the probability of occurrence and the magnitude of the impact are defined. In the risk evaluation the risk events are compared by the given risk criteria (Cooper, Grey, Raymond, & Walker, 2005), (Raz & Hillson, 2005).

The risk evaluation can be done based on relative risk severity and absolute risk severity. A short list of risk events enables to prioritize the events by pair-wise comparisons: relative evaluation. By prioritizing the more severe risk events over the less severe, a prioritized list is formed. With absolute comparison the risk events' probability and impact are defined, after which the evaluation is done using a risk assessment table or matrix (Kendrick, 2003).

The relative evaluation is not elaborated on since it is only possible for small numbers of risk events and no further tools/techniques are used. The absolute evaluation, of which the process is shown in figure 2.4, will be further elaborated on.

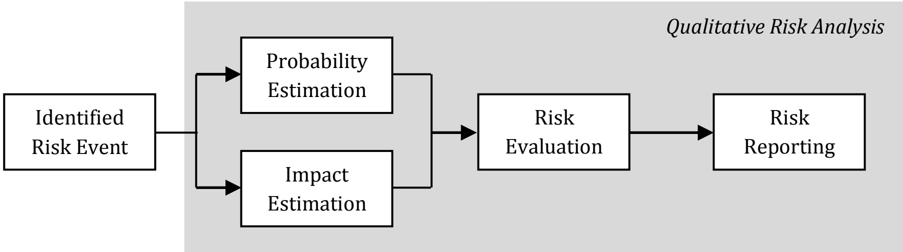


Figure 2.4: Qualitative risk analysis process

Firstly the identification of the probability and impact are discussed after which different types of risk assessment tables and matrices are presented. Thirdly, the risk evaluation will be discussed. Finally, the techniques used are discussed.

2.3.1. *Defining the Risk Events' Probability and Impact*

Firstly the probability of occurrence has to be identified. This can be done by analyzing historical events, by using empirical data and/or by experience and expertise. The probability score can be indicated using a five point scale from very low to very high. Additionally the defined scales can be linked to a percentage range as shown in table 2.2. Those ranges can be adjusted, depending on the project specific characteristics (Hillson & Simon, 2007), (Kendrick, 2003) .

After the probability determination, it should be pretended that the risk event occurs to define the magnitude of impact. The same five point scale is used. It is important that the impact is linked to the project objectives; an example is shown in table 2.2. The best method is to specify the impact scales on the characteristics of the specific project. It is possible that the risk event's impact score differs for the different project objectives. The objective with the highest impact score is used for further consideration. Techniques like team discussions, project reviews, and/or interviews with experts can be used to define the impact scores (APM, 2004), (Hillson & Simon, 2007), (Kendrick, 2003), (PMI, 2008).

Scale	*Likelihood*	*+/- Impact on Project Objectives*			
		Cost	*Time*	*Scope*	*Quality*
Very High	81 – 100%	>40% cost change	>20% time change	Very significant areas of scope changed	Very significant impact on overall functionality
High	61 – 80%	20 – 40% cost change	10 – 20% time change	Significant areas of scope changed	Significant impact on overall functionality
Medium	41 – 60%	10 – 20% cost change	5 – 10% time change	Major areas of scope changed	Some impact on overall functionality
Low	21 – 40%	<10% cost change	<5% time change	Minor areas of scope changed	Minor impact on overall functionality
Very Low	1 – 20%	Insignificant cost change	Insignificant time change	Scope change barely noticeable	Minor impact on secondary functions

Table 2.2: Example of project specific probability and impact scales (Hillson & Simon, 2007), (PMI, 2008)

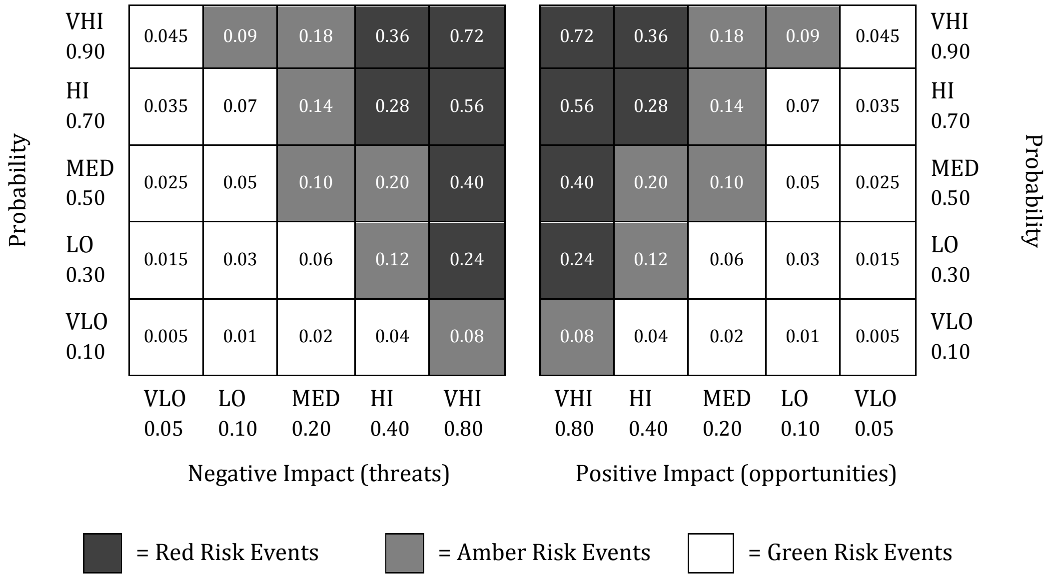


Figure 2.5: Double P-I matrix of the ATOM methodology (Hillson & Simon, 2007)

Standard/ Guideline	*Matrix Form*	*Probability Determination*	*Impact Determination*	*Risk Factor*
PRAM Guide 2004, APM	Double (mirror) P-I matrix	Linear; Very Low (0.1), Low (0.3), Medium (0.5), High (0.70), Very High (0.9)	Non-linear; Very Low (0.05), Low (0.10), Medium (0.20), High (0.40), Very High (0.80)	Risk Factor = Probability * Impact
PMBoK, 2008, PMI				
ATOM; Hillson & Simon, 2007				
Cooper, et. al. 2005	Single P-I matrix	Linear; Rare (0.10), Unlikely (0.30), Possible (0.50), Likely (0.70), Highly likely (0.80), to Almost certain (0.90).	Linear; Insignificant (0.10), Low (0.30), Moderate (0.50), Very high (0.70), to Catastrophic (0.90).	Risk Factor = Probability + Impact – (Probability * Impact)
Milosevic, 2003		Linear; from Very Unlikely (1), Low Likelihood (2), Likely (3), High Likely (4), to Near Certain (5)	Linear; from Very Low (1), Low Likelihood (2), Medium (3), High (4), to Very High (5)	Risk Factor = Probability + 2* Impact
OSPMI, 2007		Adaptable; ranking from 1 (low) to 5 (high) for which the percentage is chosen for the specific project	Focus on high and very high risk events impacts: Significant (non-linear): from Very Low (1), Low Likelihood (2), Moderate (4), High (8), to Very High (16) Or Moderate (linear): from Very Low (1), Low Likelihood (2), Medium (3), High (4), to Very High (5)	Risk Factor = Probability + Impact
Kendrick, 2003		Linear; from Very Low, Low, Moderate, High, to Very High		Risk Factor = Probability * Impact

Table 2.4: Different P-I matrix approaches of the reviewed PRM standards/guidelines

2.3.2. *Risk Assessment Tables & Matrices*

All seven reviewed PRM standards/guidelines best matching the research topic present a risk assessment matrix to evaluate the risk event's relative importance. Two of the guidelines additionally present a risk assessment table (Cooper, Grey, Raymond, & Walker, 2005), (Milosevic, 2003). This table reports the risk events with corresponding probability score, impact score and the overall risk factor. A risk factor is the combined value of the probability and impact.

But, the majority uses a risk assessment matrix. In such a matrix the risk factor is shown. One number, e.g. a percentage, or term, e.g. 'very high', represents the risk event's position in the matrix. Almost all matrices are divided into three color-coded zones where the red cabins represent high, amber represents medium, and green represents low priority risk events. Figure 2.5 is an example of a double probability-impact (P-I) matrix.

The differences between the matrices of the reviewed literature are presented in table 2.4. There are two major differences. The first is the use of a double or single P-I matrix. A double matrix clearly separates the threats from the opportunities. The second difference is the use of non-linear or linear risk factors and the asymmetric division of 'red', 'amber' and 'green' risk events. The risk factors are non-linear for most of the reviewed standards/guidelines, resulting in a significant focus on 'high-impact' risk events. The linear risk factors result in a moderate focus on 'high-impact' risk events.

When looking at the characteristics of, and the largest differences between the matrices, the question is *'which P-I matrix can be best used in practice?'* Using a broad definition for risk, a double P-I matrix is most appropriate: the threats are separated from the opportunities. Regarding the second difference, the focus should be more on the magnitude of impact instead of the probability of occurrence, i.e. an unlikely event that will kill you, should worry you more than a likely event that breaks your finger. Besides, a logarithmic impact scale gives each cell a unique value. The risk factor values should be indicated in each cell to create a valid line between the different color-coded risk events. Finally, a 5 x 5 matrix should be used for the best refinement when prioritizing the risk events; larger matrices are not advisable, this to avoid guessing (Hillson & Simon, 2007), (Simon, 2003). All this results in a P-I matrix as shown in figure 2.5.

2.3.3. *Risk Evaluation*

During the risk evaluation the risk events are compared against the defined risk factors. The final list of risk events shows the events that need a response strategy the most.

The double P-I matrix, shown in figure 2.5, can also be used to illustrate the project's risk density. Each cell presents the number of risk events related to that specific risk factor. This makes it possible to see the risk evaluation in a glimpse. Figure 2.6 shows an example of such an evaluation.

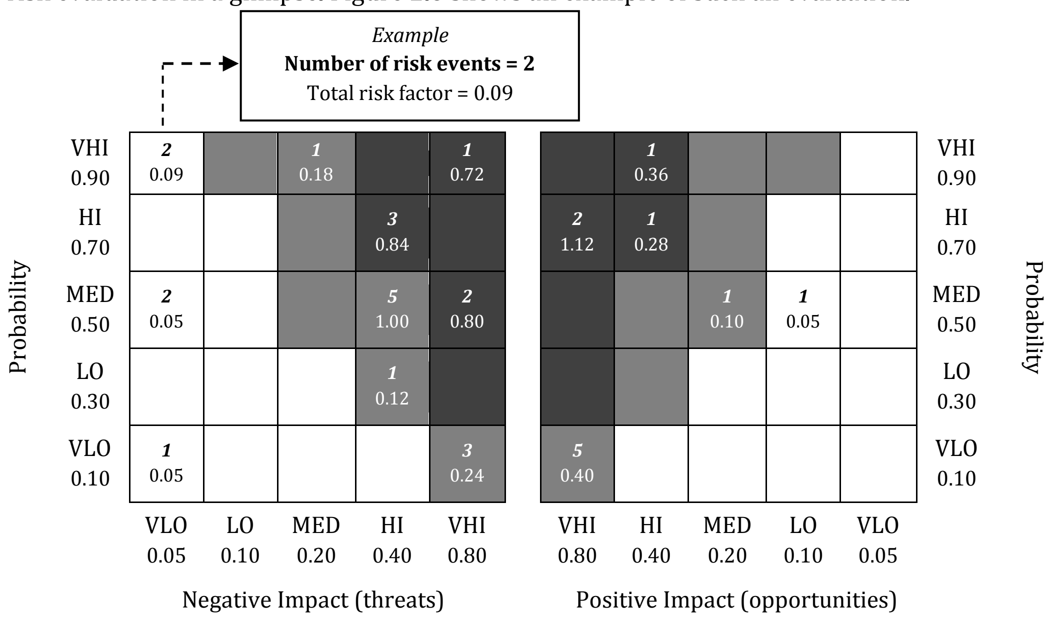


Figure 2.6: Example of double P-I matrix showing project's risk density (Hillson & Simon, 2007)

2.3.4. *Biases in Defining the Risk Event's Probability and Impact*

It is possible errors appear when defining the probability and impact using the presented techniques and tools. Firstly because of, to some extent, relying on human judgment and secondly because of inaccuracy and incompleteness in the tools. Based on Capen (Capen, 1976) and Hubbard (Hubbard, 2009) four issues concerning human subjectivity and three issues concerning biases of tools can be presented:

1) *Overconfidence of people*: research demonstrates that humans naturally are overconfident when making predictions. This means the risk events' probability and impact are underestimated (Capen, 1976), (Hubbard, 2009).
2) *Consistency of human judgment*: people are not consistent in their scoring. Predicting the same event for the second time after a certain period will result in a different score (Capen, 1976).
3) *Perception of the probability and impact scores*: the verbal scores, and to some extent the numerical scores, can be perceived totally different by two persons. This depends on one's experience and reference (Hubbard, 2009). Besides, people tend to think by intuition that the events with a high likelihood automatically have a low impact and the other way round, which results in biased scoring (Simon, 2003).
4) *Blurring of risk scores*: people tend to take more risk when they have information about near-misses, i.e. if it is known that the same identified risk event didn't occur in earlier projects, the risk event will be scored lower (Hubbard, 2009).
5) *Range compression of probability and impact scales*: looking at table 2.2., the probability is given in range of perception. It is possible that for one risk event the likelihood goes from medium to high with an increase of 1% while the other stays on medium with an increase of 18%. This could mean that the awareness goes to the wrong risk event (Hubbard, 2009).
6) *Presumption of regular intervals*: ordinal scales are often seen as computable: the intermediate steps are the same. However, it is possible that the differences between scores vary (Hubbard, 2009).
7) *Presumption of independence*: qualitative risk analysis doesn't provide insight into the combined effect of the identified risk events and doesn't take correlations between risk events in account. It is possible that medium-impact risk events have a much higher impact when they happen at the same time. With quantitative risk analysis the combined effect of risk events can be simulated and correlations can be taken into account (Hubbard, 2009).

A couple of things can be done to overcome the biases. The best way to prevent overconfidence is by training people in the definition of ranges. There are special training surveys as presented by Hubbard (Hubbard, 2009). The misperception of scales can be corrected by defining specific impact scales for each project objective, like in the example in table 2.2. Disassociating the assessment of the probability from the impact corrects the bias of e.g. rating high likelihoods intuitionally with low impacts. When first assessing the likelihood and then the impact, while hiding the likelihood, the risk factor will be less biased. It is also possible to divide the group into two parts: one part to assess the likelihood and the other part to assess the impact (Simon, 2003). Besides, disassociating the assessment also makes the process faster; it isn't necessary to switch between the different definitions of scales (Isaac, 1995). Nevertheless, it is important to be aware of the biases and, where possible, to act upon that.

2.4. Quantitative Risk Analysis

The existence of many risk events makes it difficult to create an understanding of the project risk. A project associated with high costs, long duration, innovative activities, and/or strategic importance requires a more thorough risk analysis. This is where quantitative risk analysis can be used; it provides an indication of the resulting risk events' combined effect which will provide a visualization of the project risk. A quantitative risk analysis also provides a prediction of the future project performance in relation to its objectives. Besides, it is possible to take the correlation between risk events into account.

Estimating the risk events' combined effect can be useful to decide which risk events have the highest priority when planning the response strategies. It will be even more striking when adjusting the risk event's information based on the planned response strategies. A new project estimation will make it possible to see what happens with the estimated project outcome when certain risk events are mitigated.

Since only numbers are used for the quantitative risk analysis, the results have a certain unambiguousness. This to some extent corrects the interpretation problems (Hillson & Simon, 2007).

The earlier steps of the PRM process, especially the identification and qualitative risk analysis, serve as the input for the quantitative risk analysis. Therefore it is important that the earlier steps are done truthfully since 'garbage times garbage is garbage squared' (Hubbard, 2009).

Sensitivity analysis, decision tree, influence diagram and probabilistic analysis are examples of quantitative risk analysis. All four techniques/tools will get a concise introduction. The probabilistic analysis, also known as the Monte Carlo (MC) method, will be discussed in more detail because it is the most commonly used technique in the PRM (APM, 2004), (Hillson & Simon, 2007), (Meredith & Mantel, 2010). Besides, HMC's former PRM method used this type of analysis.

2.4.1. *Techniques & Tools*

1) *Sensitivity analysis*: determines the effect one risk event has on the whole project by changing its variables. The other risk events are kept on their baseline values. This enables to compare the relative importance between risk events, e.g. with a high degree of uncertainty and the more stable risk events. It is possible to use it for time and cost impact (APM, 2004), (PMI, 2008).
2) *Decision tree*: this analysis presents the information to make project decisions. A decision point with its branched expected values and corresponding probabilities is given. Based on the expected value it is possible to have another decision point, to the point where all decisions are processed. The tree gives the possible paths through the project with the possible outcomes. Most often it is used for project cost analysis, but it can also be used for the project schedule (APM, 2004), (Milosevic, 2003).
3) *Influence diagram*: this is another way decision problems can be structured. This is done by presenting differently formed nodes representing the decisions to be made, the uncertain events, and the outcome values. The influences between the different nodes is indicated by arrows. An influence diagram links issues in a project to the risk events. It can be used to analyze cost, time and economic parameters (APM, 2004), (Loerch, 2005), (Shachter, 2010).
4) *Probabilistic analysis*: The MC method is based on random calculation of values in the risk events' probability distribution. Combining the random value of each risk event provides an overall project impact. Repeating the calculations a number of times, up to a thousand, provides a realistic view of the project outcome related to time and/or cost (APM, 2004), (Hillson & Simon, 2007).

2.4.2. *Monte Carlo Simulation*

The first electronic computer, introduced in 1945, made Stanislaw Ulam reconsider the statistical sampling techniques. Earlier the sampling techniques were unusable because of the lengthy and tedious calculations. The 1945 computer solved this problem, which triggered the development of the MC method (Metropolis & Ulam, 1949), (Metropolis, 1987). Since then the MC method has been used for decades for numerous kinds of mathematical and scientific simulations, including the probabilistic analysis in PRM (Kwak & Ingall, 2007).

The process of the MC method is presented in Figure 2.7. This process is equivalent for each MC simulation. The input and output is unique for each simulation and based on the project characteristics.

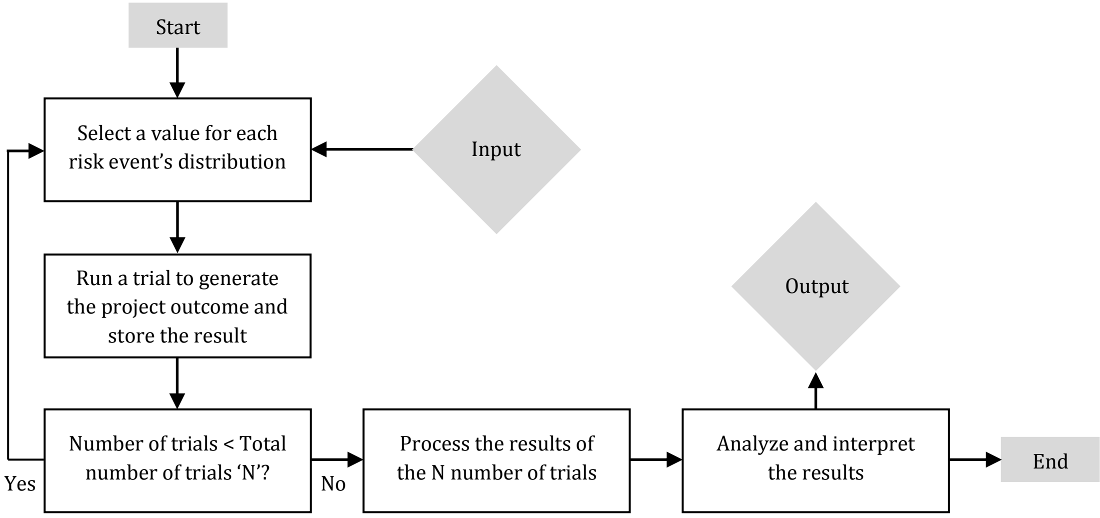


Figure 2.7: MC simulation process (based on (Milosevic, 2003))

1) *INPUT OF MONTE CARLO SIMULATION*

Firstly it has to be decided which (type of/category of) risk events are taken into account during the simulation. After that, each risk event's range and distribution of the analyzing element, regularly time and/or cost, should be determined. One risk event has the same number of distributions to be analyzed as elements to be analyzed. Most often it is the triangular distribution that is used which reflects the 'best case' on the left, 'most likely case' in the middle, and the 'worst case' on the right. But other distribution types are also possible. Figure 2.8 shows the most commonly used types (Hillson & Simon, 2007), (Milosevic, 2003), (Pugh & Soden, 1986).

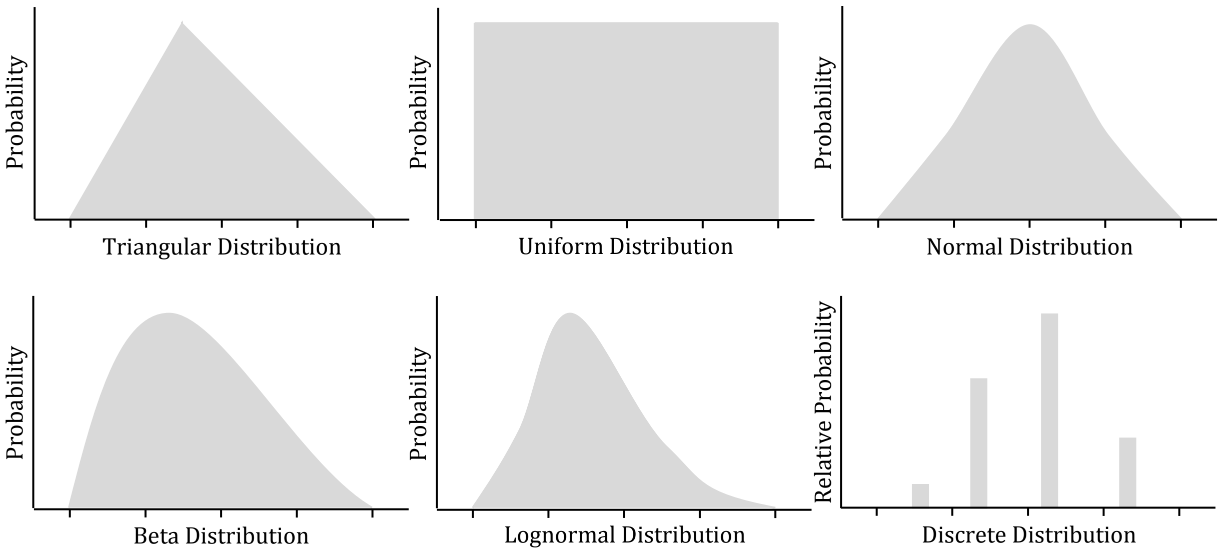


Figure 2.8: Most common distribution types used for the MC simulation (Hillson & Simon, 2007), (Milosevic, 2003)

Subsequently the correlation between risk events should be identified. It is possible that multiple activities are influenced by one risk event, or one element influences another element. Therefore it is important to identify the elements which have a positive or negative relationship with each other. Correlation factors, from -1 to +1 or -100% to +100%, are used to model the relationship strength (Cooper, Grey, Raymond, & Walker, 2005), (Hillson & Simon, 2007).

Finally the number of trials, 'N', should be determined. The number of trials depends on the project complexity; the higher the complexity the higher the number of trials. Most of the times it is between 100 and 1,000 trials. However, to be really sure all possible options are analyzed 10,000 trials should be run (Hillson & Simon, 2007), (Milosevic, 2003).

2) *OUTPUT OF MONTE CARLO SIMULATION*

After the MC simulation is finished, the gathered data should be processed. This can be done using several types of graphs/diagrams. The most common is the S-curve which shows a cumulative probabilistic distribution function (Hillson & Simon, 2007), (Oracle, 2009). Figure 2.9 shows an example of the S-curve.

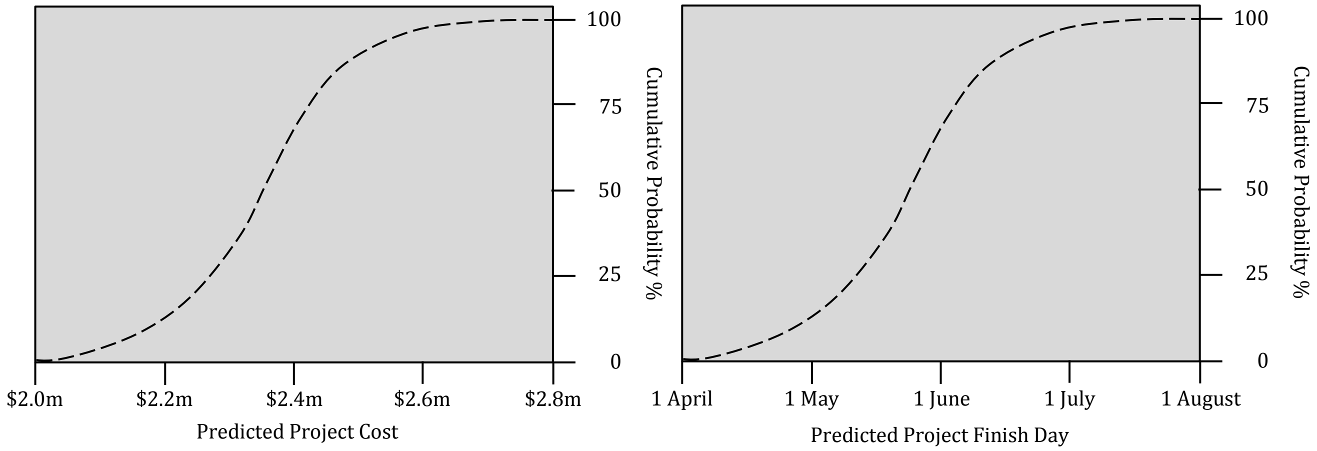


Figure 2.9: Example of S-Curves for predicted cost and time (Hillson & Simon, 2007)

It is also possible to compare the time with the costs as is done in an eye-ball plot. The dots show all the possible cost and schedule outcomes. The eye-ball encircles those dots and provides the minimum, maximum and most likely project outcome as shown in figure 2.10. The smaller the eye-ball the less uncertain the project (Hillson & Simon, 2007).

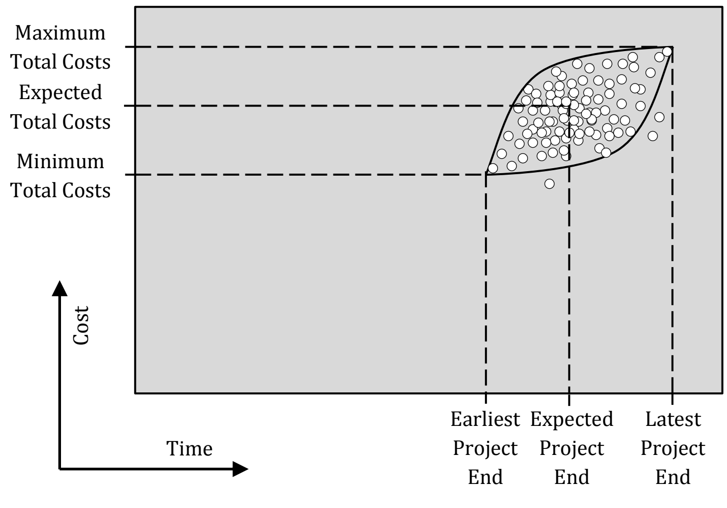


Figure 2.10: Example of an eye-ball plot (Hillson & Simon, 2007)

Finally, it is also possible to determine all the risk event's specific correlation factors (between -1 and +1) for the project outcome of the analyzed element, mostly time or cost. This cruciality analysis provides a direct link between a certain risk event and the analyzing project outcome (Hillson & Simon, 2007).

2.4.3. *CRITICAL FACTORS USING QUANTITATIVE RISK ANALYSIS*

When using the MC method it is important to be aware of the following factors to get the best input possible. Those factors are only related to the quantitative risk analysis step assuming the previous PRM steps represent the best possible truth.

1) *Overconfidence of people*: the risk events' ranges and distributions of the analyzing elements should be deliberately chosen. This is so because of the overconfidence of people, mentioned above, when determining ranges (Capen, 1976). Therefore, it is important to use the best knowledge available during the development (Oracle, 2009): rubbish in is rubbish out. According to Pugh & Soden it is best to use the experience and expertise of the project manager. Historical data can be deceptive since each project is unique (Pugh & Soden, 1986). Although, Hubbard denies this since there are limits to the value of experience because of a couple of reasons. Experience is memory based, and people are selective with what is remembered; without trustworthy feedback on earlier decisions it isn't possible to rely on experience; experience isn't random; logical errors can exist in conclusions from experience; people tend to be inconsistent in decision making, no matter their level of experience (Hubbard, 2009). This can be trained by using the calibration tests as presented by Hubbard.
2) *Taking in account both threats and opportunities*: when analyzing the risk events it is important to take both threats and opportunities into account to prevent the MC simulation results from being pessimistic. When only considering the threats, the project outcome estimation will only be affected negatively (Hillson & Simon, 2007).
3) *Correlations between risk events*: here not all PRM standards/guidelines mention it, it certainly is important to take correlations between risk events into account (Hillson & Simon, 2007), (Hubbard, 2009). A simulation that doesn't take correlations into account, will result in an unrealistic estimation of the risk events' combined effect. When a delay for one part of the project occurs, it will probably also occur for other parts of the projects e.g. because of a strike.
4) *Testing the method used*: It is important to test the quantitative risk analysis method that was used for previous projects to positively proof that the method works (Hubbard, 2009).

2.5. Which Type of Risk Analysis?

This sub-chapter discusses the use of qualitative risk analysis versus the use of quantitative risk analysis. Firstly, the view of the theory as presented in PRM guidelines and standards is shared. After that, an idea is provided of how qualitative risk analysis and, especially, quantitative risk analysis are received in practice.

2.5.1. According to Theory

If the purpose of the PRM is to get a list of risk events from most significant to least significant, a qualitative risk analysis would be sufficient. When a deeper understanding of the risk events is required, the assessment should be done in an extended form. The objective of a quantitative risk analysis is to provide a higher precision of the risk events' combined effect. An indication of the project risk can be provided and the effect of the risk events' response strategies on the project outcome can be estimated. This will ensure that the PRM's risk event treatment can be done as efficient as possible (Cooper, Grey, Raymond, & Walker, 2005), (Hillson & Simon, 2007), (Kendrick, 2003).

With the exception of Hillson & Simon (Hillson & Simon, 2007), the theory provides no additional information about when to use qualitative or quantitative risk analysis. Hillson & Simon do make a categorization between small, medium and large projects, each with a different level of PRM. Since the project size depends on many characteristics, ten to twelve criteria should be chosen to size the project. Examples of such criteria are strategic importance, technical complexity and project duration. Each organization should specify the characteristics for small, medium and large projects for its projects.

The levels of PRM for the different sized projects are (Hillson & Simon, 2007):

1) *Small*: The PRM process is integrated in the normal project management activities, no dedicated risk meetings take place. Only a qualitative risk analysis is done.
2) *Medium*: The PRM process is performed on a standard basis. A risk champion facilitates risk meetings, workshops, interviews and makes sure an ongoing PRM review is performed. Only a qualitative risk analysis is done.

3) *Large*: The PRM process of medium sized projects is extended with quantitative risk analysis and a more frequent review cycle. Both a qualitative and quantitative risk analysis is done.

2.5.2. *According to Practice*

In practice the risk event ranking, which can be viewed as qualitative risk analysis, is used 'from very limited to limited.' Besner & Hobbs have surveyed 750 project management practitioners, which has provided an insight into the actual use and perceived potential of project management techniques and tools. They scaled the use of project management tools from 'less than very limited', 'from very limited to limited' to 'from limited to extensive.' According to this research the risk ranking techniques and tools have an unrealized potential (Besner & Hobbs, 2008).

The very same research indicates that quantitative risk analysis techniques and tools are used 'less than very limited' and that it doesn't have potential to grow in the near future. This is true for probabilistic duration estimators, decision trees and MC simulations (Besner & Hobbs, 2008).

Four years earlier, in 2004, Galway interviewed several PRM researchers and practitioners on quantitative risk analysis since critical literature was missing. The conclusion was that quantitative project risk analysis is useful, although it is noted that project risk analysis (a) isn't clearly understood, (b) isn't well integrated into project management, (c) isn't easily explainable to senior decision makers, and (d) is too difficult and not worth the time and effort (Galway, 2004), (Hillson & Simon, 2007). The interviews also revealed that the evidence of quantitative risk analysis' usefulness are anecdotal: there was but little empirical evidence (Galway, 2004). The problem is that anecdotal evidence is not sufficient to conclude usefulness. However, Hubbard indicates the opposite: the occurrence of an extremely unusual event is no evidence that previously calculated estimates were wrong (Hubbard, 2009).

Hubbard discusses this because some argue that disasters such as Chernobyl or bridge collapses are evidence against quantitative risk analysis methods. This would then be evidence against qualitative and quantitative risk analysis methods since both were available. Nevertheless, the objective of quantitative risk analysis methods is not to predict the cause of an individual event, but to provide good estimates over time (Hubbard, 2009).

Galway's interview results also showed some discrepancy about whether to use qualitative or quantitative risk analysis. There was one respondent who indicated that the existence of the MC method in the risk analysis tool increased its complexity in such a way that it didn't increase the tool's usefulness. Another respondent indicated that he wasn't aware of the existence of a qualitative analysis tool that provided the same insight into the schedule as a simple quantitative analysis tool. Explicit criteria of when to use quantitative risk analysis is missing (Galway, 2004).

What is discussed by Hubbard and Galway indicates that there is a lot of misunderstanding towards quantitative risk analysis. Where ignorance is bliss, 'tis folly to be wise.

When considering why to use quantitative risk analysis methods a distinction can be made between the accuracy of the simulation results and the utility to structured thinking. When using quantitative risk analysis because of its accuracy, it's the specific estimated impact the risk events do have on the project objectives that counts. When using quantitative risk analysis for the utility of structured thinking, it is so because quantitative risk analysis forces one to think harder about several aspects of the project, i.e. numbers are added to the risk events' probabilities and impacts. Besides, it challenges to discuss/argue different ideas and perceptions with colleagues. This distinction can be found in some of the theory as well, although not one mentions it is structured thinking that makes the quantitative risk analysis methods useful (Galway, 2004).

Research on oil exploration firms was done by Fiona MacMillan, as Hubbard describes, indicating a strong correlation between the extensive use of quantitative risk analysis and the company's financial performance. The companies' financial performance improved just after additional quantitative methods were adopted (Hubbard, 2009). It is unclear whether the quantitative risk analysis was done on project or company level, and if the improved performance is because of a better accuracy or because of more structured thinking. However, it at least provides some evidence of the usefulness since quantitative methods are not often used in companies (Hubbard, 2009).

Although Besner & Hobbs (Besner & Hobbs, 2008) have created the same perception problem as with the risk scoring ranges – *'I mean how much is 'from very limited to limited use?'* – it can be concluded that on project level qualitative risk analysis techniques and tools are used more frequently than quantitative risk analysis techniques and tools. This can also be concluded from two reviewed studies (Wyk, Bowen, & Akintoye, 2008), (Taylor, 2005). Besides, the research indicates qualitative risk analysis has the potential to grow in the near future whereas quantitative risk analysis doesn't.

Hence, it can be concluded that the use of quantitative risk analysis can be useful, only empirical evidence is missing. When looking at the techniques and tools used by project management practitioners, the use of quantitative risk analysis methods is small and lacks potential for growth.

2.6. Plan of Approach for the Case Study

Now that the theory of PRM is known and an elaboration on qualitative and quantitative risk analysis has been provided, it is time to elaborate on the plan of approach to answer the remaining research sub questions. Those answers will lead towards the answers to the main research questions.

The research framework in figure 1.3 presents the steps towards the final analysis of HMC's current and former PRM methods versus the PRM literature. The activities done and the structure of analyzing are presented in both HMC's current PRM method and HMC's former PRM method.

2.6.1. HMC's Current PRM Method

Figure 2.13 presents the case study steps related to HMC's current PRM method. The following case study procedures are performed to get information:

1) *Procedure Documents*: several procedures, including the procedure for risk management on tenders and projects, of HMC are used to analyse HMC's current PRM procedure (Bree, 2009), (Bree, 2010), (Zwart, 2010).
2) *Semi-Structured Interviews*: the information needed to compare HMC's current PRM procedure, HMC's current PRM practice, and the PRM literature is mainly based on the interviews done within HMC. Thirteen project managers, the Vice President of Project Management and the Manager of Planning have been interviewed. The interviews are divided into two parts: the first part of the interviews is related to the current PRM method. The interview questions, related to the points of analysis in the research framework, are presented in Appendix B.1.1. The interview results are documented in Appendix C.
3) *Attended Risk Assessment Workshops*: information is gathered by attending three risk assessment workshops. This info is used as additional information to make the comparison between HMC's current PRM procedure, HMC's current PRM practice, and the PRM literature. The observations are documented in Appendix D.
4) *Risk Register Survey*: The project managers were asked to complete a risk register by indicating the consequence of the pre-formulated risk event and assessing the likelihood and impact score. In total ten risk events had to be completed, five for a relatively simple T&I project and five for a more difficult engineering and installation project. Ten project managers completed the risk register survey. The results are used to try to validate the shortcomings, i.e. the biases and subjectivity, in defining the risk event's probability and impact as discussed in the literature. This is done by analyzing HMC's qualitative risk analysis tool in practice. Besides, the survey results are also used to compare HMC's risk event documenting method and the metalanguage as presented in the PRM literature. The risk register survey format is presented in Appendix B.2, the results are documented in Appendix E.

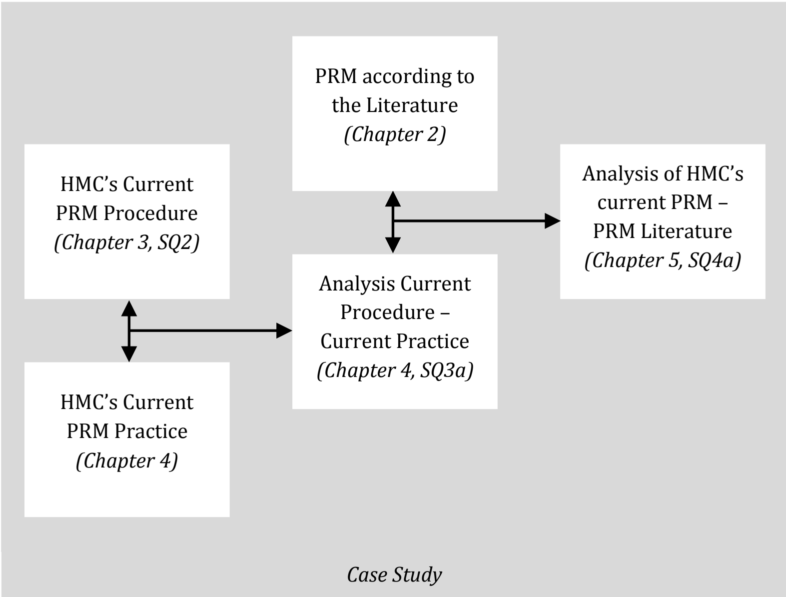


Figure 2.13: Part of the research framework (figure 1.3) related to HMC's current PRM method

The evaluation framework used to describe HMC's current PRM method in Chapter 3, 4 and 5 is as follows:

1) *PRM Initiation*
2) *Risk Assessment Workshop*
3) *Risk Event Identification*
4) *Qualitative Risk Analysis*
5) *Response Planning*
6) *Risk Documenting*
7) *PRM Review and Update*
8) *Risk Reporting to Upper Management*
9) *Health, Safety and Environment Risk Assessment*
10) *Project Feedback and Close Out*
11) *The Functioning of the Current PRM Method* (only in Chapter 4 and 5)

2.6.2. HMC's Former PRM Method

Figure 2.14 presents the case study steps related to HMC's former PRM method. The following case study procedure is used to get necessary information:

1) *Semi-Structured Interviews*: the information needed to compare HMC's former PRM practice, HMC's current PRM practice, and the PRM literature is based on the interviews done within HMC. Thirteen project managers, the Vice President of Project Management, and two former risk team members are interviewed. The interviews with the project managers and the Vice President of Project Management are divided into two parts. The second part of the interviews is related to the former PRM method. The interviews with the two former risk team members were completely dedicated to HMC's former PRM method. The interview questions, related to the points of analysis in the research framework, are presented in Appendix B.1.1 and B.1.2. The interview results are documented in Appendix C.

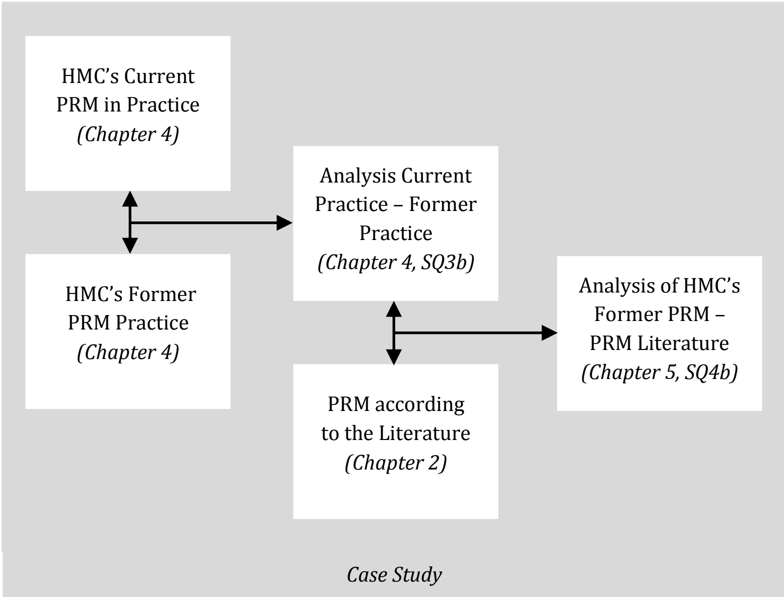


Figure 2.14: Part of the research framework (figure 1.3) related to HMC's former PRM method

The risk team had two roles in the PRM process. Firstly the facilitating role of the risk assessment workshops and the periodical review moments, and secondly the simulations of the project's future estimations based on quantitative risk analysis. These are the biggest differences with HMC's current PRM method, the other PRM activities are almost similar. Therefore, the analysis is solely focused on the former risk team's facilitating role and the additional use of quantitative risk analysis.

The evaluation framework used to describe HMC's former PRM method in Chapter 4 and 5 is as follows:

1) *Risk Team's Facilitating Role*
2) *Quantitative Risk Analysis*
3) *The Functioning of the Former PRM Method*

CHAPTER 3: HMC'S CURRENT PROJECT RISK MANAGEMENT PROCEDURE

This chapter will answer the question *'What is HMC's current project risk management procedure?'* The PRM has a link with three of HMC's procedures. The first is Risk Management for Tenders & Projects, which is the main PRM procedure. The second is monthly Progress Status Report (PSR) meetings in which exposures and opportunities are reported. And the third is the Health, Safety and Environment (HSE) Risk Assessment. This chapter will present HMC's PRM procedure and its link with the PSR and HSE procedure.

Risk Management for Tenders & Projects (Bree, 2010)	Monthly Progress Status Reports; Exposures and Opportunities (Zwart, 2010)	Health Safety and Environment Risk Assessment (Ketel, 2010)

Figure 3.1: HMC's activities related to PRM

3.1. HMC'S CURRENT PRM METHOD

HMC defines PRM as 'the process of identifying, assessing, monitoring, mitigating and reporting risk', where risk is 'an event or circumstance which, if it occurs, could affect the expected outcome both in terms of opportunity and exposure.' An opportunity when positively affecting the project objectives and an exposure when negatively affecting the project objectives (Bree, 2010). From now on a risk event will be divided in exposure and opportunity, instead of threat and opportunity as used in the PRM literature.

At the moment the contract is awarded, the tender phase moves into the project phase. The tender phase has a risk process that is similar to the project phase, including a risk assessment workshop. Risk management in the tender phase is reported in a risk register which will be handed over to the project manager. This will be the input for the PRM process. The process is shown in figure 3.2.

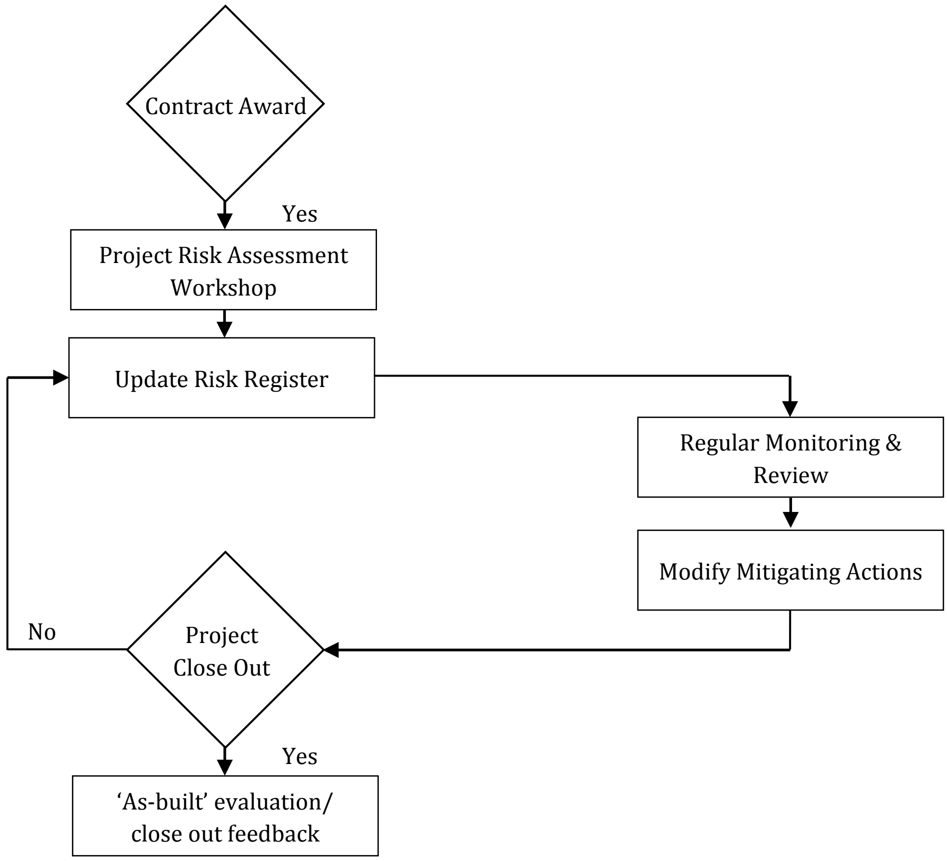


Figure 3.2: HMC's PRM process (Bree, 2010)

According to HMC's PRM procedure, the PRM starts with a risk assessment workshop and finishes with project feedback and close out. The remainder of this chapter will present the PRM activities as required according to HMC's current PRM procedure ('SOLL') based on the evaluation framework as presented in Chapter 2.6.

3.1.1. PRM INITIATION

HMC's PRM procedure presents different depth levels of PRM depending on the revenue value and/or the existence of special risk events. HMC's project sizing tool is as follows:

1) Revenue <$30M – a simplified risk assessment using a qualitative risk workshop by the Project Manager, Project Team using standard templates.
2) Revenue $30M - $75M – a standard risk assessment using a qualitative risk workshop by the Project Manager, Project Team, and appropriate specialists.
3) Revenue >$75M or with Special Risk – an extensive risk assessment using qualitative risk workshops for each specific topic by the Project Manager, Project Team, and appropriate specialists.

A project team typically includes a Project Controller (monitoring, forecasting and reporting all financial matters), Project Engineer, Project Secretary, Document Controller, Engineers (for detailed engineering), Planner, Purchasing & Subcontracting Coordinators, Operational Manager (responsible for all arrangements regarding the SSCVs), QESH (Quality, Safety, Environment and Health) Coordinator, Welding/Quality Control Coordinators, and Equipment Management Coordinators (Bree, 2009).

The PRM responsibilities within the organization are as follows:

1) *Vice President of Project Management*: reviews the risk register together with the project manager and approves the risk acceptance, controls and mitigation.
2) *Project Manager*: responsible for the risk meetings, with participation of the project team, to identify risk events and evaluate probable impact on cost, schedule and quality. Responsible for the development of mitigation actions for all opportunities and exposures. Has to monitor and mitigate the risk events and ensures the risk register is kept up to date.
3) *Project Controller*: responsible for the provision of the budget information necessary for a quantitative risk assessment. Has to translate the risk model output into exposures and opportunities for the PSR.

3.1.2. RISK ASSESSMENT WORKSHOP

The PRM process starts with a Project Risk Assessment Workshop within two to three months after the formal hand-over. HMC's aim with the project risk assessment workshop is to identify both the project's opportunities and exposures, assess them and identify the mitigation actions. The results are documented in the project risk register. The events will be categorized based on the relevant WBS, e.g. in Project Management, Engineering, Preparations, Procurement, etc. The workshop consists of the following phases:

1) *Introduction (±10 min by facilitator)*: the PRM process and reporting method will be introduced to the workshop participants. Additional attention is given to the definition of 'risk' treating both opportunities and exposures.
2) *The project and the objectives (±20 min by the project manager)*: the project manager will present the scope of work, project constraints and assumptions, the project objectives, key milestones, permits/consents, and the role of the key stakeholders.
3) *Risk identification (±90-120 min in total)*: is done in three phases. First: an individual brainstorm (±5-10 min). Second: sharing the identified risk events in a small group of at least three persons (±20 min). Third: a full group sharing.
4) *Assessment of the risk events (±60 min)*: the risk statement sheets (Appendix A.3) are completed in small groups of at least three persons. The project manager composes these groups based on specialism or cross-discipline. If agreed on the groups, the risk statements will be created. It is

required that the opportunities and exposures are related to the affected project objectives and constraints. Finally, the opportunity's or exposure's likelihood and impact is scored based on the Risk Evaluation Matrix (REM), figure 3.3. The risk statement is ranked by the risk factor.

5) *Identification of mitigation actions (±60 min)*: in a full group brainstorm possible mitigation actions are identified. This discussion starts with the highest scored risk event and works its way down to the lowest scored risk event.

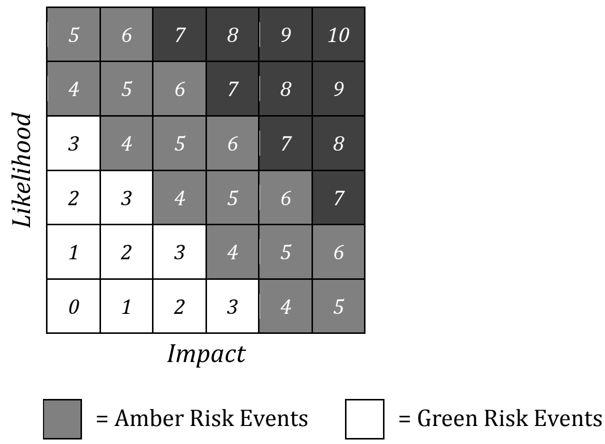
3.1.3. *Risk Event Identification*

Possible risk events are identified by using the following techniques:

1) Risk workshops with key personnel, i.e. the risk assessment workshop.
2) Interviews with responsible personnel in specific risk areas.
3) Reviewing project close outs and other historical data.
4) Utilizing standard templates where appropriate.

3.1.4. *Qualitative Risk Analysis*

The risk events' likelihood and impact scores are identified using the risk rating benchmarks as presented in figure 3.3. The events will be prioritized based on the risk factor: the sum of the likelihood and impact score. The risk factor corresponds with one of the cubes in the Risk Evaluation Matrix (REM).



	Likelihood
5	Happens once every month (50%)
4	Happens twice every year (10%)
3	Happens once a year (5%)
2	Happened once in the last 5 years (1%)
1	Has happened in the last 10 years (0,5%)
0	Never happened yet worldwide (0,2%)

	Impact
5	*Very high* – major financial gain or loss, improvement or failure on almost all project objectives, major delay or schedule improvement
4	*High* – significant financial gain or loss, improvement or failure on most project objectives, significant delay or schedule improvement
3	*Medium* – Serious threat to, or improvement on, project objectives
2	*Low* – Small effect on project outcomes
1	*Very Low* – Very small effect on project outcomes
0	*No effect on project outcomes*

Figure 3.3: HMC's Risk Evaluation Matrix (Bree, 2010)

3.1.5. *Response Planning*

The mitigation actions will be identified during the risk assessment workshop. The top ten opportunities and exposures, which follows from the risk evaluation, need focused attention. The mitigation actions should have at least one of the following effects:

1) The mitigation action should reduce the impact of the exposure or increase the impact of the opportunity.

2) The mitigation action should reduce the probability of the exposure occurring or increase the probability of the opportunity arising.
3) The mitigation action should improve understanding of the nature and scale of the opportunities and exposures.

3.1.6. Risk Documenting

The risk register is used to control and monitor the risk events on project level. This register reports the identified risk event's cause, effect and consequence. The identified risk events are prioritized by the risk factor. The mitigation actions and the responsible person/department is presented as well. Table 3.1 shows the format of HMC's risk register.

Risk Id Number	*Cause (There is an event that...)*	*Effect (that will result in...)*	*Consequence (budgetary)*	*Likelihood score (1-5)*	*impact*	*Score*	*Mitigation/ action*	*Person/ Department tasked*
xxx001								
xxx002								
xxx003								

Table 3.1: HMC's Risk Register format (Bree, 2010)

3.1.7. PRM Review and Update

The PRM is an ongoing process; both opportunities and exposures are identified and assessed, mitigation actions are developed and where possible conducted, and the risk register is kept up to date. This process stops when the project is finished. Figure 3.4 shows the flow diagram of the risk process.

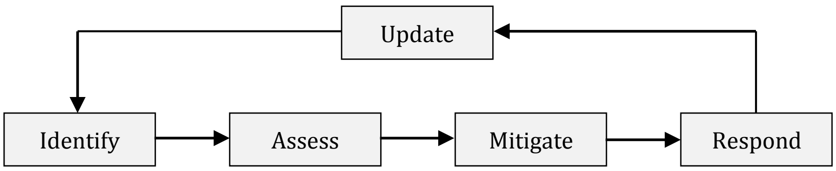


Figure 3.4: Risk process flow diagram (Bree, 2010)

Hence, the project manager is responsible for updating the risk register on an ongoing basis, at least once a month. The update should be performed seven days before the PSR meeting. The top ten risk events have to be included in the PSR as opportunities and exposures.

3.1.8. Risk Reporting to Upper Management

The project manager prepares a PSR each month. This is the basis for the monthly PSR meeting with the Vice President of Project Management, Head of Project Control and the Board of Directors. A part of the report consists of the Monthly Project Opportunities and Exposures Report, prepared by the project controller in consultation with the project manager. This report describes all the potential revenues and the top ten highest scored risk events. The percentage of occurrence, estimated cost impact, if applicable the delays in days and the year of potential occurrence is presented in the report. This results in a financial forecast.

Table 3.2 is an example of an opportunity and exposure report. In the upper table the materialized opportunities and exposures are presented, i.e. the ones that have occurred. The table in the middle presents the top ten opportunities and exposures with their corresponding probability, cost impact and, where applicable, time impact. The tables on the left present the estimated impact at the time of occurrence (at 100%) and the tables on the right present the calculated impact with respect to the probability of occurrence. The lowest table provides the total project results per year. The following abbreviations are used:

1) *Rev $*: The revenues, in US Dollars.
2) *Direct $*: The direct money involved, in US Dollars.

3) *Alloc*: Allocations, the cost for using HMC's equipment (vessels, tugs, etc.) and associated man-hours in US Dollars.
4) *SSCV/DCV days*: The days HMC's vessels, tugs, etc. are delayed.
5) *P.R.$*: Provisional Result, the calculated outcome.

An exposure can be recognized based on the negative project cost outcome (*P.R.$*) and/or number of days delayed. An opportunity can be recognized based on the positive project cost outcome (*P.R.$*) and/or the number of days advanced. The unidentified opportunities are those opportunities that unexpectedly have occurred.

Materialized			%	AT 100% Rev$	Direct$	Alloc.	SSCV/DCV days	P.R.$	Prev. Month P.R.$	Variance P.R.$
1	Risk event 001	2010	100%		75		1.3	-75	-75	
2	Risk event 002	2010	100%		300			-300	-300	
3	Risk event 003	2010	100%		50		2	-50	-50	
4	Risk event 004	2010	100%	325				325	325	
5	Risk event 005	2011	100%		12			-12		12
6	Risk event 006	2011	100%	82		80	1.5	2	4	2
				407	**437**	**80**		**-110**	**-96**	**14**

2011		%	AT 100% Rev$	Direct$	Alloc.	SSCV/DCV days	P.R.$	CALCULATED Rev$	Direct$	Alloc	SSCV/DCV days	P.R.$	Prev. Month P.R.$
1	Risk event 007	99%		15			-15		15			-15	-15
2	Risk event 008	25%		60			-60		15			-15	-15
3	Risk event 009	80%	15				15	12				12	12
4	Risk event 010	10%	432	28	176	0.5	228	43	3	18	0.05	22	22
5	Risk event 011	90%			50		-50			45		-45	-50
6	Risk event 012	1%		140	250	6	-390		14	25	0.6	-39	-39
7	Risk event 013	60%		60			-60		36			-36	
8	Risk event 014	45%		200		1	-200		90		0.45	-90	
9	Risk event 015	25%		-52	57		-5		-13	14		-1	
10	Risk event 016	50%	241	233			8	121	117			4	10
Total identified opportunities			688	684	533		-529	176	277	102		-203	-75
Unidentified opportunities													15
			688	**684**	**533**		**-529**	**176**	**277**	**102**		**-203**	**-60**

Total Project	%	AT 100% Rev$	Direct$	Alloc.	SSCV/DCV days	P.R.$	CALCULATED Rev$	Direct$	Alloc	SSCV/DCV days	P.R.$	Prev. Month P.R.$
2010		21	110	51		-140	8	51	14		-57	-57
2011		668	684	533		-529	176	227	102		-203	-75
Total identified opportunities												
2010												
2011												15
Unidentified opportunities												
		689	**794**	**584**		**-669**	**184**	**278**	**116**		**-260**	**-117**

Table 3.2: Example of opportunities and exposures report in the PSR (Zwart, 2010)

3.1.9. *HEALTH, SAFETY AND ENVIRONMENT RISK ASSESSMENT*

For each project a number of Health, Safety and Environment (HSE) risk assessments are performed to make sure the HSE risk is as small as possible. Those meetings are called HSE Hazard Identification and Assessment (HAZID), but since the operational project procedures are often discussed, the term Hazardous Operability study (HAZOP) is also used.

During the HAZID/HAZOP meetings, potential hazards are identified, ranging from occupational hazards such as slipping, falling and electrocution, to major hazards, like the risk of a collision or dropped load. If possible, action is taken to reduce the frequency of occurrence and/or the impact of occurrences. Hazards are the events that cause injury to or death of personnel, damage to or loss of vessel and/or equipment, and/or environmental damage.

3.1.10. *Project Feedback and Close Out*

During the project close out the project manager and project controller will report how the identified risk events have been mitigated and will formally close the risk register. This information is shared with the Sales & Business Development (S&BD) department that is responsible for the tenders.

3.2. Conclusions

HMC's PRM procedure format isn't really structured. Therefore, it was a puzzle to present HMC's procedure according the established framework of evaluation. For example, two different flow diagrams are used (figure 3.2 and figure 3.4) that definitely have a relation with each other. Nevertheless, the relation doesn't become clear from HMC's PRM procedure.

The PRM procedure also isn't complete. The risk ownership isn't discussed and the response strategies as presented are not complete. Furthermore, several tools, methods and techniques used differ from the same kind of tools in the PRM literature. This will be further discussed in Chapter 5 which compares HMC's PRM procedure and practice with the PRM literature.

CHAPTER 4: HMC'S PROJECT RISK MANAGEMENT PRACTICE VERSUS HMC'S PROJECT RISK MANAGEMENT PROCEDURE

HMC's PRM procedure ('SOLL'), as presented in Chapter 3, and practice ('IST') are compared by using the methodology as described in the first chapter. This chapter is divided in two parts, the first answering the question *'How does HMC's current project risk management practice differ from HMC's current project risk management procedure?'* and the second answering the question *'How does HMC's former project risk management practice, with risk team and quantitative risk analysis, differ from HMC's current project risk management practice?'* In this chapter, and the upcoming chapters, references are made to the interviews performed and risk assessment workshops attended. This is referred to as (C.#) and (D.#) meaning Appendix C and Appendix D and the corresponding sub-part.

4.1. HMC'S CURRENT PRM METHOD

4.1.1. PRM INITIATION

None of the interviewed project managers has mentioned HMC's project sizing tool as presented in Chapter 3.1.1. Four of the project managers were asked how they started the PRM process; only one mentioned starting the PRM process with planning the risk assessment workshop on that moment the scope of work is sufficiently known (C.9), the others just started with the PRM activities (C.11, C.12, C.13). Hence, in practice the depth level of the PRM method isn't determined as required by HMC's procedure. Nevertheless, several project managers indicate the PRM activities could differ per project, e.g. whether to execute a risk assessment workshop or not (C.4, C.8). This indicates the PRM initiation step is done during the execution of the PRM process.

4.1.2. RISK ASSESSMENT WORKSHOP

Of the thirteen interviewed project managers one indicates not using a risk assessment workshop in the PRM process (C.3). C.3 is a highly experienced project manager and works mainly on T&I projects. According C.3 reviewing the contract is enough to establish a risk register. For two other project managers it depends on the project complexity a risk assessment workshop is used. The other project managers always start the PRM activities with a workshop (C.4, C.8).

Where the PRM procedure indicates the workshop should be done within two to three months it becomes clear from the interviews it is more significant to do the workshop at the moment the scope of work is sufficiently known (C.9). From the project team it most often are the project manager, project engineer(s), (specialist) engineer(s) and operational manager(s) that are participating (C.4, C.8, D.1, D.2, D.3). Some project managers invite specialist outside the project for an unmarked project view (C.4). Another project manager specifies the workshop results are equal when inviting a large group of people or only the people strictly needed (C.8). Although, it always is the question if the invited people also show up (C.8, D.2, D.3).

Almost all the project managers that started a new project after the abandonment of the risk team, still use the same structure to perform the risk assessment workshop, i.e. the structure as developed by the risk team. In practice the workshop starts with an introduction describing the PRM activities and an introduction of the project's scope of work and objectives. Subsequently, the participants are asked to individually identify risk events by brainstorming and writing them down on sticky notes (C.4, C.9, C.12, C.14, D.2, D.3). This way of individual brainstorming was initiated by the former risk team, this ensured the more shy people also took part in the risk event identification (C.15). Afterwards, the identified risk events are discussed and ordered to content in a full group sharing (C.5, C.9, C.11, C.12, C.14, D.2, D.3). Some project managers do it differently by (a) starting the first brainstorm in small groups (C.4), (b) discussing the individually identified risk events only in small groups (C.7), or (c) ask the participants to do the individual brainstorming before the workshop and immediately start with a full group discussion (C.8). Where the procedure asks for individual brainstorming, followed by small group sharing and finally a full group sharing, none of the project managers perform those steps precise. Although, two of the three steps are performed during all the workshops.

The procedure says the qualitative risk analysis has to be done in small groups during the workshop. In practice the objective is to do the qualitative risk analysis during the workshop, although it regularly is postponed till after the workshop (C.5, C.7, C.9, D.2). This because of time shortage during the workshop (C.7) or because the group is too large (C.9). If done after the workshop it is in consultation with the project manager and project engineer.

According the procedure the identification of the mitigation actions also should be done during the workshop. Although, the mitigation actions are often identified at a later stage in consultation with the risk owner (C.4, C.7, C.9, C.12, D.2, D.3). This because it takes too much time during the workshop. Besides, most of the project managers see the risk event identification as the most important action during the workshop.

During the workshop a risk statement sheet is used to report the identified risk events (Appendix A.3). All the risk statement sheets together will form the risk register.

4.1.3. Risk Event Identification

Besides the brainstorming techniques as used in the risk assessment workshop, the project managers review the contract (C.3, C.11), the tender phase risk register and other hand-over documents (C.4, C.10, C.8, C.11, C.12) to identify risk events. This together with the risk assessment workshop results in an ordered risk register which is the foundation of the risk process during the project.

In HMC's PRM procedure it's written that there should be a focus on identifying both exposures and opportunities. In practice it are especially exposures that are identified (C.13, C.14). This also noticed in the risk assessment workshops attended (D.2, D.3) and from the risk registers reviewed. The risk registers reviewed are presenting far more exposures than opportunities.

In HMC's PRM practice difficulties are experienced in identified risk events with a really small likelihood and a very large impact, e.g. *'the sinking of a vessel'* (C.12), (C.13). But, also the risk events with a cause similar to *'adverse weather'* raises questions since it e.g. is included in the contract (C.4). The Vice President of Project Management gives the answer to this indistinctness; these risk events shouldn't be included in the PRM, this because it are risk events on corporate level instead of risk events on project level (C.18). Though, this isn't known by all the project managers. If it is possible to manage a corporate risk event on project level, the risk event should be included on project level, e.g. when it is possible to sail a different route with HMC's vessel to reduce the chance of occurrence of a delay because of adverse weather.

4.1.4. Qualitative Risk Analysis

The assessment is done based on HMC's Risk Evaluation Matrix (REM) (Appendix A.2). Almost all project managers have indicated that the assessment, based on the REM, is subjective (C.3, C.4, C.5, C.8, C.9, C.12). One project manager even indicates classifying the risk events by pair-wise comparison instead of using the REM (C.8).

Another remarkable contradiction is that there is a project manager that adjusts the risk events' likelihood and impact scores after the group discussion, this because the scores may differ from the project manager's experience (C.12). Other project managers believe it is better to do the qualitative risk analysis in a group creating a weighted average (C.7, C.9, C.11, D.1, D.3).

No factual data is used for the identification of the risk events' likelihood and impact. It is totally based on the experience of the people involved in the qualitative risk analysis (C.7).

4.1.5. Response Planning

As already indicated, the identification of the mitigation actions often is done after the risk assessment workshop. The mitigation actions are identified in consultation with the responsible person, i.e. the person best able managing the risk event (C.5). Though, eventually the project manager stays in control of all the risk events. One of the project managers (C.10) indicates the following possible actions:

1) Trying to reduce the exposure
2) Trying to transfer the risk event to the client
3) Trying to enhance the opportunity
4) Trying to economize on the project costs in the case of a lump sum contract or get additional work in the case of a reimbursable contract.

The second and fourth bullet point are not presented in HMC's PRM procedure. Those are the response strategies focused on transferring the risk event's impact to the client.

The risk event's likelihood and impact scores are not directly adjusted based on the identified mitigation actions (C.4, C.5).

4.1.6. Risk Documenting

During the risk assessment workshop the risk statement sheets (Appendix A.3) are completed. Those sheets are documented in HMC's risk register format. The risk register is used by the project team to get an idea of the project's future (C.7).

HMC's PRM procedure asks to document the cause, effect and consequence of an identified risk event. This by completing the sentence: '*There is an event that <cause>, that will result in <effect>*.' In practice, the consequence is defined in relation to schedule, costs, revenues and/or reputation of the project (Appendix A.3). It should be indicated if the consequence is an exposure (-), an opportunity (+), or both (±). This way of defining the consequence is most often used in the reviewed risk registers.

One of the project managers indicate the risk register is only made once, just after the risk assessment workshop. If new risk events pop up it only is updated in the PSR (C.5).

4.1.7. PRM Review and Update

According the procedure the risk register should be reviewed on a continuous basis and at least seven days before each monthly PSR meeting. This is done to check if the earlier identified risk events are still active and if there are possible new risk events to identify (C.12). The project managers working on HMC's only EPIC project review all risk events each month since they use the PSR as their risk register (C.2, C.10). A recently appointed project manager, working on a T&I project, is aiming to review the risk register more often than once a month (C.11), though it is not yet realized in practice since C.11 is at the start of his first PRM process. Most of the project managers indicate that it is the aim to review the risk register each month. Nevertheless, the high workload causes it is only done each two to three months (C.5, C.7, C.9, C.14), or each three to six months (C.12, D.2).

4.1.8. Risk Reporting to Upper Management

The monthly PSR meeting is the only way the project's risk events are reported to the Board of Directors, Vice President of Project Management, and the Head Project Control. The project manager explains the changes in the project and discusses the reported exposures and opportunities in detail. This meetings are also used to agree upon the mitigation actions planned. The sum of the reported exposures and opportunities provides an indication of the total impact. The risk register is used internally in the project team. Even though it's described in HMC's PRM procedure, the Vice President of Project Management doesn't review the risk register (C.18).

Where the procedure is to report the top ten highest scored risk events in the PSR a distinction can be made between HMC's large EPIC project of this moment, Block 31, and the T&I and EPRD projects in practice. All identified risk events in the large EPIC project are reported as exposures and opportunities in the PSR (C.2, C,10). Also the Aegir new build vessel project has the objective to report all identified risk events in the PSR in the near future (C.14). The probability of the risk event occurring can be adjusted regarding the changed project characteristics each month. The cost impact is determined at the risk event's first identification in cooperation with the cost estimator. At the moment the probability becomes close to 100% it is important to check the identified cost impact again (C.14).

For the T&I and EPRD projects it is more divided in (a) reporting the top ten highest scored risk events (C.11, C.13), (b) the most important risk events and the ones of which money is involved (C.3, C.5, C.8, C.12) to (c) only reporting those risk events of which money is involved (C.4, C.7, C.9), i.e. already had financial impact for e.g. the performed mitigation actions or contractual problems. Figure 4.1 presents the number of project managers related to the way the PSR is used to report which identified risk events.

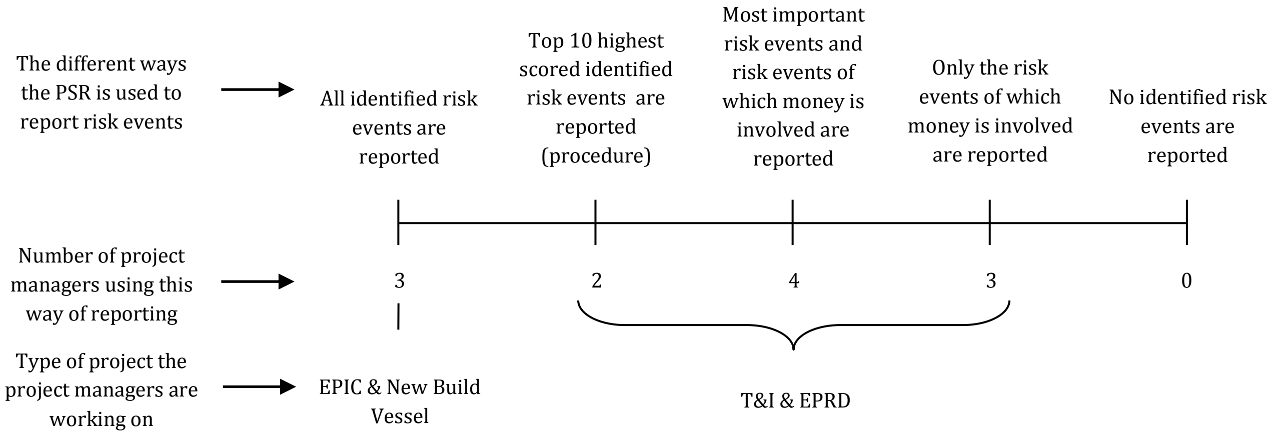


Figure 4.1: Distribution of how the project managers report identified risk events in the PSR

The project managers working on HMC's large EPIC project use the PSR as the only register to document the identified risk events. The other project managers do have a risk register which is used parallel with the PSR. The PSR is seen as the direct financial management were the risk register is used as forecast for the project's future (C.7).

The exposure and opportunity register is used to get an indication of the project risk, i.e. the accumulated impact of the reported risk events (C.10, C.12, C.14, C.18). Though, some project managers indicate it either is very difficult to get an indication of the project risk (C.13), or the project risk estimation is relatively vague since the main focus is on the project's exposures (C.14).

It is clear that not all the project managers link the PRM with the PSR as intended by HMC's PRM procedure. This probably because some don't know it is in the procedure (C.4, C.7, C.17), or even some don't know there is a PRM procedure (C.11). Furthermore, the Vice President of Project Management indicates that the request to report the top ten highest scored risk events in the PSR was random decision (C.18).

4.1.9. Health, Safety and Environment Risk Assessment

The HAZID/HAZOP meetings are between a few months till a few weeks before execution. Those meetings are focused on the hazards related to safety and environmental issues during the project execution (C4, C.8, C.9). The link between the regular PRM and the HAZID/HAZOP is only small, i.e. if money is involved in the mitigation actions of the identified hazards it is updated as exposure or opportunity in the PSR. It also is possible new information or another project view leads to identifying new risk events. If so, those new risk events are taken in account in the regular PRM process (C.9, C.10, C.12).

Though, one of the workshops I observed (D.1) was a combination of a HAZID and a normal risk assessment workshop. The objective of this meeting was to inspire confidence by the client. Already identified risk events and hazards were discussed, and new risk events and hazards were identified. In this particular meeting there was a high link between the two pursuits. This also was visible in the risk register, seven of the sixteen reported events were hazards.

4.1.10. Project Feedback and Close Out

The risk process stops with the feedback and close out meeting in which the risk events that have been mitigated during the project are discussed. In practice the project managers most often refer to it as reporting the 'lessons-learned', i.e. the risk events that have occurred are discussed (C.5, C.7). If the project feedback and close out is done (C.8), it is in doubt if it is used afterwards (C.4, C.12).

It is slightly different in HMC's current EPRD project. Every year, the EPRD group looks back at the projects finished to adjust the budget for the upcoming year. An estimation of the financial risk events' impact is made and the lessons learned are reported. This is used as input for the upcoming PRM processes (C.13).

4.1.11. The Functioning of the Current Project Risk Management Method

Most of the project managers have indicated HMC's current PRM method as insufficient, this because of time shortage. The current work pressure is too high to sufficiently do all the PRM activities (C.6, C.7, C.8, C.9, C.12, C.13). Besides, according some project managers the discipline to do the PRM activities is lower since the abandonment of the risk team (C.4, C.7, C.11, C.12).

Two of the project managers indicate it is not totally clear how the PRM procedure works (C.9, C.11). The people responsible for the PRM are not trained in all the risk assessment activities (C.9). This are relatively new project managers which are appointed after the abandonment of the risk team. Hence, didn't get the support other project managers did get from the risk team in the past. Also an experienced project manager has indicated the current PRM guidelines are not totally clear (C.10).

A couple of project managers have indicated that the PRM activities also should be further extended for more complex, uncertain and/or new types of projects (C.3, C.4, C.5, C.7). The extension proposed may include additional quantitative risk analysis for e.g. the more complex EPIC and EPRD projects (C.3, C.4, C.7, C.12) or may include additional workshops and more review moments (C.5). Interesting to mention is that it are the project managers on the relatively simple T&I projects proposing such an extended process where the project managers of HMC's more difficult and complex EPIC project (C.2, C.10) and of the complex new built vessel project (C.14) are satisfied with the current PRM process. It also are those three project managers interviewed (C.2, C.10, C.14) who are reporting, or going to report, all risk events as exposures and opportunities in the monthly PSR.

Also the Vice President of Project Management thinks the current PRM process is functioning well enough. In the last 5,5 years 180 projects have been finished of which only one finished with a loss. Almost all other projects finished within the budget, i.e. five other projects overran the budget, but still finished with a profit (C.18).

4.2. HMC's Former PRM Method

The risk team, abandoned in September 2009, has contributed to the PRM procedure currently used. At the start of the risk team, in September 2006, the team was not yet experienced in PRM. Though, the PRM process rapidly developed (C.15, C.17). In this analysis the former PRM practice is reviewed over the period it was functioning the 'best.'

The risk team did have two roles in the PRM process: (a) the facilitating role of the risk assessment workshops and the periodically review moments, and (b) the simulations of the identified risk events' combined effect by the use of quantitative risk analysis (C.1, C.15, C.17). Both the facilitating role and the quantitative risk analysis are not present in HMC's current PRM procedure.

In this sub-chapter the PRM activities that are different from the current PRM practice are discussed. This is done based on the evaluation framework as presented in Chapter 2.6. Hence, the differences are allocated to the risk team's facilitating role and the use of quantitative risk analysis.

4.2.1. Risk Team's Facilitating Role

The facilitating role was required to get the input for the MC simulations. In the beginning this was done with open discussions in consultation with the project team. It was a laborious process with an undesired result. This caused the risk team developed a format for the risk assessment workshop as it still is included in HMC's PRM procedure (Chapter 3.1.2), (C.1, C.15, C.17). This with the difference that the risk team did have a facilitating role (C.5, C.7, C.10, C.12). The risk team organized the workshop, explained the PRM activities and guided the participants through the workshop.

After the workshop was finished and the MC simulation results were shared with the project manager the risk process started. The risk team invited the project manager each month to review the top ten risk events, and each three months to review the total risk register with the MC method (C.15). The project managers highly appreciated the risk team's reminders to and facilitation of the monthly risk meetings. Despite the high workload more time was available for the risk meetings (C.4, C.7, C.11, C.12). The MC simulation was repeated each three to six months (C3, C.5), although it partly depended on the project manager's acceptance towards the MC method if those reviews were done (C.3).

4.2.2. *QUANTITATIVE RISK ANALYSIS*

After the risk assessment workshop the input for the MC simulation was prepared. This was done in consultation with the risk team and the project manager (C.1). The input was based on the project manager's experience. The range of the time and cost impact, and the related distributions of all identified risk events were determined. The output was an eye-ball plot which did put the project's additional vessel days against the extra money needed (C.15).

Figure 4.2 shows such an eye-ball plot of the project outcome, this including the planned response strategies (i.e. after mitigations). This estimation indicates the project probably will cost a bit more than planned, though the vessel will be in use for approximately seven additional days. The size of the eye-ball gives an indication of the project risk's magnitude. To get an indication: for this particular plot it is important to investigate the cause of the dots at the lower right. It is also possible to compare (a) the project outcome estimation including the risk events' response strategies with (b) the project outcome excluding the response strategies, this providing an indication of the response strategies' effect. Figure 4.3. shows an example: the eye-ball plot becomes smaller, i.e. the project risk decreases.

The eye-ball plot also was used to see what happens when mitigating a certain risk events. This was done by leaving a risk event out when simulating or adjusting the risk event's information based on the response planning, which resulted in an estimation without that particular risk event. Also another graph, as shown in figure 4.4, was used presenting the top ten risk events' likelihood and impact scores.

The MC simulation output was shared with the project manager on which the risk treatment could be adapted. Though, not all project managers used the risk team's estimations (C.3, C.5, C.8, C.10, C.11). They didn't use the estimations because (a) the results were not trusted (C.3), (b) the results were not understood (C.5), and/or (c) it didn't give more insight than the top ten risk events available from the qualitative risk analysis (C.5, C.11). No surprises popped up, the risk events that had to be mitigated according the MC simulations had to be mitigated anyway (C.5, C.10, C.11). There is also a project manager indicating it is a tool for the Board of Directors: to get an idea of the risk on company level (C.8, C.13).

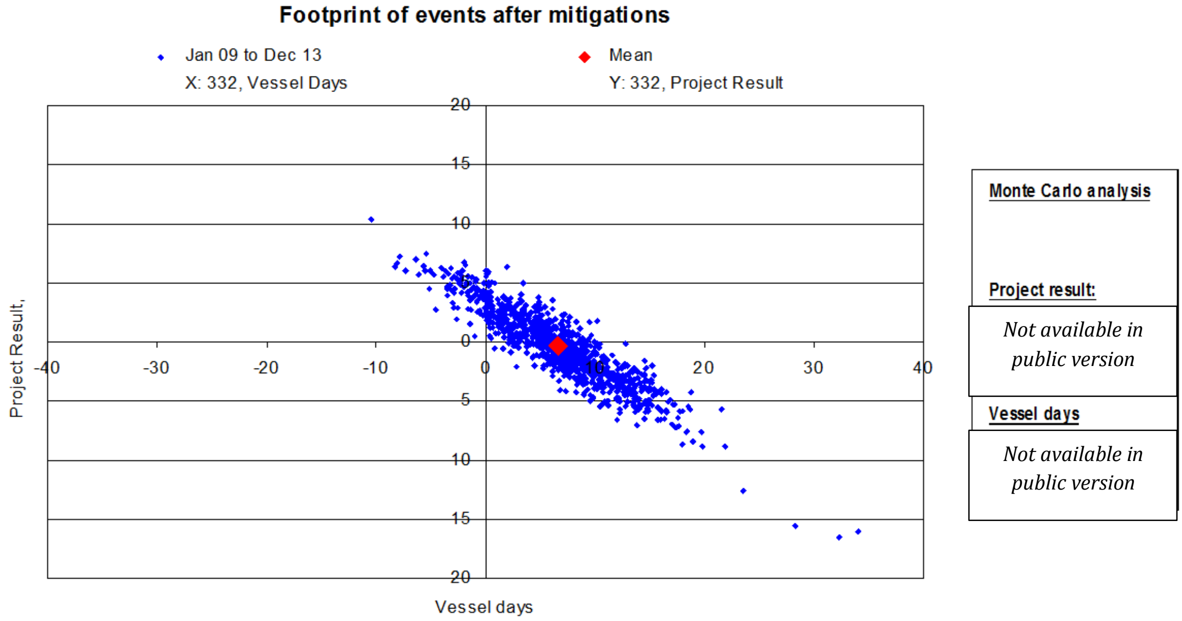


Figure 4.2: MC simulation results after mitigation of one of HMC's previous projects

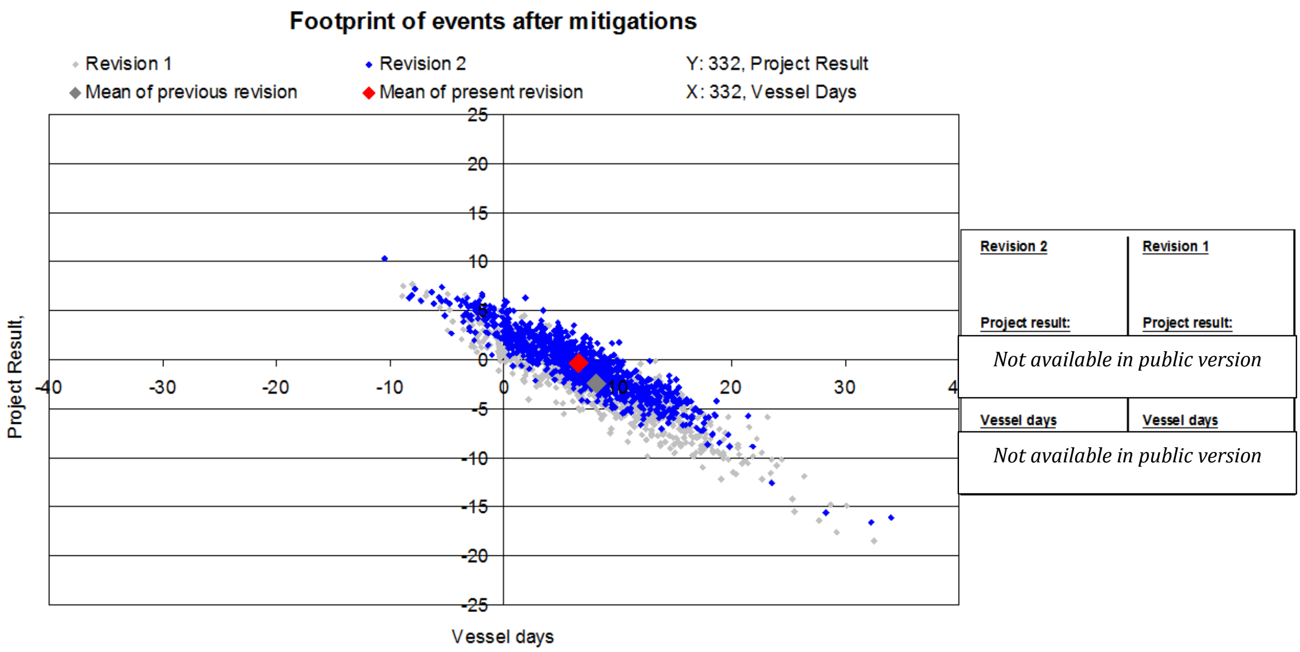


Figure 4.3: MC simulation results before and after mitigation of one of HMC's previous projects

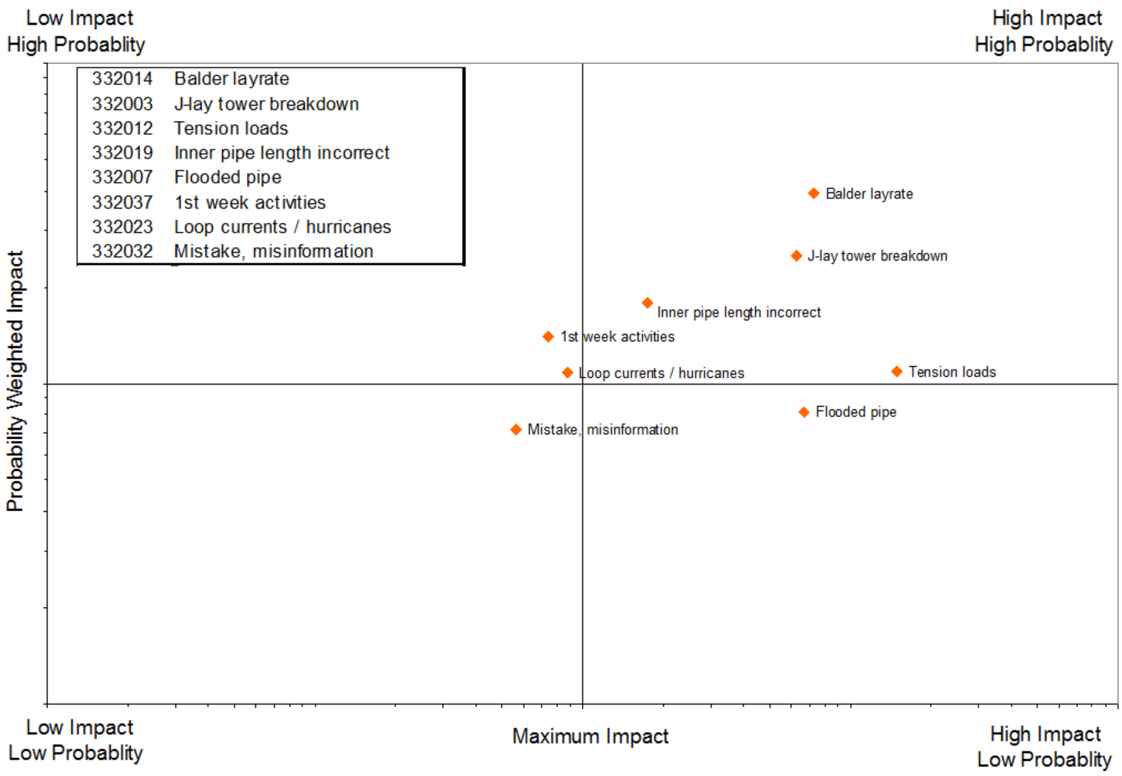


Figure 4.4: Likelihood and impact scores of the top ten risk events of one of HMC's previous projects

The project managers that used the MC simulation results (C.4, C.7, C.12, C.13) solely used it as an awareness, as trend watcher. The location of the eye-ball in the graph and its size gave a visualization of the project risk (C.12), and when treating the risk events it could be checked if the eye-ball was shrinking (C.4). It also was used to check if the estimation was equal to what was expected, if not the PRM required another focus (C.12). Though, no real surprises have come forward in the time the MC method was used (C.4, C.7). This also indicated by the project managers that didn't use the MC simulation results. The top ten risk events that came forward from the simulations didn't differ at all or not much from the top ten risk events defined by the qualitative risk analysis (C.3, C.5, C.11). This also visible in a reviewed project, in which the project had eight MC simulation revisions: the top ten most important risk events barely changed.

None of the project managers indicated that the MC simulation results were used for its precise estimation, i.e. the exact estimated project result expressed in money and vessel days. This is confirmed by a former risk team member (C.15): "It's the eye-ball that was interesting, the one point of the estimated project outcome didn't say that much." According C.15 there is a 90% probability the project outcome falls within the eye-ball. This should be the awareness starting to mitigate those risk events making the eye-ball smaller. Nevertheless, the MC method provided more information than what was used by the project managers (C.15).

Another effect of the MC simulation was to get free of subjectivity. It was more difficult for the project manager to manipulate the project outcome estimations. For example, if a project manager does have a bad experience a disproportional amount of energy is put on that one risk event. Quantitative risk analysis levels the effect of that one risk event since the combined effect of all risk events is taken in account (C.15).

Though, it has to be mentioned the main purpose of the risk team was to get an indication of the risk on company level. Since the company risk is for 80% within the projects, the project risk analyses were of high importance. This is why the risk team additionally facilitated the PRM and did the MC simulation estimations on project level. The MC simulations done for all projects made it possible to look at the knock-on effect of a project on other, later scheduled, projects. This gave an insight on HMC's project portfolio and was used for the decision making by the upper management. This could have resulted in e.g. decisions in benefit of the portfolio which were in detriment for the project (C.15). The Vice President of Project Management took the MC results in account as additional information when making decisions concerning HMC's portfolio. He indicates the MC analyses did have value, only it isn't possible to say if the additional information led to other, better, decisions (C.18).

4.2.3. The Functioning of the Former Project Risk Management Method

When asking the project managers about the abandonment of the risk team it is especially the facilitating role that is missing. The facilitating role ensured a certain discipline doing the PRM activities (C.4, C.7, C.10, C.11, C.12) and took a lot of workload away from the project manager (C.8, C.9, C.11, C.12). Also the PRM expertise of the risk team is missed by several project managers (C.4, C.9, C.10, C.11, C.12). The PRM reviews worked better in consultation with the risk team instead of the project engineers, this because the risk team was specialized focusing on the risk events with the highest importance (C.4) and because the risk team knew to ask the right questions getting the information needed (C.11). Furthermore, the project managers also learned from the risk team, e.g. that it is important to treat both the exposures as well as the opportunities in the PRM process (C.12). It is noteworthy that the project manager currently working in consultation with one of the former risk team members, who performs the same facilitating role, is very pleased the way the PRM is done (C.14).

The risk team worked closely with all the project managers, this also caused a uniform PRM process (C.4, C.8, C10, C.15, C.17). This standard ensured the PRM of all projects was reported the same (C.10, C.15, C.17). The risk team's objective view on all different projects also caused uniformity over all projects. This made it possible to challenge the project managers by e.g. indicating that risk events were missing or that the risk event evaluation was incorrect (C.15). This caused that information was shared between the different projects, resulting in a wealthier PRM.

Concerning the MC simulations the opinion of the project managers is more divided. Most project managers didn't use the MC simulation results and are not missing it (C.2, C.5, C.10, C.11, C.14). For the project managers that used the analysis results it served as a visualization of where the project was going (C.4, C.7, C.12). Though, according one project manager it also was a bit too much of PRM. On the other hand, he indicated that the PRM was more transparent than it is today (C.12). Some T&I project managers would consider using a quantitative risk analysis when working on a larger, more difficult, and/or complex project (C.4, C.7, C.12). For the T&I projects it isn't necessarily needed. Another project manager also would consider using quantitative risk analysis for the more complex projects, although it should be a different, better, method than used in the past (C.3). Nevertheless, the project managers on those larger, more difficult, and/or complex projects are indicating HMC's current PRM method is functioning well enough and are indicating that an additional quantitative risk analysis is not needed (C.2, C.10, C.14).

Two other project managers, of which one didn't use the MC simulation results in the past, have indicated that it could be very useful to use a quantitative risk analysis method in the future. Although, on company level instead of project level (C.8, C.13). When analyzing the projects on a higher level it is possible to get an indication of the impact a project has on another project. This knock-on effect can only be seen in an overall view (C.13). Though, another project manager says a risk team doing the PRM for all projects, without quantitative risk analysis, makes it also possible to get this overall view (C.10).

According one of the former risk team members the abandonment was too early. The risk team was developing and needed another few years to become a real mature risk management tool (C.15).

4.3. CONCLUSIONS

From the comparison between HMC's current PRM procedure and HMC's current PRM practice the following notable differences, *ordered from most significant to less significant*, have been revealed:

1) The procedure requires to review and update the risk register on a monthly basis. In practice it is only done each two to six months because of the time issues, and partly because of discipline problems.
2) HMC's PRM procedure requires to report the top ten highest scored risk events in the PSR, in practice the way of using the PSR to report the risk events is highly diversified between the project managers interviewed.
3) The risk assessment workshop's activities as presented in the procedure slightly differ from the activities as performed in practice.
4) Besides the response strategies in the procedure, other additional response strategies are used in practice.
5) The project sizing tool to define the depth level of the PRM process, as presented in HMC's procedure, is not used in practice.
6) The project feedback and close out, as presented in the procedure, is not always done, and if it is done it is in doubt if it is used afterwards.

A major concern is the fact that the project managers put too little effort in the PRM process, especially concerning the PRM review and update moments. The time issues, and partly the lack of discipline, makes it that the PRM isn't done as subscribed in the procedure (C.4, C.5, C.6, C.7, C.9, C.12, C.13, C.14, D.2).

There is also a large discrepancy concerning the link between the PRM and the PSR as described in the procedure and as it is linked by the project managers. This makes it possible that the PRM reported to the upper management isn't complete and uniform. It seems that the existence of the PRM procedure is not known or not well understood by all project managers (C.4, C.7, C.11, C.17).

The differences between the risk assessment workshop as described in the procedure and done in practice is not a cause for concern. All activities are done either during the workshop or yet later in collaboration with the most important people. Also the differences regarding the PRM initiation and the response planning is not a major problem: the PRM planning is done by intuition during the PRM process and the additional response strategies used are only in benefit of the risk events' response planning.

When looking at differences between the former PRM practice and the current PRM practice, the PRM procedure was largely the same, except for the facilitating role of the risk team and the additional use of quantitative risk analysis. The facilitating role of the risk team was widely appreciated. It took work away from the project manager and ensured a certain level of discipline. Furthermore, the risk team maintained a uniform PRM process in the company. This caused that the PRM activities were standardized. The former risk team took away the factors that causes the biggest differences between HMC's current PRM procedure and current PRM practice. It is not surprising several project managers consider the former PRM method, exclusively referring to the facilitating role, as better than the current

PRM method (C.4, C.8, C.9, C.11, C.12). This is confirmed by the project manager who is satisfied about the fact a former risk team member is facilitating the PRM activities on his current project (C.14).

The quantitative risk analysis' simulation results were not widely used. The project managers that didn't use the MC results indicated that the MC simulation's results were not trusted/understood (C.3, C.5), and/or didn't give more insight than the top ten risk events already available from the qualitative risk analysis (C.10, C.11). The identified risk events had to be mitigated anyway (C.10). The project managers that were using the MC estimations did use it as an awareness, i.e. the visualization of the combined effect of the identified risk events was used to check if it was equal to what was expected (C.4, C.7, C.12). Besides, it also was used to play with the estimations by looking what happened when a risk event's possible response strategies were taken in account. Based on this information the response strategies' decisions were made (C.7, C.12, C.15). Though, the project managers that did use the MC results indicate no real surprises came forward from the MC simulations (C.7, C.12).

Yet, there are a few project managers that would consider the use of a quantitative risk analysis method in more complex and difficult projects (C.3, C.4, C.7, C.12), i.e. an EPIC project, EPRD project or a new built vessel project. This contradicting with the project managers currently working on such complex and difficult projects, i.e. the EPIC project (C.2, C.10) and new built vessel project (C.14). They are indicating that HMC's current PRM method is functioning well enough and an additional quantitative risk analysis is superfluous (C.2, C.10, C.14).

CHAPTER 5: HMC'S PROJECT RISK MANAGEMENT PROCEDURE & PRACTICE VERSUS THE PROJECT RISK MANAGEMENT LITERATURE

This chapter puts HMC's PRM procedure and practice against the PRM literature. This is done by answering the following two sub-questions: '*How do HMC's current project risk management procedure and practice differ from the project risk management according to the literature?*' and '*How does HMC's former project risk management practice differ from the project risk management according to the literature?*' This is done according the evaluation framework as presented in Chapter 2.6.

5.1. HMC'S CURRENT PRM METHOD

5.1.1. PRM INITIATION

HMC's PRM procedure describes a project sizing tool similar to the sizing tool as described in the literature (Hillson & Simon, 2007), (Chapter 2.5.1). Depending on the project size the PRM activity details are determined. Though, the sizing tool used by HMC is not totally accurate since a couple of project managers indicate that the PRM activities should be extended, i.e. by doing more risk assessment workshops or by using quantitative risk analysis, for the more uncertain and/or complex types of projects (C.3, C.4, C.5, C.7).

5.1.2. RISK ASSESSMENT WORKSHOP

The literature describes it is best to have a large group of participants for the risk assessment workshop, with an ideal number of ten to sixteen (Hillson & Simon, 2007). This is confirmed by one of HMC's project managers, ten to fifteen people are present during his workshops. He indicated that the workshop was done with a lot more people in the past. The results were disappointing, after a whole day the input was similar to the current workshop results (C.8). The risk assessment workshops observed were participated by less people, i.e. six to nine (D.1, D.2, D.3).

HMC's PRM procedure provides an indication of the duration for each risk assessment workshop's activity (Chapter 3.1.2.). A directive of approximately five hours is indicated for the total duration of the workshop. The observed workshops lasted no more than three hours, although not all procedural activities were performed (D.1, D.2, D.3). The PRM literature describes that a risk assessment workshop should last for one to three days (Hillson & Simon, 2007). Hence, in practice HMC's risk assessment workshops are shorter in duration than described in the PRM literature. This isn't a point of concern; the workshop duration highly depends on the project's characteristics. Besides, one project manager indicated that a workshop of a whole day didn't give better results than the ones of a couple of hours (C.8).

The workshop activities in HMC's procedure are very similar to the workshop activities as described in the literature. Though, there are some differences to appoint. Sometimes the qualitative risk analysis is postponed till after the risk assessment workshop (C.5, C.7, C.9, D.2). It is best doing the qualitative risk analysis during the workshop since all important people are present (Hillson & Simon, 2007). This will ensure a certain weighted average of the risk event's likelihood and impact scores (C.7, C.9, C.11, D.1, D.3).

Furthermore, the literature indicates to define the risk events' response strategies after the workshop in consultation with the risk owner (Hillson & Simon, 2007). HMC's PRM procedure asks to do this during the workshop. The project managers have already noticed it is more practical to do define the response strategies after the workshop (Chapter 4.1.2.). This together with the people treating the risk event (C.4, C.7, C.9, C.12, D.2, D.3).

Also the risk owners should be pointed during the workshop, or just afterwards. HMC's PRM procedure doesn't mention risk ownership, only that it is the project manager who is responsible for the development and monitoring of the mitigation actions. In practice most project managers do take that responsibility (C.5, C.8, C.11). This contradicts with the literature that points the project manager should only be the risk owner when it is beyond doubt the one best managing the risk event (Hillson & Simon, 2007). Another project manager indicated the risk ownership can be divided over a couple of departments (C.8). This in contradiction with another project manager who indicated the risk owner has to be one individual (C.7), which also is indicated as a necessity in the literature (Hillson & Simon, 2007).

5.1.3. Risk Event Identification

The risk event identification in HMC's PRM method is reasonably consistent with the methods described in literature. For HMC it's the brainstorming during the risk assessment workshop that is most important to identify risk events.

A point of concern is the untruthful division between exposures and opportunities in the identified risk events. Where HMC's PRM procedure asks to focus on both exposures and opportunities, it are especially exposures identified in practice (C.13, C.14). When analysing the combined effect of the risk events it is important to treat both the exposures and opportunities to prevent a pessimistic view on the project outcome (Hillson & Simon, 2007).

In the past, a pre-listed checklist with the most important risk events per type of project was used (C.17). This to guarantee that previous happened or standard risk events of comparable projects were considered (Hillson & Simon, 2007). During the interviews the project managers were asked if they used such a pre-listed risk register, or if wanted to use such a pre-listed risk register. Some project managers indicated that it's a disadvantage to use such a list at the start of the risk identification since important risk events will be overlooked (C.3, C.9, C.11, D.3). Though, using it as checklist after the risk event identification could be useful (C.9). Other project managers indicate it could be useful to use such a list as input for the risk assessment workshop, this to make it possible to elaborate the brainstorming on more project specific risk events which will shorten the risk identification process (C.5, C.7, D.2). Rationally speaking, it is better using such a list after the risk identification as check-up. The danger of not identifying an '*unknown unknown'* outweighs the time saved during the risk assessment workshop.

5.1.4. Qualitative Risk Analysis

When assessing the identified risk events, first the likelihood should be determined after which it should be imagined the risk event occurs to get an identification of the impact. The literature specifies that it is best to apply the likelihood and impact scales on the project's characteristics. The impact scales should be linked to the different project objectives (Hillson & Simon, 2007), (Kendrick, 2003). HMC's assessment tool, as used in all projects, has fixed scales for both determining the likelihood and the impact.

HMC expresses the likelihood in frequency of occurrence per time unit. Those expressions are coupled to a percentage of occurrence on ordinal scale, i.e. the increments are unequal, from 0.2% to 50%. In the literature often a ratio scale, i.e. the increments are equal, is used from 1% to 100%. This means HMC focuses more on the risk events with a high probability since a probability of 50% or higher gives the highest likelihood factor. Table 5.1 shows the differences.

Likelihood scale as used by HMC	
5	Happens once every month (50%)
4	Happens twice every year (10%)
3	Happens once a year (5%)
2	Happened once in the last 5 years (1%)
1	Has happened in the last 10 years (0,5%)
0	Never happened yet worldwide (0,2%)

Likelihood scale most often used in literature	
Very High	81% - 100%
High	61% - 80%
Medium	41% - 60%
Low	21% - 40%
Very Low	1% - 20%

Table 5.1: Likelihood scale as used by HMC and as used in literature

Though, the frequency of occurrence per time unit as expressed by HMC cannot be related to a probability. If a risk event only can occur once a year and occurs every year the probability of occurrence is approximately 100%. According HMC's likelihood scale the probability of occurrence would be 5%. An experienced project manager probably won't make such a mistake, nevertheless the likelihood scale may confuse. Especially when the one rating the risk events asks himself "did this happen the last month, year, etc.?" as was done during one of the risk assessment workshops attended (D.3).

HMC's scaling of the risk event's impact are related to the 'project outcomes' from 'no effect' to 'low effect', after which it is switched to 'project objectives' for a 'medium' impact and is supplemented with 'financial gain or loss' and 'schedule delay or improvement' for the 'high' and 'very high' impact scores. Table 5.2 shows the precise descriptions.

Impact scale as used by HMC	
5	*Very high* – major financial gain or loss, improvement or failure on almost all project objectives, major delay or schedule improvement
4	*High* – significant financial gain or loss, improvement or failure on most project objectives, significant delay or schedule improvement
3	*Medium* – Serious threat to, or improvement on, project objectives
2	*Low* – Small effect on project outcomes
1	*Very low* – Very small effect on project outcomes
0	*No effect on project outcomes*

Table 5.2: The impact scale as used by HMC

It is clear the impact scale partly is related to the project objectives and an additional focus on the financial and schedule objective is added for the higher impact scores. Though, the different used terms may lead to confusion, i.e. *what is the difference between an effect on the project outcomes and an effect on the project objectives?* Furthermore, the project objectives are not specified related to e.g. scope or quality. This is where the impact scale derived from the PRM literature (Chapter 2.3.1, table 2.2) is more complete and uniform; each project objective is specified in more detail for all impact scores.

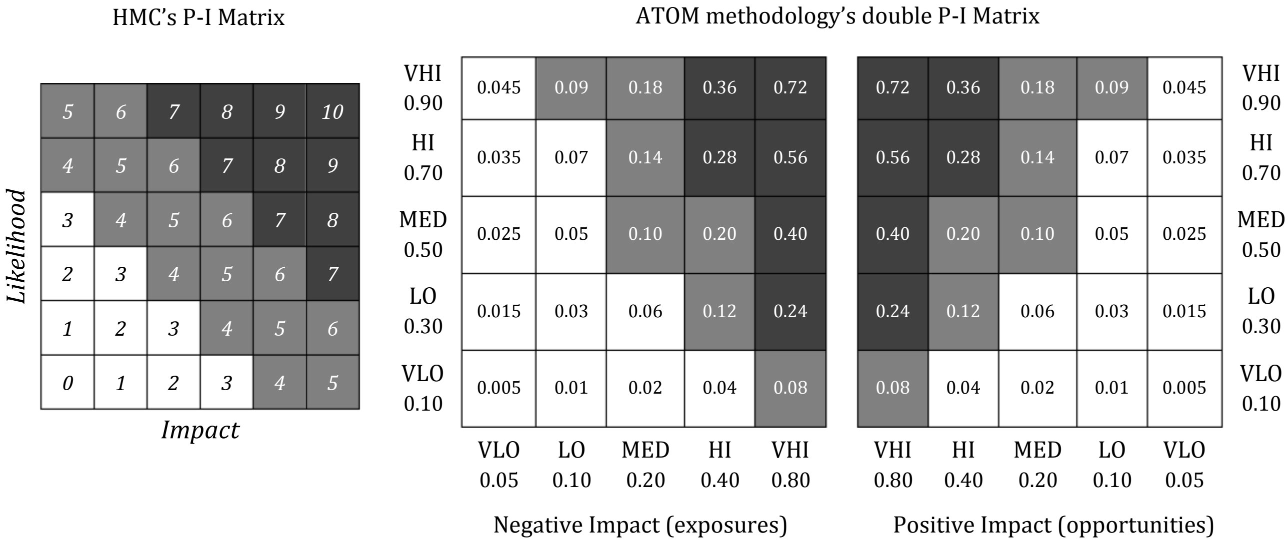


Figure 5.1: HMC's P-I matrix against the ATOM's double P-I matrix (Hillson & Simon, 2007)

In Chapter 2 ATOM's double P-I matrix (Hillson & Simon, 2007), as shown in figure 5.1, was awarded as the best to use in practice. When comparing it with the P-I matrix of HMC five differences can be noticed. The first, and clearest, is that HMC uses a single P-I matrix. The double P-I matrix makes a clear distinction between exposures and opportunities, something HMC tries to focus on according its PRM procedure. The second difference is HMC's linear impact scale and ATOM's non-linear impact scale, and the third difference is ATOM's asymmetric distribution of the 'red', 'amber', and 'green' risk factors in comparison with a symmetric distribution in HMC's P-I matrix. Both the differences will provide a higher focus on the 'high-impact' risk events, which is more sensible (Chapter 2.3.2). The fourth difference is the size; the literature presents two 5x5 matrices where HMC has a 6x6 matrix. HMC makes a distinction between a really small likelihood or impact and no likelihood or impact at all. A risk event with a zero likelihood or impact is not really a risk event. Besides, matrices larger than 5x5 are discouraged to

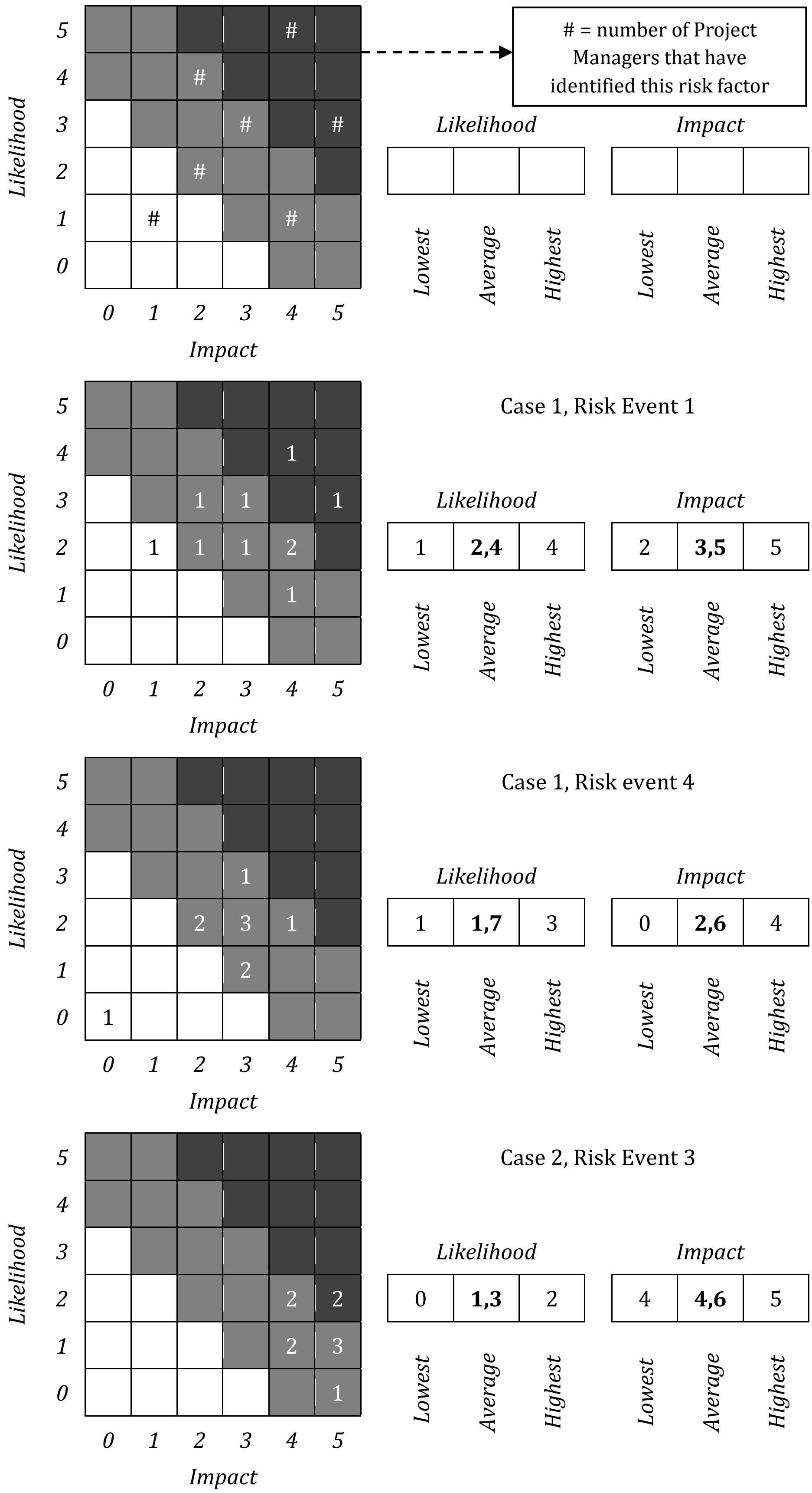


Figure 5.2: Three risk event results from the risk register survey

overcome gambling (Hillson & Simon, 2007), (Simon, 2003). The fifth difference is concerning the risk factor, i.e. the combined likelihood and impact score. HMC sums the two scores where the literature multiplies the two scores. Multiplying the scores is more logical, i.e. a likelihood of 45% and impact of 1 Million Dollars can only be multiplied to get the risk factor. Besides, summing the scores could be confusing for clients. This was the case in one of the attended risk assessment workshops (D.3); in a former risk register, which was shared with the client, the likelihood and impact scores were multiplied.

Assessing identified risk events with qualitative risk analysis as presented above are often associated with subjectivity. HMC's project managers are aware of HMC's qualitative risk analysis tool's subjectivity (C.3, C.4, C.5, C.8, C.9, C.12). This also becomes clear from the survey each interviewed project manager was asked to complete. Ten project managers completed two risk registers, each with five pre-identified risk events. They indicated the consequence of the risk event and assessed the likelihood and impact score. The survey format is presented in Appendix B.2 and the results in Appendix E.

The perception of the likelihood and impact scores highly depend on the rater's experience. Also the rater's personality has influence on the rating, a risk averse person will rate the scores higher than a risk seeking person (Hubbard, 2009). The survey result of risk event 1 in case 1 (figure 5.2) is a good example of the differences between the project managers' perceptions. The likelihood and impact scores are distributed over almost the entire matrix. Other risk events results show a similar result (risk event 2 of case 1 and risk event 1, 2 and 4 of case 2).

The overconfidence of people also is a subjectivity that can bias the likelihood and impact scores. According the literature humans are naturally overconfident (Capen, 1976), (Hubbard, 2009). It is hard to indicate the existence of overconfidence in the results of the survey since historical data of the pre-identified risk events is missing. Though, the result of risk event 4 in case 1 (figure 5.2) is remarkable. Nine of the ten project managers have scored this risk event quite consistent. One project manager indicates that the risk event won't occur, and if it occurs won't have an impact. With the knowledge this risk event is important to manage, it probably is a perception problem of the particular project manager resulting in an overconfidence.

Another subjectivity that can be present is that people tend to score a risk event with a high impact by intuition with a low likelihood, and the other way around (Simon, 2003). Risk event 3 in case 2 of the survey (figure 5.2) could be an example of this. All project managers score the damaging of a life pipeline with pollution as result with a low probability and high impact. The similar, although less obvious, could be true for three other risk events (risk event 3 and 5 of case 1, and risk event 5 of case 2). This subjectivity possibly can be avoided when scoring the likelihood and impact in isolation, e.g. one group rating the likelihood and another group the impact (Simon, 2003), (Chapter 2.3.4).

Not all biases as described in Chapter 2.3.4 can be noticed in the survey results. This first of all because historical data concerning the risk events' occurrence is missing. But, also the fact the project managers only have completed the risk register survey once makes it impossible to check the rater's consistency over time. If a bias or subjectivity isn't related to the survey results it doesn't mean the bias or subjectivity isn't present in the survey results and/or in HMC's PRM practice.

Fortunately, the project managers are aware of the qualitative risk analysis' subjectivity. This enables them to act upon the subjectivity. Nevertheless, the way being dealt with it is different among the project managers. To repeat, one project manager indicates the risk factors are adjusted on the perception of the project manager (C.12), where other project managers think it is better to do the assessment in a large group creating a weighted average (C.7, C.9, C.11).

5.1.5. Response Planning

HMC's PRM procedure indicates that a mitigation action should reduce an exposure or enhance an opportunity's likelihood of occurrence and/or magnitude of impact. The literature also presents this response strategy (Hillson & Simon, 2007). Another response strategy in HMC's PRM procedure, which isn't present in the literature, is that a mitigation action should improve the understanding of the nature and scale of the risk event. Though, an action giving more insight information about the risk event does not immediately mitigate the risk event. Of course, it is very useful to have more insight information on the risk event. Nevertheless, it is that information on which the decision of how to mitigate the risk event is made. It always is necessary to improve the understanding of the nature and scale of the risk event before making the decision.

HMC's PRM procedure doesn't present more types of response strategies. The literature does provide more response strategies including (a) avoiding, transferring and accepting an exposure or (b) exploiting, sharing and accepting an opportunity (Chapter 2.2.4). Those response strategies are also found in HMC's PRM practice, i.e. transferring risk events to the client (C.3, C.10) or the existence of contingency plans as seen in a couple of risk registers.

5.1.6. *Risk Documenting*

HMC uses the risk statement sheets (Appendix A.3) to report the identified risk events during the risk assessment workshop. Those risk statement sheets subsequently are used to fill in the risk register. The language used to define the risk events is quite similar to the metalanguage as presented in the literature, though doesn't completely match. Figure 5.3 presents the differences.

HMC's format to verbalize risk events

Cause (There is an event that...)	*Effect (that will result in...)*	*Consequence (budgetary)*	
		Schedule	
		Costs	
		Revenues	
		Reputation	

Metalanguage to verbalize risk events

Cause (As a result of...,)	*Event (... may occur,)*	*Effect on objectives (which would lead to...)*

Figure 5.3: Documenting the risk events according HMC's procedure and the literature (Hillson & Simon, 2007)

HMC's risk register describes the cause, effect and consequence of the risk event. For example, *there is an event that* will damage the life pipeline, *that will result in* pollution. As presented in Chapter 4.1.6 the risk statement sheet enquires to indicate if the consequence is an exposure (-), an opportunity (+), or both (±) for the schedule, costs, revenues and/or reputation of the project.

In the risk register survey the project managers where asked to indicate the risk events' consequence with a (-), (+), (±), or if applicable leaving it open. From the survey's results (Appendix E) it turns out that the project managers' scores are very diverse. This partly because a project manager can see a risk event as an exposure where another project manager sees it as an opportunity. The variation can also be because project managers interpret the way of reporting differently. Taking the damaging of the life pipeline with pollution as result as example (Case 2, Risk event 3): two project managers indicate the costs with a (+), where the other eight project managers indicate it with a (-). When such an event occurs it definitely will increase the project costs. Depending on the project manager's interpretation it can be coupled to a (+) since the costs are increasing, or to a (-) since it is an exposure for the financial project outcome.

Therefore, it is important describing a risk event as specific as possible (Isaac, 1995). This makes it easier to communicate the identified information and will prevent indistinctness. It is better to verbalize a risk event in more detail. For example, *as a result of* damage to the life pipeline, pollution *may occur, which would lead to* a delay in the schedule, additional project costs and a loss of reputation.

5.1.7. *PRM Review and Update*

The PRM steps so far discussed don't ensure the identified risk events are actually managed well enough. The actions agreed on should be implemented and possible new risk events should be identified (Hillson & Simon, 2007). The purpose of the review moments is very clear to the project managers: it's checked if already identified risk events are still active and, if applicable, new risk events are identified (C.12). Though, the review and update moments not done on a monthly bases as requested by HMC's PRM procedure (Chapter 4.1.7).

The Vice President of Project Management has indicated that it also is important the risk event status is reported (C.18). Nevertheless, the procedure doesn't describe a method to report the risk event's status.

5.1.8. Risk Reporting to Upper Management

It is clear that there is a division within HMC's reporting of the projects' risk events to the upper management. Although HMC's PRM procedure requires the inclusion of the ten highest scored risk events in the PSR, it isn't the standard in practice. Comparing the projects is difficult because the project managers aren't reporting the project's risk events the same (Chapter 4.1.8). Furthermore, even if all the project managers are reporting the top ten highest scored risk events a comparison between the projects can be subjective. The risk register survey results (Appendix E) show that some risk events' risk factors have a very large distribution. When taking risk event 1 from case 1 in consideration (figure 5.2), the lowest scored risk factor is 3 and the highest 8. For the risk registers reviewed it would mean that this particular risk event will be outside the top ten risk events for the one project manager where it will be within the top ten for the other. Hence, when only the top ten risk events are reported in the PSR, the upper management will have an incomplete overview over all the projects. The subjectivity in the qualitative risk analysis will not be noticed since a complete comparison between the projects stays out. The concept of reporting all identified risk events in the PSR, as done by a couple of project managers (C.2, C.10, C.14), provides a more complete and uniform overview. This will benefit the decisions made on project level and additionally on HMC's portfolio level.

The way the exposures and opportunities are reported in the PSR is powerful. The exposures and opportunities' probability of occurrence is defined in a single-value percentage and an estimation of the financial impact also is indicated with a single-value. Despite the fact that the MC method asks for more elaborated risk event details, i.e. the ranges and distributions, and additionally a simulation is done, the PSR method also provides an indication of the combined effect of the exposures and opportunities reported. Besides, Galway presents a second reason why to use quantitative risk analysis, which also is valid for the exposures and opportunities reporting method: the project manager is forced to think more elaborated on the several facets of the risk events since more detailed information is required (Galway, 2004).

5.1.9. Health, Safety and Environment Risk Assessment

It is important there is an additional focus on Health, Safety and Environmental (HSE) hazards, this with the aim to protect the employees and environment. HMC's HAZID/HAZOP meetings (Chapter 3.1.9) will have, among others, the following benefits:

1) It will reduce the probability of injuries (C.4, C.8, C.10), (Chism, 2011)
2) Operations will be standardized which ensures an acceptable safety (C.4, C.8, C.9), (Chism, 2011)
3) Providing information for the employee's knowledge regarding the project's characteristics, e.g. by walking through the total execution phase with the offshore personnel (C.4), will ensure a standardized project execution (Chism, 2011)

There should be a total focus on HSE hazards during the HSE risk assessment workshop. The link between the HAZID/HAZOP meetings and the regular PRM (Chapter 4.1.9) therefore is suitable. It is just a good thing when a risk event related to the regular PRM accidentally pops up.

5.1.10. Project Feedback and Close Out

Each successful finished project will have a contribution to the organizational experience and will benefit future projects. Therefore, it is important project experiences are documented and shared (Hillson & Simon, 2007). In practice it turns out that the project close out isn't always done (C.8), and it also is in doubt if the close outs done are used in new projects (C.4, C.12). Hence, the loop between the 'lessons learned' and new projects isn't closed.

5.1.11. The Functioning of the Current Project Risk Management Method

Four critical success factors making PRM work have been presented: *A supportive organization; competent people; appropriate methods, tools and techniques; and a simple to use, scalable, and documented process* (Hillson & Simon, 2007), (Chapter 2.1). For HMC's current PRM method there is room for improvement in all four factors.

The project managers do see the importance of PRM, there is even a project manager saying that project management is equal to risk management (C.8). There definitely is a positive attitude towards PRM, something that is necessary to make PRM effective (Hillson & Murray-Webster, 2004). Though, the attitude does not mean the PRM is done well enough. Many project managers indicate too less time is put in the PRM because of the high workloads, and partly because of discipline problems (C.4, C.6, C.7, C.8, C.9, C.11, C.12, C.13). Hence, concerning the time problem the organization could be more supportive.

Also the competency of the project managers responsible for the PRM process is put in discussion (C.9). The project managers are not trained in the PRM process and activities, there is only a PRM procedure which can be used as guideline. This guideline doesn't give the support needed for the PRM process, this indicated by a relatively new project manager who is missing support in the PRM process (C.9). Besides, the guideline isn't functioning properly, this given the fact not all project managers know what is written in the procedure (C.4, C.7, C.17), or even don't know the existence of the procedure (C.11).

When looking at the methods, tools and techniques used some issues already have come forward in the previous paragraphs. The use of HMC's qualitative risk analysis tool, but also the way of documenting the risk events may lead to some confusion. When looking at HMC's PRM infrastructure it maybe is too little, this regarding the way the exposures and opportunities are reported to the upper management. It should be a bit more complete and structured to ensure the exposures and opportunities are reported as requested by the upper management.

5.2. HMC's Former PRM Method

5.2.1. Risk Team's Facilitating Role

The PRM literature describes that it is possible to appoint a 'risk champion' guiding the project team through the PRM process. Besides a facilitating role a risk champion also contributes to a uniform PRM since such a specialist is operating independently and unbiased in each project's PRM method (AIRMIC, ALARM, IRM, 2002), (Hillson & Simon, 2007), (Keizer, Halman, & Song, 2002), (Chapter 2.2.10). This is confirmed by HMC's former PRM practice: besides the fact that the risk team took away a part of the PRM workload of the project manager (C.8, C.9, C.11, C.12) and ensured a certain level of discipline (C.4, C.7, C.10, C.11, C.12), the team also ensured a certain PRM uniformity within the company (C.15). It did have an objective view on all projects which made it possible to challenge the project managers (C.15).

Another advantage of the risk team was the continuously development of the PRM process. Most PRM activities currently used in practice or stated in the procedure were developed by the former risk team, e.g. the format for the risk assessment workshop. Also little improvements such as the use of sticky notes during the workshop ensuring the input of more shy people was taken into service by the former risk team (C.15). Those sticky notes are still used by most of the project managers (C.4, C.9, C.12, C.14, D.2, D.3). This learning curve has been stopped at the moment of the risk team's abandonment.

5.2.2. Quantitative Risk Analysis

The PRM literature presents four critical factors when making use of quantitative risk analysis (Chapter 2.4.3). The quantitative risk analysis method used in HMC's former PRM method is compared with those four critical factors.

The first critical factor concerning the MC simulation is deliberately identification of the ranges and distributions of all identified risk events (C.17), (Hillson & Simon, 2007). This identification was done in consultation with the risk team and the project manager (C.1, C.15). The identification of the ranges and distributions was based on the project manager's experience and expertise. According one of the former risk team members the identification should be practical, besides the historical data is embedded in the project manager's experience (C.15). This confirms Pugh & Soden's description that it is best using the experience and expertise of the project manager; the fact is that historical data can be deceptive because of each project's uniqueness (Pugh & Soden, 1986). Hubbard thinks differently by indicating that the decision making process based on experience has it limits (Hubbard, 2009), (Chapter 2.4.3). Besides, a couple of the biases discussed are also present when defining the input of the MC simulation, i.e. the overconfidence of people when defining ranges (Capen, 1976), (Hubbard, 2009). A cure against this overconfidence are the calibration tests introduced by Hubbard. Those tests haven't been used by HMC in the past.

The second critical factor is important to ensure a realistic estimation of the risk events' combined effect. It is important to take both exposures and opportunities in account. When only the exposures are taken in account the estimation of the project outcome will be pessimistic (Hillson & Simon, 2007). HMC's former risk team was aware of this fact (C.15, C.17). Though, it was more difficult to identify opportunities since the risk workshops were intuitionally focused on exposures. The risk team tried to stimulate the identification of opportunities or identified possible opportunities themselves (C.15, C.17). Yet, one of the project managers has indicated that the focus was too much on the exposures which resulted in a pessimistic view on the project (C.13).

Also the third critical factor is important to get a realistic estimation of the risk events' combined effect, i.e. the importance of taking the correlations between risk events in account (Hillson & Simon, 2007). Possible correlations between risk events were not taken in account in HMC's MC simulation (C.1, C.2, C.4, C.5, C.7). The former risk team members have indicated that some correlations were taken in account, e.g. 'if risk event A occurs also risk event B occurs' (C.15). But, taking the correlation of two risk events happening at the same time for which the impact shouldn't be summed in account, e.g. if both the materials and equipment is too late the delay should be shared, was more difficult (C.15). This is where HMC's MC method lacked quality: a simulation lacking to take correlations in account can result in an unrealistic estimation of the risk events' combined effect (Hillson & Simon, 2007), (Hubbard, 2009). Nevertheless, the MC results have been thoroughly checked in the past. "When getting experienced with the MC simulation the estimations become predictable, so there is a feeling if the estimation is realistic. If the estimation was different from what was expected it was checked why" (C.15).

The fourth critical factor, when using quantitative risk analysis, is the importance of positively testing the method used also works (Hubbard, 2009). This was also suggested by some of the project managers, though it never happened (C.3, C.15). One of the former risk team members has indicated that testing the project estimations against the real project outcome wasn't that useful, this because the project characteristics often changed during the project (C.15).

5.2.3. THE FUNCTIONING OF THE FORMER PROJECT RISK MANAGEMENT METHOD

The four critical success factors making PRM work (Hillson & Simon, 2007), (Chapter 2.1) also will be used for the discussion of HMC's former PRM method. For HMC's former PRM method the functioning was divided, i.e. the existence of the risk team ensured a supportive organization and competent people were involved in the PRM process, where the MC method used was experienced as too difficult and/or not useful.

It already is clear that the risk team's facilitating role is missed by most of the project managers, this because more time was available for the PRM activities and a certain level of discipline was ensured (Chapter 4.2.3). This is logical when considering the PRM workload largely was shifted from the risk team to the project managers at the time of the risk team's abandonment. The former risk team also ensured a certain PRM standard and uniformity over all the projects. Hence, the organization was supportive regarding the time scheduled and resources needed for the PRM activities.

The existence of the risk team also ensured competent people for the PRM activities: the risk team members did have PRM expertise and the risk team additionally trained the people involved in the PRM process. The project managers learned from the cooperation with the risk team, e.g. to take both exposures and opportunities in account (C.12). The team also contributed to the PRM standard, e.g. the risk assessment workshop still has the same format as developed by the former risk team (C.15). It also can be confirmed that training convinces the people involved from the PRM benefits (Hillson & Simon, 2007). At the time the risk team started there was a lot of resistance for the whole PRM process facilitated by the risk team (C.15) were the risk team currently is missed.

When reviewing the methods, tools, and techniques used it can be noticed the quality of the MC method was questioned by some of the interviewed project managers (C.3, C.13). According one project manager HMC was not able to do such analysis (C.3), this because the MC results estimated unrealistic project outcomes. This possibly because the division between exposures and opportunities was not truthfully, and the correlations were not sufficiently taken in account. It also is possible the MC simulation's input wasn't truthfully because of the subjectivity in the identified ranges and distributions. Garbage in is garbage out (Hubbard, 2009). On the other side, the project managers that used the MC simulation did trust the results (C.4, C.7, C.12). The lack of confidence in the MC simulations' results could have contributed to the fact that several project managers regarded the MC method as useless.

The PRM process was divided into two parts functioning parallel from each other. The PRM process as currently done was performing parallel to the quantitative risk analysis, i.e. it depended on the project manager's acceptance towards the MC method if the simulation was done (C.3). This made it easily possible for the project managers to ignore the MC method (C.3, C.5, C.8, C.10, C.11). The project managers that did use the estimations used it as additional information, i.e. the decisions were not necessarily based on the MC results. This also confirmed by a former risk team member indicating it is better to not hold too much to the MC simulation results, but using it as a directive (C.15). The acceptance of the MC method may have suffered from the fact that the method wasn't properly integrated in the PRM process, this indicated as one of the problems quantitative risk analysis isn't used often in PRM (Galway, 2004). But, it also appears that the project managers did have a misunderstanding regarding the MC method, which isn't outlandish since this is also concluded in the PRM literature (Chapter 2.5.2).

Regarding the factor that the PRM should be a simple to use and scalable process some project manager indicated the former process as a bit too scientific (C.5, C.12, C.15). One project manager indicated that he didn't understand the quantitative risk analysis and therefore didn't use the estimations (C.5). Other project managers indicated that it is not useful using quantitative risk analysis because it will cost too much time (C.14). This relating to the remark quantitative risk analysis often is seen as too difficult and not worth the time and effort (Hillson & Simon, 2007).

5.3. CONCLUSIONS

From the comparison between HMC's current PRM procedure and practice, and the PRM literature the following notable differences, *ordered from most significant to less significant*, have been revealed:

1) The way HMC's PRM procedure asks to report, and HMC's PRM practice reports the risk events in the PSR provides an incomplete and unequal overview into the project.
2) HMC's qualitative risk analysis tool may lead to confusion, this because of the likelihood and impact scales used. Furthermore, the tool used in practice confirms some points of subjectivity as presented in the PRM literature (Chapter 2.3.4).
3) HMC's risk documenting already is comparable to the PRM literature's metalanguage, though the procedure shows room for improvement to overcome confusion.
4) The risk assessment workshop in HMC's PRM practice is more similar to the PRM literature's workshop format than the format presented in HMC's PRM procedure.
5) The response strategies presented in HMC's PRM procedure are not complete. Opportunely, the response strategies used in HMC's PRM practice are more in line with the PRM literature's response strategies than with the response strategies in HMC's PRM procedure.
6) The truthful division between exposures and opportunities as required by HMC's PRM procedure and the PRM literature isn't reflected in HMC's PRM practice.
7) HMC's procedural project sizing tool to define the PRM depth level is similar to the one presented in the literature, nevertheless the tool isn't used in HMC's PRM practice.

Currently, the reporting of the project's risk events to the upper management doesn't give a complete and uniform overview into the project risk. This (a) because not all project managers are reporting the risk events the same, and (b) because the project managers' perception may differ much. When the reporting in the PSR is more structured a more complete and uniform indication of the project risk is estimated. Besides, the method of reporting the risk events in the PSR forces the project manager to think more elaborated about the risk events (Galway, 2004).

The qualitative risk analysis tool as used in HMC's PRM method shows room for improvement, especially the likelihood and impact scales that are used. Both the scales used in HMC's PRM method may lead to confusion. Also HMC's P-I matrix can be lifted to a higher level when comparing it with the 'best-practice' P-I matrix (Chapter 2.3.2), i.e. (a) a higher focus on 'high-impact' risk events, (b) a clear division between exposures and opportunities, and (c) a risk factor that is the multiplication of the likelihood and impact instead of the sum. Concerning the subjectivities and biases in defining the likelihood and impact scores as described in the PRM literature (Chapter 2.3.4), (a) the problem of perception, (b) the overconfidence of people, and (c) the bias on low likelihood high impact scores are found present in HMC's PRM practice. Other subjectivities and biases not detected in the risk register survey results doesn't confirm they are not existing. Fortunately, the project managers are aware of the qualitative risk analysis' subjectivity.

It is noteworthy that, at some points, HMC's procedure is completed/adjusted in practice which causes that the PRM method becomes more similar to the PRM literature. In practice it turned out that it is more efficient to define the response strategies after the workshop than during the workshop, which is confirmed by the PRM literature (Hillson & Simon, 2007). The response strategies presented in HMC's PRM procedure are not complete compared to the response strategies in the PRM literature. This incompleteness is not existing in practice, the project managers are using response strategies in addition of the strategies in HMC's PRM procedure.

When comparing HMC's former PRM practice with the PRM literature it becomes clear that HMC's former risk team did benefit the PRM method, this also as described in the PRM literature. Besides the fact the PRM workload was taken away and a certain level of discipline was ensured, the risk team also contributed to a uniform PRM over all projects and ensured a competent PRM method.

The former used quantitative risk analysis's input was based on the experience of the project manager. In the PRM literature there is a division concerning the knowledge used as input of quantitative risk analysis. Hubbard (Hubbard, 2009) indicates decision making based on experience has its limits and Pugh & Soden (Pugh & Soden, 1986) indicates the project manager's experience is the best knowledge available. The misunderstanding towards the MC method, as emerges from Chapter 4.2.3, isn't outlandish. Hubbard (Hubbard, 2009) and Galway (Galway, 2004), (Chapter 2.5.2) have this misunderstanding confirmed as present in PRM practice in general.

The MC method used by HMC's former risk team lacked to ensure a truthful division between exposures and opportunities, and lacked to sufficiently take the correlations between risk events in account. Probably also the overconfidence of people when defining the risk event's information has given untruthful simulation inputs. This possibly resulted in unrealistic and/or pessimistic estimations of the risk events' combined effect (Hillson & Simon, 2007), which also was indicated by some of the project managers (C.3, C.13). Testing the MC method wasn't done, this because it was not useful according the former risk team (C.15).

CHAPTER 6: RECOMMENDATIONS FOR HMC'S PROJECT RISK MANAGEMENT METHOD

The recommendations for HMC's future PRM method are divided in two parts: the first part will present the short term PRM recommendations which will provide the 'quick wins' for HMC's PRM method. The second part will present the improvements that are recommended for HMC's PRM method on the long term.

6.1 SHORT TERM RECOMMENDATIONS FOR HMC'S PRM METHOD

The 'quick wins' in direct benefit of HMC's PRM method presents two relatively significant recommendations: the advice of appointing a risk champion and the changes regarding the exposures and opportunities reporting to the upper management. Subsequently, a recommendation for HMC's PRM process and for HMC's PRM methods, tools and techniques will be given.

6.1.1. APPOINTING A RISK CHAMPION

The majority of the project managers have indicated that HMC's current PRM method isn't functioning well enough. According the project manager it's the high workload that makes it impossible to properly perform all the PRM activities (C.6, C.7, C.8, C.9, C.12, C.13), and to a certain extent it is also the lack of discipline on the part of the project manager (C.4, C.7, C.11, C.12). It is noteworthy that it was the risk team that resolved those problems in HMC's former PRM practice. It also isn't surprising that several project managers consider HMC's former PRM method, exclusively referring to its facilitating role, better than the current PRM method (C.4, C.8, C.9, C.11, C.12). This is more or less confirmed by a project manager who is pleased with the fact that a former risk team member currently is facilitating the PRM activities on his running project (C.14).

The time issues, and to some extent the discipline problems, are inducing the recommendation to appoint a risk champion. The risk champion's facilitating role will take away most of the project manager's PRM workload and will ensure that the PRM activities are consistently done (AIRMIC, ALARM, IRM, 2002), (Hillson & Simon, 2007). HMC's PRM method additionally will benefit from appointing a risk champion since a risk champion will have an objective view on all projects (Keizer, Halman, & Song, 2002). This makes it possible to compare the different projects (C.15), and to challenge the people involved in the PRM process (C.4, C.11, C.15). Also the expertise of a risk champion will benefit the PRM for several reasons: (a) there is substantive guidance during the PRM activities, (b) the people involved will be trained in the PRM activities, and (c) a higher quality of PRM practice will be developed over time.

It's recommended to appoint one risk champion to support all project managers/projects. The risk champion should perform the following actions:

1) *PRM initiation*: at the moment a contract is awarded the risk champion, in association with the project manager, should decide on the PRM activities for that particular project.
2) *Facilitation of the risk assessment workshop*: it is the job of the risk champion to invite the workshop participants and host the workshop. During the workshop all PRM activities will be explained by the risk champion. After the project manager has presented the project's scope of work and the important technical details the risk champion will be the guide through the workshop activities.
3) *Response planning*: if applicable, the risk champion will support the project manager and specific risk owner during the identification of the specific risk event's response strategy.
4) *Preparation of exposures and opportunities register in the PSR*: this will be done after the workshop by translating the risk events in exposures and opportunities as to be reported in the PSR. This in consultation with the project manager, and if applicable with the cost estimator or project controller.

5) *Facilitate the PRM review and update moments*: the risk champion will organize a meeting on an need basis, at least once in the two/three months, to review and update the PRM. This is done in consultation with the project manager, and if applicable with additional knowledgeable people.
6) *Facilitate the project close out and feedback meeting*: at the project close out the risk champion facilitates a meeting to discuss the project regarding the PRM process followed.

6.1.2. Semi-Quantitative Risk Analysis

HMC's current PRM shows a large improvement concerning the way the risk events are reported to the upper management. First of all, the current state isn't complete and uniform. Not all project managers are reporting the top ten risk events, but even if all project managers consistently report the top ten risk events, the indication of the project risk can be opaque (Chapter 5.1.8).

The method used by HMC to report the exposures and opportunities is a powerful tool. Nevertheless, it could be used more efficiently. The reporting method can be appointed as semi-quantitative risk analysis, i.e. situated between qualitative and quantitative risk analysis. The term semi-quantitative risk analysis is also used in the PRM literature (Cooper, Grey, Raymond, & Walker, 2005). To make the differences clear the three definitions are presented concise:

1) *Qualitative risk analysis*: prioritizing the identified risk events based on the probability of occurrence and magnitude of impact indicated by the use of *ordinal scales* (Hillson & Simon, 2007), (Chapter 2.3).
2) *Semi-quantitative risk analysis*: an estimation of the project risk, i.e. the combined effect of the risk events, for HMC's projects based on the identified risk events' probability of occurrence and magnitude of impact done by a calculation of the risk events' *single-values*.
3) *Quantitative risk analysis*: an estimation of the project risk, i.e. the combined effect of the risk events, based on the identified risk events' probability of occurrence and magnitude of impact done by a (*computerized*) normalized simulation of the risk events' *ranges and distributions* (Hillson & Simon, 2007), (Chapter 2.4).

The reason this distinction is made is because HMC's method of reporting the exposures and opportunities in the PSR (a) is more elaborated than the qualitative risk analysis method used in HMC's former and current PRM method, and (b) less elaborated than the MC method used in HMC's former PRM method. The introduced term also is sensible since the method can be seen as a possible springboard to a quantitative method in the future of HMC's PRM, which will be discussed in more detail in Chapter 6.2.

With a couple of improvements the semi-quantitative risk analysis can become a more powerful risk analysis tool. The first advice is to report 'all identified risk events', assuming a truthful division between exposures and opportunities. To understand the quote of reporting 'all identified risk events' the following additional information is needed:

1) The risk events that are seen as important by the project manager and risk champion are included in the semi-quantitative risk analysis, i.e. the risk events that are significant enough to be documented. It is important to mention that an overload of less important risk events will increase the analysis' effort without giving more insight on the project risk.
2) The risk events that are managed externally from the project level, i.e. on corporate level, are excluded from the semi-quantitative risk analysis. Those type of risk events are only included when manageable on project level (Chapter 4.1.3).
3) The HSE related hazards, identified during the HAZID/HAZOP meetings, are excluded from the semi-quantitative risk analysis (Chapter 4.1.9).

When all identified risk events are reported as exposures and opportunities, instead of only the top ten highest scored risk events, an estimation project risk is provided. If done consistently a complete and uniform indication of the project risk is given. This will make it possible to truthfully compare HMC's different projects.

The project manager will have to translate the risk events' likelihood and impact scores in single-values, i.e. the percentage of occurrence and the estimated financial impact and the impact on the vessel schedule days. This is best done with a cost estimator when at the start of the project, and with the project controller when the project is running. In the PSR the exposures and opportunities are documented separate from each other, this to make the differences clear. The register with the exposures and opportunities will be reviewed and updated for each PSR, i.e. the risk event's information is adjusted on the developments of the previous month and new identified risk events will be added to the register. The risk event's additional information, i.e. the detailed description, the response strategy, and the risk owner, can be found in the separated risk register attached to the PSR. Table 6.1 shows the adjusted PSR format for the semi-quantitative risk analysis.

During the monthly PSR meetings the focus should remain on the top ten highest scored exposures and opportunities. This to overcome a too complex and elaborated meeting with the Board of Directors, Vice President of Project Management, and Head of Project Control. Besides, the highest scored risk events will contain most of the important information. This also known as the Parato effect, i.e. the law of the vital few. The additional information provided by the semi-quantitative method can be used on a need basis, i.e. when it is necessary to have a more elaborated discussion about the project.

The exposures and opportunities register additionally can be used for a more extensive analysis. This by placing the number of risk events valid for that particular risk factor in the double P-I matrix. Figure 6.1 presents an example of the risk evaluation based on the exposures and opportunities reported in table 6.1. It provides an indication of the project's risk event density. The impact scale of the risk events will be automatically calculated based on the highest absolute financial risk event impact. This by using the following equation:

$$\text{Risk event's impact percentage} = \frac{\text{Risk event's financial impact}}{\text{The highest absolute financial impact}} * 100\%$$

Since the exposures and opportunities are separately presented in the double P-I evaluation matrix the division can be easily examined. Besides, the completed P-I matrix can be used as management summary for the upper management, i.e. the project's identified risk events can be reviewed at a glance. The advantage of using the double P-I matrix instead of a graph is that the matrix already is known by the people involved in the PRM process. This to overcome the analysis isn't understood. Figure 6.1 is an example of a completed P-I matrix based on the exposures and opportunities reported in table 6.1.

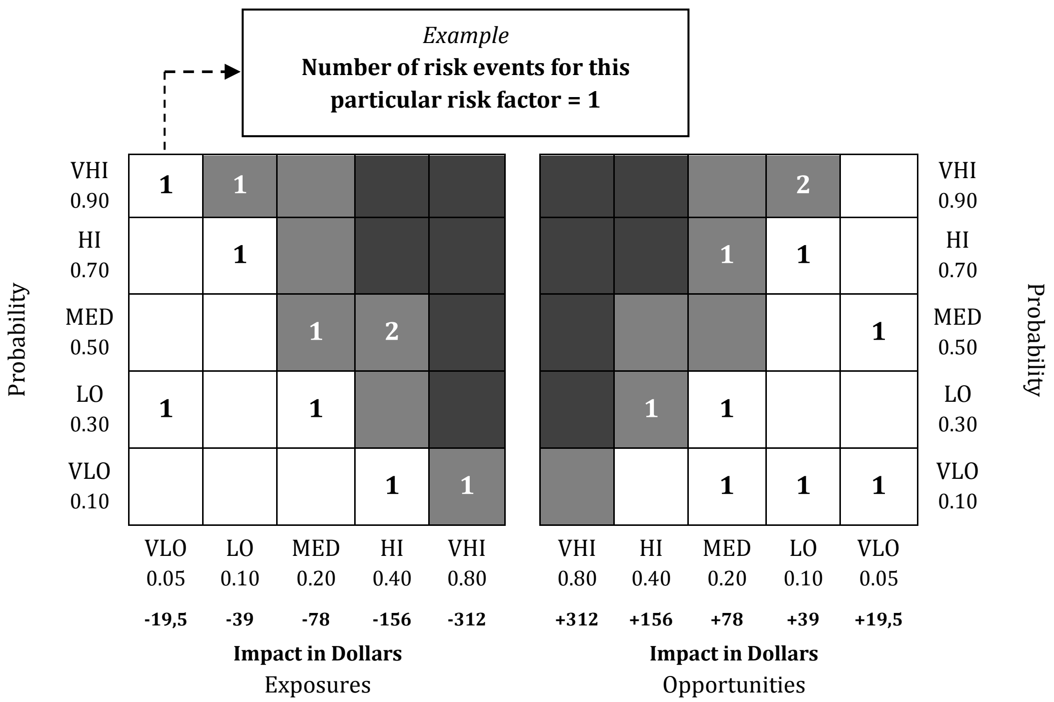


Figure 6.1: Recommendation for risk event evaluation in HMC's future PRM method, risk evaluation of the exposures and opportunities reported in table 6.1, based on ATOM's double P-I matrix (Hillson & Simon, 2007)

Status	Materialized			%	AT 100% Rev$	Direct$	Alloc.	SSCV/DCV days	P.R.$	Prev. Month P.R.$	Variance P.R.$
OCCURRED	1	Risk event 001	2010	100%		75		1.3	-75	-75	
OCCURRED	2	Risk event 002	2010	100%		300			-300	-300	
OCCURRED	3	Risk event 003	2010	100%		50		2	-50	-50	
OCCURRED	4	Risk event 004	2010	100%	325				325	325	
OCCURRED	5	Risk event 005	2011	100%		12			-12		
OCCURRED	6	Risk event 006	2011	100%	82		80	1.5	2	4	
					407	**437**	**80**		**-110**	**-96**	

Status	2011 - Exposures		%	AT 100% Rev$	Direct$	Alloc.	SSCV/DCV days	P.R.$	CALCULATED Rev$	Direct$	Alloc	SSCV/DCV days	P.R.$	Prev. Month P.R.$
ACTIVE	1	Risk event 007	50%		233			-233		117			-117	
NEW	2	Risk event 008	45%		200			-200		90			-90	
ACTIVE	3	Risk event 009	90%			50	1	-50			45	0,9	-45	
ACTIVE	4	Risk event 010	60%		60			-60		36			-36	
NEW	5	Risk event 011	80%	15	45		1,5	-30	12	36		1,2	-24	
ACTIVE	6	Risk event 012	10%		126	78		-204		13	8		-21	
ACTIVE	7	Risk event 013	25%		60		2	-60		15		1,2	-15	
ACTIVE	8	Risk event 014	99%		15			-15		15			-15	
CLOSED	9	Risk event 015	1%		140	250	6	-390		1,5	2,5	0,06	-4	
ACTIVE	10	Risk event 016	25%		-52	57	2	-5		-13	14	0,5	-1	
	11	... etc.												
		Total identified exposures		15	827	435	12,5	-1.247	12	310,5	69,5	3,86	-368	
		Unidentified exposures												
				15	**827**	**435**	**12,5**	**-1.247**	**12**	**310,5**	**69,5**	**3,86**	**-368**	

Status	2011 - Opportunities		%	AT 100% Rev$	Direct$	Alloc.	SSCV/DCV days	P.R.$	CALCULATED Rev$	Direct$	Alloc	SSCV/DCV days	P.R.$	Prev. Month P.R.$
ACTIVE	11	Risk event 017	40%	432	28	176	1	228	173	11	70	0,4	92	
ACTIVE	12	Risk event 018	85%		-100	50		50		-85	42,5		42,5	
NEW	13	Risk event 019	70%	60				60	42				42	
ACTIVE	14	Risk event 020	90%	250	212		-0,5	38	225	191		-0,45	34	
ACTIVE	15	Risk event 021	35%		-60			60		-21			21	
ACTIVE	16	Risk event 022	60%	15			-0,5	15	9			-0,3	9	
NEW	17	Risk event 023	15%		-30		-1	30		-4,5		-0,15	4,5	
ACTIVE	18	Risk event 024	5%	52	10			42	2,5	0,5			2	
ACTIVE	19	Risk event 025	10%	30	15			15	3	1,5			1,5	
DELETED	20	Risk event 026	1%	100			-6	100	1			-0,06	1	
	21	... etc.												
		Total identified opportunities		939	75	226	-7	638	455,5	93,5	112,5	-0,56	249,5	
		Unidentified opportunities												
				939	**75**	**226**	**-7**	**638**	**455,5**	**93,5**	**112,5**	**-0,56**	**249,5**	

	Total Project	%	AT 100% Rev$	Direct$	Alloc.	SSCV/DCV days	P.R.$	CALCULATED Rev$	Direct$	Alloc	SSCV/DCV days	P.R.$	Prev. Month P.R.$
	Exposures 2010												
	Exposures 2011		15	827	435	12,5	-1.247	12	310,5	69,5	3,86	-368	
	Total exposures		15	827	435	12,5	-1.247	12	310,5	69,5	3,86	-368	
	Opportunities 2010												
	Opportunities 2011		939	75	226	-7	638	455,5	93,5	112,5	-0,56	249,5	
	Total opportunities		939	75	226	-7	638	445,5	93,5	112,5	-0,56	249,5	
			954	**902**	**661**	**5,5**	**-609**	**467,5**	**404**	**182**	**3,3**	**-118,5**	

Table 6.1: Recommendation of the adjustments to HMC's current PSR format for reporting the exposures and opportunities in HMC's future PRM method

The Vice President of Project Management indicated the importance of reporting the risk event's status each month. In HMC's current PRM practice the risk event's status is put in the side line of the PSR report, though it isn't an official procedure (Chapter 5.1.7). This leading to the recommendation to update the risk event's status for each update in the separate column of the exposures and opportunities register of the PSR. A risk event in the exposures and opportunities register normally has the status 'active.' When a new risk event is updated, the status is 'new' for that monthly PSR. When a risk event is 'deleted', 'expired' or 'closed' it is updated in the exposures and opportunities register for that monthly PSR and is omitted after the PSR meeting is finished. When the risk event 'occurred' it will be updated in the 'materialized' table in the exposures and opportunities register. In table 6.1 an example of the risk events' status is presented.

The advantage of using this type of risk analysis is that the project manager himself is doing the analysis. Comments as 'I do not understand the analysis', or 'the analysis are too difficult' are no longer valid. The project manager also will be 'forced' to report the identified risk events, this guarantees a certain level of discipline. Additionally the problem of perception and the presumption of regular intervals will be deduced with this reporting method. And also the problem of human judgments' inconsistency when scoring the risk events will be less severe because the scores are reviewed each month. Nevertheless, the subjectivity will not be eliminated.

A disadvantage of the semi-quantitative risk analysis is that when the risk event with the highest absolute impact score is changed, the impact's range for the evaluation matrix also is changed. When holding the two matrices next to each other it is more difficult to compare them. A solution could be to adjust the previous (when the highest absolute impact increased) or new (when the highest absolute impact decreased) matrices based on the previous/new highest absolute impact. Other disadvantages are that the impact only is based on the financial impact and correlations between risk events are not taken in account.

6.1.3. Recommendation for HMC's PRM Process & Method, Tools, and Techniques

It is recommended to implement some changes to HMC's current PRM process which directly starts at the moment the contract is awarded, figure 6.2 presents the recommended process. Furthermore, the recommendations concerning a couple of HMC's PRM methods, tools and techniques are presented based on the PRM process. Only the recommended changes are discussed. So, when not mentioned, the method, tool or technique stays unchanged as presented in HMC's current PRM procedure. It is assumed the risk champion is in office and the semi-quantitative risk analysis is in use.

1) *PRM Initiation*

At the moment a contract is awarded the risk champion, in association with the project manager, should decide on the PRM activities for that particular project. The project sizing tool as presented in HMC's current PRM procedure is used as guideline (Chapter 3.1.1).

2) *Risk Assessment Workshop & Interviewing the Risk Owner*

In HMC's current PRM practice the qualitative risk assessment sometimes is postponed till after the risk assessment workshop (C.5, C.7, C.9, D.2). It should be ensured, i.e. the risk champion makes sure, that the qualitative risk assessment is done during the workshop. This will provide a weighted average of the assessed scores and provides insight in why participants are giving a risk event that particular score.

Concerning the identification of the response strategies HMC's PRM format should be adjusted to what already is done in practice (Chapter 5.1.2) and what is recommended by the literature (Hillson & Simon, 2007), i.e. the response strategy identification should be done after the risk assessment workshop. The identification is done in consultation with the risk owner, and if applicable additional specialists. This introducing the following recommendation to add in HMC's PRM procedure: appointing a risk owner for each identified risk event during the risk assessment workshop (Hillson & Simon, 2007). Chapter 2.2.5 presents the important factors concerning risk ownership.

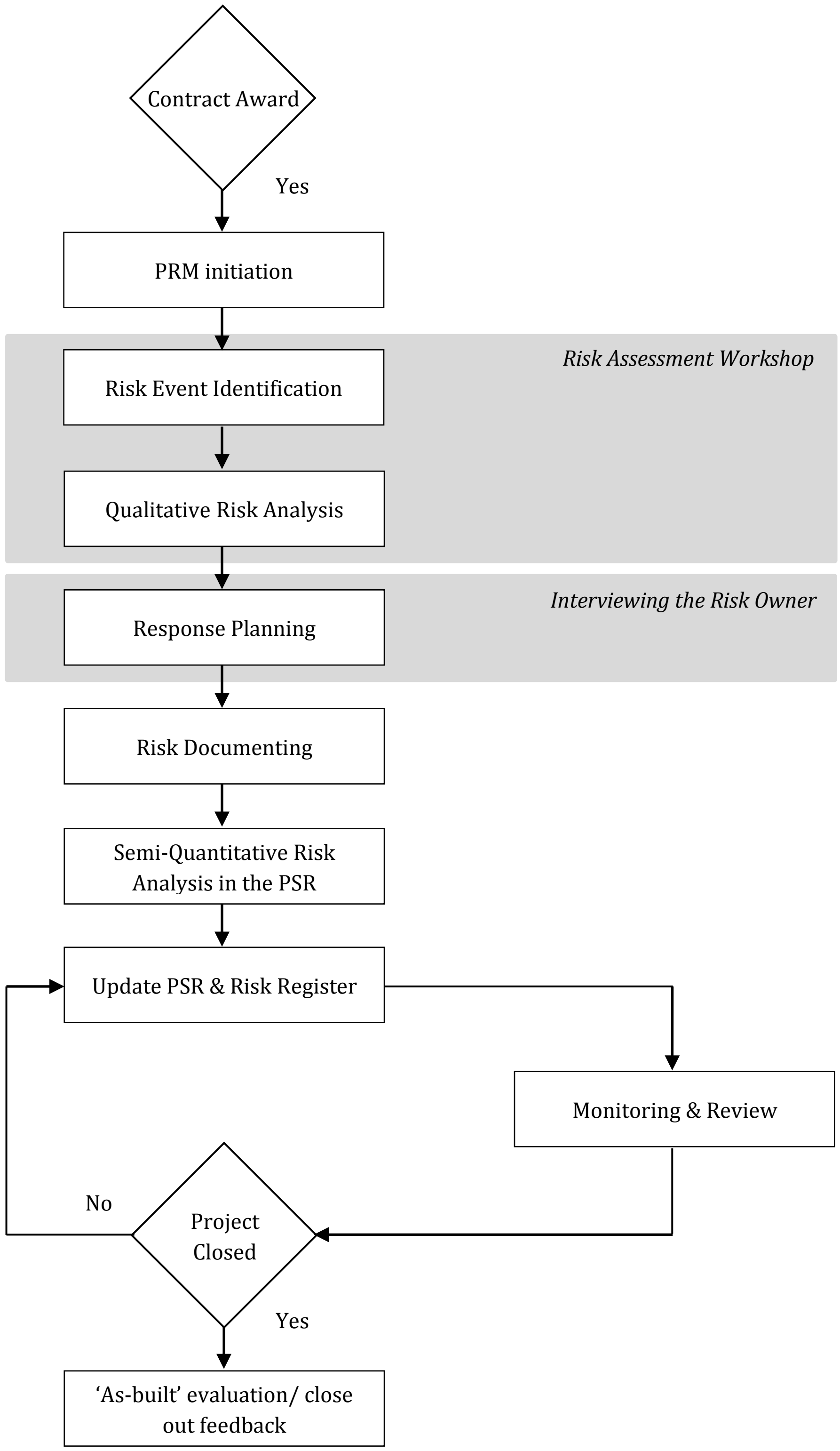


Figure 7.3: Recommended PRM process, based on the previous PRM process (Chapter 3.1), for HMC's future PRM method

3) *RISK EVENT IDENTIFICATION*

It is advisable to put additional focus on identifying opportunities. This because the risk event identification is by intuition focused on exposures. It is better to clearly divide the focus on exposures and opportunities, e.g. using different coloured sticky notes during the brainstorm sessions. If the brainstorm provides an unrealistic number of opportunities, it is advisable to start another brainstorm session solely based on the identification of opportunities.

Another recommendation will be the (re-)introduction of a pre-listed risk register. This used as a check-up at the end of the risk event identification. The pre-listed risk register also will present the risk events that are valid on corporate level and therefore can be excluded from the PRM process, e.g. the sinking of the vessel. This taking away the concern project managers have about the unmanageability of risk events on corporate level (Chapter 4.1.3). It is the risk champion's responsibility to keep the pre-listed risk register up to date.

4) *QUALITATIVE RISK ASSESSMENT*

HMC's current likelihood scale may lead to confusion and the impact scale used isn't transparent (Chapter 5.1.4). Therefore the recommendation to replace HMC's current scales for the likelihood and impact scales as presented in Chapter 2.3.1. If the scales are modified on the project's characteristics, it should be done during the PRM initiation phase at the start of the PRM process.

Also HMC's P-I matrix used shows room for improvement, i.e. (a) a higher focus on 'high-impact' risk events, (b) a clear division between exposures and opportunities, and (c) a risk factor that is the multiplication of the likelihood and impact (Chapter 5.1.4). Therefore, it is recommended to use the double P-I matrix awarded as the one best-used in practice as presented in Chapter 2.3.2.

The same double P-I matrix will be used for the risk event evaluation of the semi-quantitative risk analysis (figure 6.1). This with the advantage the participants of the risk assessment workshop will also understand the risk evaluation in the PSR.

The qualitative risk analysis solely done during the risk assessment workshop will have two functions: (a) it gives an indication of the risk assessment workshop's participants opinion about the importance of certain risk events and (b) it will give the input for the following steps, i.e. the response planning and the semi-quantitative risk analysis.

5) *RESPONSE PLANNING*

HMC's response strategies in the PRM procedure are not complete and/or correct according HMC's PRM practice and the PRM literature (Chapter 5.1.5). The 'mitigation' action in HMC's PRM procedure improving the understanding of the nature and scale of the risk event is an important action, though not mitigating the risk event. It is recommended to use this action at the start of the response planning, i.e. to get the risk event's information needed to decide on the risk event's response strategy.

The other mitigation actions in HMC's PRM procedure (Chapter 3.1.5) should be supplemented by the response strategies that avoid, transfer and accept an exposure, and exploit, share and accept an opportunity as presented in Chapter 2.2.4.

6) *RISK DOCUMENTING*

It has become clear, among others from the risk register survey results, that the documenting of the risk event's information should be done as precise as possible (Chapter 5.1.6). HMC's current risk documenting method shows some room for improvement, therefore the recommendation to use the metalanguage as presented in the PRM literature (Chapter 2.2.6): *'As a result of <cause>, <event> may occur, which would lead to <effect on objectives>'* (Hillson & Simon, 2007).

The risk events identified are documented as precise as possible in the risk register using the format as presented in table 6.3. This risk register will be used during the risk assessment workshop, the qualitative risk analysis and the first response planning. At the moment the risk events are translated to the PSR the risk register will get the format of table 6.4 which can be found attached to the monthly PSR, i.e. the qualitative risk analysis scores are no longer needed.

Risk Id Number	*Cause (As a result of…,)*	*Event (… may occur,)*	*Effect on objectives (which would lead to…)*	*Likelihood score*	*impact*	*Score*	*Response Strategy*	*Risk Owner*
xxx001								
xxx002								
xxx003								

Table 6.3: The recommended risk register for HMC's future PRM method.

Exposures	*Risk Id Number*	*Risk event status*	*Cause (As a result of…,)*	*Event (… may occur,)*	*Effect on objectives (which would lead to…)*	*Response Strategy*	*Risk Owner*
1	xxx001						
2	xxx002						
3	xxx003						

Opportunities	*Risk Id Number*	*Risk event status*	*Cause (As a result of…,)*	*Event (… may occur,)*	*Effect on objectives (which would lead to…)*	*Response Strategy*	*Risk Owner*
1	xxx001						
2	xxx002						
3	xxx003						

Table 6.4: The recommended risk register as attached in HMC's monthly PSR.

7) *SEMI-QUANTITATIVE RISK ANALYSIS*

The first risk register (table 6.3) established will be used as input for the translation of the identified risk events to exposures and opportunities for the semi-quantitative risk analysis. For the semi-quantitative risk analysis the single-value estimations are defined in consultation with the project manager, risk champion, and the cost estimator or project controller. The steps towards the analysis' results are performed as described in Chapter 6.1.2.

8) *MONITORING & REVIEW - UPDATE PSR & RISK REGISTER*

The risk champion will arrange a meeting on a need basis, at least once in the two/three months, for the review of all risk events and to identify possible new risk events. Subsequently, both the semi-quantitative risk analysis and the exposures and opportunities register are updated. This is done in consultation with the project manager and if applicable additional people.

9) *PROJECT FEEDBACK AND CLOSE OUT*

The project feedback and close out is important for the contribution to the organizational experience (Chapter 2.2.9). At the end of the project the risk champion facilitates a meeting with the project manager, and if applicable additional people. During the meeting the 'lessons learned' are defined and the PRM process is reviewed. The risk champion will document the feedback and will update the pre-listed risk register based the gathered information. This will ensure the loop between feedback and close out, and the start of the PRM process is closed. If done correctly the company's body of knowledge will benefit future projects.

6.2. LONG TERM RECOMMENDATIONS FOR HMC'S PRM METHOD

The fact that HMC's former quantitative risk analysis' results only were used little by the project managers was mainly because of the project managers' misunderstanding towards the method used. What also contributed to the little use of the MC simulation's results was the fact that the simulation didn't give more insight information on the project. Though, there also where project managers that saw the usefulness of the MC method. Even a couple of project managers have indicated that it could be useful to use a quantitative risk analysis method for HMC's more complex, difficult and/or new projects. A quantitative method isn't necessarily needed for the relatively simple T&I projects according those project managers (Chapter 4.2.3).

Hence, it could be useful to use a quantitative risk analysis, i.e. a MC method, for HMC's more complex projects. Knowing that HMC's core business is shifting more towards those complex projects, i.e. the clients are transferring more of their risk to the contractor, induces the recommendation to start using a quantitative risk analysis method in HMC's PRM method. In this future PRM method the MC method should be used on a need basis, i.e. only for the projects that are complex, difficult and/or new, and/or when the project manager considers it as worthwhile to execute a MC simulation.

Though, to increase the probability of success for the re-introducing of the MC method it is important to deal with two difficulties: (a) the misunderstanding most of HMC's project managers do have regarding the MC method, and (b) ensuring a higher quality MC method than used by HMC in the past. This is what causes that the re-introduction of the MC method is a long term recommendation; the two difficulties should be dealt with first.

Some of the short term recommendations, as presented in Chapter 6.1, will develop an understanding towards the MC method. The semi-quantitative risk analysis can be used as a springboard towards the quantitative risk analysis. The step from a semi-quantitative method towards a quantitative method is less difficult than from a qualitative method towards a quantitative method. Since it are the project managers themselves doing the semi-quantitative risk analysis an understanding for the more complex risk analysis method will be developed. But also the risk champion's expertise will benefit the project managers' development towards an understanding of the MC method. The risk champion will train and guide the project managers during the PRM activities; this will convince the participants of the PRM's benefit (Hillson & Simon, 2007), (Chapter 2.1).

Concerning the quality of the MC method it is important the risk champion successfully is taken in office, this because the risk champion will perform the quantitative risk analysis. The MC method that will be used should be of higher quality than the method used by HMC in the past (Chapter 5.2.2), this to ensure a truthful estimation of the risk events' combined effect. It is important to improve the following factors: (a) the overconfidence of people when defining the risk events' ranges and distributions, (b) taking both exposures and opportunities in account, (c) taken the existing correlations between risk events in account, and (d) positively testing the method used also is truthful. Chapter 2.4.3 discusses those factors in more detail.

The re-introduction of the MC method will give a couple of advantages in comparison to the semi-quantitative method as presented in Chapter 6.1.2. For the semi-quantitative method a normalized simulation stays out. The MC method's simulation is based on the ranges and distributions defined for the risk event's likelihood and impact (Chapter 2.4.2). The advantage of this simulation is that an estimation of the size of the project risk is given, i.e. the best project outcome, the most likely project outcome, and the worst project outcome. Using the quantitative method to get an indication of the effect of the planned response strategies, this by adjusting the risk event's information based on the response strategy when running a new simulation, will give a more meaningful indication of the risk event's effect on the project risk. It's the size of the eye-ball plot that provides an indication of the project risk's magnitude. This should be the awareness starting to manage those risk events making the eye-ball smaller, i.e. making the project risk smaller (Chapter 2.4.2), (Chapter 4.2.2).

CHAPTER 7: CONCLUSIONS & RECOMMENDATIONS

This chapter will present the thesis' conclusions and the recommendations. The conclusions will provide the answers to the two main research questions: *'Which aspects of HMC's current project risk management method show room for improvement?'* and *'What is the usefulness of quantitative risk analysis in HMC's project risk management?'* The recommendations is divided in (a) the recommendations for future research and (b) the recommendations for HMC's future PRM method. Finally, the thesis' reflections will be presented.

7.1. HMC'S PRM ASPECTS THAT SHOW ROOM FOR IMPROVEMENT

According to the Vice President of Project Management the answer to the functioning of HMC's PRM is relatively simple. Since a large majority of the projects are finished within the project budget, the PRM must be good enough (Chapter 4.1.11). The PRM definition as given in literature is: 'PRM is the controlled process of understanding and managing risk events and the accumulated project risk. [...]Properly executed PRM will increase the likelihood that the project meets its objectives with respect to time, cost, quality and scope' (Chapter 2). At first glance the statement of the Vice President of Project Management may seem right, although if the project meets its objectives with respect to time, cost, quality and scope it does not automatically mean that the PRM was properly done. It is possible that the project meets its objectives because of other reasons. When questioned, the project success is most often because of change order requests, i.e. additional work in opportunity of HMC's project outcome. The project's cost are almost never lower than budgeted (C.18), this enabling that there could be room for improvement in HMC's current PRM method.

The comparison between HMC's PRM 'SOLL' and 'IST' situation, i.e. the PRM procedure and PRM practice, shows that the project managers assess the current PRM method as insufficient. The activities are not properly done because of the project managers' high workload, and to some extent because of discipline difficulties (Chapter 4.1.11). The comparison between HMC's former and current practice indicates that the main issues causing that HMC's current PRM method is declared as not good enough, was eliminated by HMC's former risk team. The risk team's facilitating role eliminated most of the project managers' PRM workload and provided a certain level of discipline. It isn't surprising that several project managers consider HMC's former PRM method, exclusively referring to the facilitating role, better than the current PRM method. This also is confirmed by a project manager who is pleased with the fact that a former risk team member currently is facilitating the PRM activities on his running project (Chapter 4.2.1).

At the time the risk team was in office, the team provided substantive guidance during the PRM activities, and trained the PRM participants. This also contributed to the acceptance of the PRM method as proven in the period the risk team was in office. Additionally, the risk team did have (a) an objective view on all projects, (b) produced a companywide PRM uniformity, and (c) developed a higher quality PRM method (Chapter 4.2.3). Hence, appointing a risk champion, as recommended for HMC's future PRM method (Chapter 6.1.1), who will function in approximately the same way as the former risk team, will benefit HMC's future PRM method. The importance of a risk champion has also been confirmed in a previous research concerning HMC's PRM method (Joustra, 2009).

In addition, the functioning of the PRM methods, tools and techniques used in HMC's PRM process also raise concerns. The comparison made between HMC's current PRM procedure and practice has indicated that the content of HMC's PRM procedure is not known by all project managers. Some even don't know the existence of the procedure. This emerges from the fact that the practice of reporting the project's risk events to the upper management differs among all project managers (Chapter 4.1.8, Chapter 4.1.11).

Therefore, the largest improvement possible in the methods, tools and techniques used concerns the reporting method of the risk events to the upper management. Since not all project managers are reporting the top ten risk events consistently, the current state isn't complete and uniform. But, a complete and uniform overview of all the projects' risk events also stays out when the top ten risk events are consistently reported. The risk register survey results show that the perceptions of the project managers may differ so much that the same risk event can be in the top ten for one project manager and not even close to the top ten for another project manager (Chapter 5.1.8). Comparing different projects becomes more difficult. Furthermore, if it is required to consistently report all important identified risk events in the PSR, a certain level of discipline will be guaranteed as well.

The method for reporting the exposures and opportunities is a powerful tool, which could be used more efficiently. It can be referred to as semi-quantitative risk analysis, i.e. it (a) is more detailed than qualitative risk analysis and (b) less detailed than the quantitative risk analysis method used by HMC in the past. When all important identified risk events are reported as exposures and opportunities instead of only the top ten highest scored risk events, an estimation of the project risk related to money is provided. Besides, the improved method won't ask much more time from the project manager, this to make sure the project manager's workload doesn't become an issue. A couple of project managers are already reporting all identified risk events in the PSR (C.2, C.10, C.14). These project managers are the most satisfied with HMC's current PRM method. Chapter 6.1.2 describes the improved version of the semi-quantitative risk analysis.

From the comparison of HMC's current PRM procedure and practice with the PRM literature, it turned out that several other methods, tools and techniques used in HMC's PRM method are of poorer quality. Especially the following points show room for improvement:

1) *Risk assessment workshop & interviewing the risk owner*: currently, the risk assessment sometimes is done after the workshop, this to the prejudice of the weighted average created when assessing the identified risk events in a group. HMC's PRM procedure describes to define the response strategies during the workshop, where HMC's PRM practice and the PRM literature have indicated it is better to do this after the workshop (Hillson & Simon, 2007). The appointment of the risk owner isn't presented in HMC's current PRM procedure, where it is seen as important in HMC's PRM practice and the PRM literature (Chapter 4.1.2, Chapter 5.1.2).
2) *Risk event identification*: the focus on identifying both opportunities and exposures in HMC's PRM procedure isn't noticed in HMC's PRM practice: it are especially exposures that are identified. This may provide an unrealistic view on the project risk (Chapter 4.1.3, Chapter 5.1.3).
3) *Qualitative risk analysis*: HMC's qualitative risk analysis presents a likelihood and impact scale that is vague and may lead to confusion. This, together with the regular biases and subjectivities (Chapter 2.3.4), may lead to subjective likelihood and impact scores. This also proven by the risk register survey results (Chapter 4.1.4, Chapter 5.1.4).
4) *Response planning*: the response strategies presented in HMC's PRM procedure are supplemented by additional response strategies in HMC's PRM practice, this causing the practice is more in line with the response strategies presented in the PRM literature than presented in HMC's PRM procedure (Chapter 4.1.5, Chapter 5.1.5).
5) *Risk documenting*: the risk documenting method used by HMC is to some extent similar to the metalanguage as presented in the PRM literature. Nevertheless, the way the risk event's consequence is documented may lead to confusion (Chapter 4.1.6, Chapter 5.1.6).

Chapter 6.1.3 presents the 'quick wins' recommended for HMC's future PRM method for the improvement of the above mentioned points.

7.2. The Usefulness of Quantitative Risk Analysis in HMC's PRM Method

HMC's former PRM method did make use of quantitative risk analysis by using a MC method. The purpose of using the MC method was to get an indication of the enterprise risk. Since the company's risk lies for 80% within its projects, the MC simulations of each separate project was of high importance. This produced the advantage that the simulation's results were also available for the PRM.

The MC simulation was done at the start of the PRM process, i.e. after the risk assessment workshop, and additionally done approximately each three months during the project review moments

(C.15). The MC simulation's output, i.e. the eye-ball plot, presented the risk events' combined effect. This eye-ball plot provided a visualization of the estimated project costs and project execution schedule. Additional analyses were done to get an indication of the effects that certain risk events had on the project outcome; this was done by leaving that specific risk event out of the simulation or by adjusting the risk event's information based on possible response strategies. The quantitative risk analysis provided an elaborate insight on the project. This was in benefit of the decision making process concerning the response planning (Chapter 4.2.2).

However, most of the project managers didn't use the MC simulation results. This because the results weren't trusted, not understood and/or didn't provide more insight into the project's risk events in comparison to the qualitative risk analysis that was done (Chapter 4.2.3). This attitude towards the MC method isn't outlandish. Galway (Galway, 2004) and Hubbard (Hubbard, 2009) have indicated that, in general, there is a lot of misunderstanding towards the quantitative risk analysis. Galway concluded from a critical review that the quantitative risk analysis is seen as useful in practice, though undergoes some difficulties, e.g. that it is experienced as too difficult and not worth the time and effort (Chapter 2.5.2). When also taking Besner & Hobs (Besner & Hobbs, 2008) their conclusion in account that quantitative risk analysis is only used very limited and doesn't show potential for growth in the near future, it appears that the quantitative risk analysis suffers from the misunderstanding. This misunderstanding also was present in HMC's former PRM method.

But, even if the project managers do have a good understanding towards the quantitative risk analysis it still is the question if a quantitative risk analysis is useful for HMC's PRM method. A truthful MC estimation of the project risk always has value, even if the decisions concerning the PRM are only based on a fragment of the analysis' results. Though, it is vital to don't lose sight of the main purpose of PRM, i.e. the management/response planning of the identified risk events to ensure project success. Therefore, it is important to find the right balance between analyzing and managing the risk events.

The couple of project managers that did use the MC simulation results used it as an awareness, i.e. to check if the estimation was equal to what was expected. Some of the project managers that used the MC simulation results, indicated that no real surprises had come forward from the MC results. Most of the time, the top ten risk events were the same for both the qualitative and quantitative risk analysis' results, only the ordering differed sometimes (Chapter 4.2.3). Hence, the most important risk events were already highlighted based on the qualitative risk analysis and the intuition and expertise of the project manager, as equal to HMC's current PRM. The risk events that needed attention for the response planning according the MC simulations was nearly identical to what was already known. This indicating the balance was too much towards analyzing the risk events.

Nevertheless, there are some project managers that have indicated it could be useful to use the MC method on HMC's more complex, difficult and/or new projects (further referred to as 'complex projects'). According to them it isn't necessary for the relative simple T&I projects, HMC's core business. It is noteworthy that the project managers working on HMC's complex projects are indicating that HMC's current PRM method is functioning well enough and an additional quantitative risk analysis is not needed.

It can be concluded that a quantitative risk analysis isn't useful for HMC's PRM method at this moment. This mainly because of the misunderstanding most of the project managers do have regarding the previous used MC method. Re-introducing a quantitative method probably will provide the same problems as in the past. Also the fact the MC method didn't provided additional information to most of the project managers has contributed to this conclusion.

What also strongly contributed to the conclusion, is the fact that there is room for improvement in HMC's method of reporting the exposures and opportunities. An indication of the project risk is also provided when all important risk events are taken into account in the semi-quantitative risk analysis. Additionally, an indication can be given of the project's risk density based on the information reported in the PSR. The advantage of the semi-quantitative risk analysis is that it is the project manager himself who performs the analysis. This way the method is always understood and never perceived as too difficult. Furthermore, this analyzing method is well integrated into the PRM process. And as goes for the quantitative risk analysis, the semi-quantitative risk analysis will also force the project manager to use structured thinking when defining the analysis' input. Chapter 6.1.2 presents the upgraded semi-quantitative risk analysis method.

Though, the quantitative risk analysis shouldn't be totally rejected. When the misunderstanding regarding the quantitative risk analysis is solved a quantitative method will be more effective in HMC's PRM process. The semi-quantitative risk analysis could be used as a springboard towards the quantitative risk analysis. Since the project managers are performing the semi-quantitative risk analysis themselves, they will develop an understanding to the method. The step from a semi-quantitative method towards a quantitative method is smaller than from a qualitative method towards a quantitative method. It also is important the risk champion is successfully taken in office, since it is the risk champion that will perform the quantitative risk analysis in consultation with the project manager.

The advantage of a MC method, in comparison with the semi-quantitative risk analysis, is that a normalized simulation of the risk event's ranges and distributions is done. The MC simulation can be used to get an idea of the effect the response strategies have on the project risk. The size of the eye-ball, the MC simulation output, provides an indication of the project risk's magnitude, it is the art to get the eye-ball as smaller when planning the response strategies (Chapter 4.2.2).

According the project managers that perceive the quantitative risk analysis as useful for more complex projects, a quantitative method isn't necessarily needed for the relatively simple T&I projects. It is more useful for HMC's complex projects. With the knowledge HMC's core business is shifting more towards those complex projects, this because the clients are transferring more of their risk to the contractors, a quantitative risk analysis could be useful in the future. The method should be used on a need basis, i.e. only the projects that do have such complexity and/or where the project manager perceives such an analysis as worthwhile.

There were also a couple of project managers who indicated that the MC method was something for the upper management, i.e. for the decision making process on HMC's portfolio level (Chapter 4.2.3). The Vice President of Project Management reviewed the MC simulation results. He indicated that the MC analyses did have value, but that it wasn't possible to say that the additional information led to other/better decisions (C.18). When the MC method will be used for the more complex projects the value of reviewing the results on HMC's portfolio level will return.

When the quantitative risk analysis is re-introduced, it is important to use a truthful method. This because the MC method used by HMC in the past lacked some quality: (a) the overconfidence of people when identifying the risk event's information has probably provided untruthful inputs, (b) there wasn't a truthful division between exposures and opportunities, (c) correlations between risk events were not sufficiently taken into account, and (c) the method used was not tested based on previously finished projects (Chapter 5.2.2). Chapter 6.2 presents the requirements concerning a new quantitative method in the future of HMC's PRM method.

7.3. Recommendations for Future Research in the PRM Literature

7.3.1. The Usefulness of a Risk Champion

One of the conclusions in this thesis is that a risk champion will benefit HMC's PRM method. From the analysis it turns out that HMC's project managers are missing the former risk team's facilitating role. The PRM literature describes the possibility of appointing a risk champion and presents several advantages of having a risk champion in office (Chapter 2.2.10). Though, empirical evidence that it is worthwhile to appoint a risk champion is, so far I know, missing. It could be very interesting to get insight on the benefit of appointing a risk champion: (a) if the probability of project success increases, (b) if the project managers' attitude towards the PRM improves, and (c) if the PRM activities are of higher quality than when having no risk champion in office. Therefore, it is recommended to do research regarding the functioning of a risk champion in the PRM process.

7.3.2. *When to Use a Qualitative and/or Quantitative Risk Analysis*

Concerning the decision of when to use a qualitative and/or quantitative risk analysis method clarity is missing (Galway, 2004). There is only little empirical evidence that a quantitative risk analysis improves the company's financial performance. For this evidence it is unclear if the quantitative method was used on project level (Hubbard, 2009), (Chapter 2.5.2). It could be useful to have additional research on the influence a quantitative method will have on project success. This, on high level, regarding the financial performance as result, and in more detail regarding the differences between a project manager's decision making process in case of a qualitative or quantitative risk analysis. The last comparison will be a more psychological research. The results will highly depend on the researched person's attitude towards PRM and the project working on. Though, when done with many project managers/projects it could be possible to get an impression of when to use a qualitative and/or quantitative risk analysis method.

7.3.3. *Overcome the Misunderstanding towards Quantitative Risk Analysis*

Besner & Hobbs have indicated that the quantitative risk analysis methods are only used very limited in the PRM, and that the use doesn't show potential grow in the near future (Besner & Hobbs, 2008). From the critical review, done by Galway, it turns out that it is generally the misunderstanding towards the quantitative methods that an extensive use in practice stays out (Galway, 2004). The method is perceived as too difficult, not explainable to senior decision makers, etc. (Chapter 2.5.2), this also demonstrated in HMC's former PRM method (Chapter 7.2). Several reference works have indicated this misunderstanding as unnecessary, a quantitative risk analysis method isn't as difficult and time consuming as thought by many (Hillson & Simon, 2007), (Hubbard, 2009). Though, the literature doesn't mention how to overcome those misunderstandings. It's recommended to research why the misunderstanding isn't valid in the PRM methods that successfully have taken a quantitative risk analysis method into service. This will give insight on how to overcome the misunderstandings to ensure success when implementing a quantitative risk analysis method.

7.3.4. *The Integration of PRM in Project Management*

HMC's PRM method is used in addition of the regular project management activities. The information available from the PRM isn't used in other project management activities such as the planning, asset management, and/or quality management. Only a part of the PRM information is taken in account for the project's financial forecast, i.e. in the exposures and opportunities report in the PSR (Chapter 3.1.8). The PRM literature also describes the PRM as a separated process. When the PRM process is more integrated into all the project management activities the PRM effort could become more valuable. Therefore, the recommendation to perform research on (a) how the project performance could benefit from such an integration and (b) how it could be possible to integrate the PRM into the project management more interwoven.

7.4. Recommendations for HMC's PRM Method

The recommendations for HMC are divided in two parts: the short term improvements, i.e. the 'quick wins', and the long term improvements.

7.4.1. *Short Term Recommendations for HMC's PRM Method*

The project managers' time issues, and partly the discipline problems have induced the recommendation to appoint one risk champion for HMC's future PRM method. The risk champion's facilitating role will take away most of the project manager's PRM workload and will ensure the PRM activities are consistently done (AIRMIC, ALARM, IRM, 2002), (Hillson & Simon, 2007). Besides, the risk champion will benefit HMC's PRM method on several other points: the risk champion (a) will have an objective view on all projects (Keizer, Halman, & Song, 2002), (b) will give substantive guidance during the PRM activities, (c) will train the people involved in the PRM activities, and (d) will ensure the development of a higher quality PRM practice over time. Chapter 6.1.1 presents the recommendation to appoint a risk champion in more detail.

The method of reporting the risk events to the upper management shows large room for improvement. Therefore the recommendation to improve the semi-quantitative risk analysis in HMC's PSR. By reporting 'all identified risk events', i.e. the ones that are significant enough to be documented, with a single-valued likelihood of occurrence and financial magnitude of impact, a single value estimation of the risk events' combined effect is provided. The analysis also will give an insight on the project's risk density by presenting the reported risk events in ATOM's double P-I matrix (Hillson & Simon, 2007). The method will have the advantage (a) that it becomes easier to compare the different projects, (b) that the project manager himself is doing the analysis which will overcome misunderstanding towards the method used, and (c) that the project manager is forced to think in more detail about the project during the analysis (Galway, 2004). Chapter 6.1.2 presents the recommendation for the semi-quantitative risk analysis in more detail.

There are also several recommendations concerning other PRM methods, tools and techniques used in HMC's current PRM method. Chapter 6.1.3 presents those improvements in detail. The following five improvements can be perceived as most significant:

1) *Risk assessment workshop & interviewing the risk owner*: it is better to perform the qualitative risk analysis during the workshop creating a weighted average, and to execute the response planning during interviews with the earlier appointed risk owners.
2) *Risk event identification*: it is sensible to ensure an additional focus on identifying opportunities, i.e. ensuring a truthful division between exposures and opportunities. This to avoid a pessimistic/ unrealistic view on the project risk.
3) *Qualitative risk analysis*: it's recommended to change the likelihood and impact scales used to overcome confusion, and to reduce the subjectivity during the identification of the risk events' likelihood and impact scores. It's also is recommended to interchange HMC's Risk Evaluation Matrix for ATOM's double P-I matrix (Hillson & Simon, 2007).
4) *Response planning*: the response strategies should be supplemented with the response strategies that (a) avoid, transfer, accept an exposure and (b) exploit, share and accept an opportunity, this to ensure HMC's PRM procedure is equal to what already is done in practice and what is described in the PRM literature.
5) *Risk documenting*: Concerning the subjectivity in documenting the risk event's consequence it is recommended to adjust HMC's method of risk documenting to the metalanguage presented in the PRM literature (Hillson & Simon, 2007).

7.4.2. Long Term Recommendations for HMC's PRM Method

The re-introduction of a MC method in HMC's PRM method could be useful. This knowing that there are some project managers indicating a quantitative risk analysis could be useful for HMC's more complex projects, and that HMC's core business is shifting more towards those complex projects. When re-introduced the MC method should be used on a need basis, i.e. only for the complex projects, and/or when the project manager considers it as worthwhile to perform a MC simulation.

To increase the probability of success for the re-introduction of the MC method it is important to deal with two difficulties: (a) the misunderstanding most of HMC's project managers do have regarding the MC method (Chapter 5.2.3), and (b) ensuring a higher quality MC method than used by HMC in the past (Chapter 5.2.2). This is what causes the re-introduction of the MC method is a long term recommendation: the two difficulties should be dealt with first. Chapter 6.2 presents the re-introduction of the MC method in more detail.

7.5. Thesis Reflections

7.5.1. Reflections of the Research Methodology Used

The thesis is based on the research triangle comparing HMC's PRM procedure ('SOLL'), HMC's PRM practice ('IST'), and the PRM literature (Chapter 1.4). Firstly, this comparison has given detailed insight in the difference between how HMC's PRM is done in practice, and how it should be done in practice according HMC's PRM procedure. This in interest of HMC to see how the PRM method is performing. Secondly, the comparison has given detailed insight in the difference between the PRM literature and HMC's PRM practice. This in interest of the scientific community, i.e. the results can be used as empirical evidence afore or against the PRM methods, tools and techniques as discussed in theory. Figure 7.1 presents the different interest perspectives.

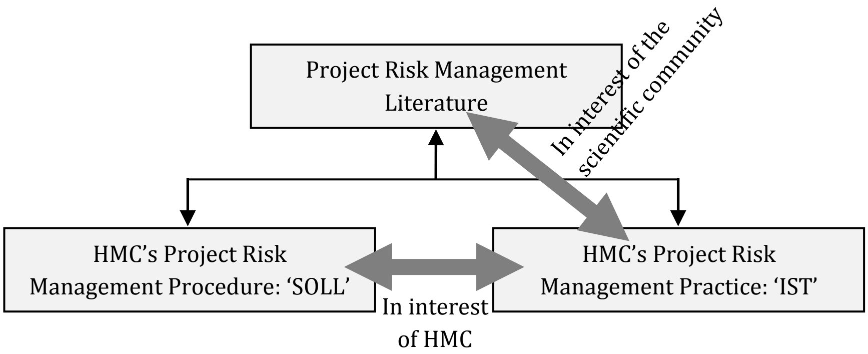


Figure 7.1: Research triangle indicating the perceptions of interests

The advantage of doing such detailed analysis based on a PRM method's practice is that evidence afore or against the PRM theory is provided. Another advantage of having HMC as case study is that HMC did have two different PRM methods to analyse: the former PRM method, with risk team and quantitative risk analysis, and the current PRM method. This made it possible to compare the performance of the different methods in detail. The recommendations for HMC's future PRM method benefits from this comparison. A risk team/risk champion already have been successfully in the past, this as warrant the appointment of a new risk champion also will have success. Also the advice of using a quantitative risk analysis method in HMC's future PRM benefits from this comparison; because a quantitative method has been in office before, it is known the project managers' misunderstanding should be dealt with first before the implementation, and the method only should be used for the complex projects. This comparison also benefitted the scientific conclusions; the importance of a risk champion has been proven and the misunderstanding towards quantitative risk analysis confirmed.

7.5.2. *Reflections of HMC's PRM Aspects that Show Room for Improvement*

The conclusions based on HMC's current PRM method are specific for the company. Therefore, the generalization of the conclusion to other PRM methods is not possible. However, several aspects that have been concluded from HMC's PRM method could be the same for other PRM methods as well. The subjectivity of HMC's qualitative risk analysis method, as proven by the risk register survey, is possibly also valid for qualitative risk analysis methods used by others. This suggested in PRM literature (Chapter 2.3.4). But, generalizing the qualitative risk analysis' subjectivity isn't automatically. So far I know there isn't empirical evidence on the subjectivity, except for the overconfidence of people when defining ranges. Additional empirical evidence is needed before generalizing this conclusion.

7.5.3. *Reflections of the Usefulness of Quantitative Risk Analysis in HMC's PRM Method*

It is concluded that it isn't useful to use a quantitative risk analysis method in HMC's PRM method at this moment, though that it could be useful for HMC's PRM method in the future. The conclusions are based on the view of HMC's project managers towards the MC method and on HMC's current PRM method. The possibility to improve the semi-quantitative risk analysis has largely contributed to this conclusion. What needs to be said is that the usefulness of a quantitative risk analysis method depends on the PRM method used or the type of projects working on. To make it possible to generalize the conclusion to other PRM methods it is necessary to test this particular conclusion on other companies' PRM methods.

Furthermore, the conclusion is only for HMC's PRM method. A quantitative risk analysis method could possibly also be useful for the decision making process concerning HMC's portfolio level, i.e. all projects together. Some of the project managers interviewed have suggested that HMC's former MC method was more valuable for the decision making process of the Vice President of Project Management and the Board of Directors (C.8, C.13). This could be true, although such a conclusion requires research which is outside the scope of this thesis.

HMC's former MC method was also used outside the project management, e.g. at the operation department. The MC simulations were done for all the equipment on HMC's SSCVs. The purpose was to decide on the planned investments. An estimation of the future cost, when investing and when not investing, was provided to reconsider the planned maintenance. This just started to run properly at the moment the Board of Directors abandoned the risk team. A study on the usefulness of a quantitative risk analysis method for the maintenance on HMC's SSCVs could be very useful.

7.5.4. Personal Reflections

The thesis, started in February 2011, did have another perspective at the beginning. The early plan was solely focused on the added value of a MC method in HMC's PRM method. This by comparing HMC's former PRM method (including the MC method) with HMC's current PRM method (excluding the MC method). During the literature research and the first meetings with HMC it became clear that the focus shouldn't be solely on the MC method, but also on the other PRM activities. The value of a MC method is subsidiary to the quality of the PRM method in general, i.e. the activities prior to a quantitative risk analysis, and the PRM participants' attitude towards the PRM. Therefore, the decision to focus on (a) the aspect in HMC's PRM that show room for improvement and (b) the usefulness of a quantitative risk analysis. This caused that the thesis was broadened, with the result that a part of the literature research became useless and additional literature research was needed. When redoing this thesis the first phase could be done more efficiently.

During the interviews with HMC's project managers, and additional people related to the PRM, HMC's PRM procedure and the PRM theory became more clear. This also because the PRM theory was new for me at the start of the project. Hence, the whole process has been a learning path. For example, I considered the risk team's facilitating role as not really important at the start of the case study. Though, the team apparently did have a large influence on HMC's former PRM quality. This caused little modifications to the content of the interviews. Such modifications also were necessary concerning the procedure of reporting identified risk events in the PSR, it firstly wasn't known to me that there was such a procedure. Finally, it turned out that the information concerning the differences in how to report the identified risk events in the PSR was very important. Also the interviewing technique itself developed over time. I experienced the first interview as really difficult, though I became more experienced in interviewing which resulted in more valuable data.

The road to the thesis' conclusions and recommendations have been a real quest. By knowing the outcomes the whole process could have been more efficient, and at some points more focused on certain details. Though, since every case is unique and the answers aren't known upfront any new PRM case study would result in a comparable quest.

7.5.5. Reflections of the Thesis' Validity & Reliability

For the validity of the thesis the documents used and data gathered concerning HMC's PRM method have been selected as objective as possible. Therefore, project specific documents have been compared with the same type of documents of other projects and the list of interviewed people has been deliberately developed. To ensure the reliability of the thesis the methodology is described in detail and most of the information gathered is presented in the Appendices, i.e. the interviews (Appendix C), the risk assessment workshop attended (Appendix D), and the risk register survey results (Appendix E). This makes it possible to validate the conclusions drawn.

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APPENDICES

APPENDIX A: TOOLS AND SHEETS OF HMC'S PRM PROCEDURE

A.1. RISK REGISTER TABLE

The Risk Register table that standard is used by HMC (Bree, 2010).

Risk Id Number	*Cause (There is an event that...)*	*Effect (that will result in...)*	*Consequence (budgetary)*	*Likelihood score (1-5)*	*impact*	*Score*	*Mitigation/ action*	*Person/ Department tasked*
xxx001								
xxx002								
xxx003								

A.2. RISK EVALUATION MATRIX

In HMC's Risk Evaluation Matrix (REM) each risk is identified based on its likelihood and impact score, this to make it possible ranking the risks. The overall score is the sum of the likelihood score and impact score. The matrix gives the combination of both scores and the definition of those scores as defined by HMC, the sum of the likelihood and impact scores (Bree, 2010).

A.2.1. LIKELIHOOD

5. Happens once every month (50%)
4. Happens twice every year (10%)
3. Happens once a year (5%)
2. Happened once in the last 5 years (1%)
1. Has happened in the last 10 years (0.5%)
0. Never happened worldwide (0.2%)

LIKELIHOOD						
	5	6	7	8	9	10
	4	5	6	7	8	9
	3	4	5	6	7	8
	2	3	4	5	6	7
	1	2	3	4	5	6
	0	1	2	3	4	5

IMPACT

A.2.2. IMPACT

5. Very High: Major financial gain or loss, improvement or failure on almost all project objectives, major delay or schedule improvement.
4. High: Significant financial gain or loss, improvement or failure on most project objectives, significant delay or schedule improvement.
3. Medium: Serious threat to, or improvement on, project objectives.
2. Low: Small effect on project outcomes.
1. Very Low: Very small effect on project outcomes.
0. No effect on project outcomes.

A.3. Risk Statement Sheet

Risk Statement
Cause (There is an event that … - event or circumstances)
Event (That results in …)
Consequence (that will threaten [-] / improve [+] (or both [±]) … which **project objectives**?) [ ] Schedule (Vessel days) [ ] Costs [ ] Revenues [ ] Man-Hours (PM, Engineering, etc.) [ ] Cargo Barge days / Towing tug days [ ] … [ ] …
Risk Assessment Likelihood (0 – 5) [ ] Impact (0 – 5) [ ]
Mitigation Plans Action — Responsible person / debt

APPENDIX B: CASE STUDY PROCEDURES

This Appendix presents the interview questions used for the interviews with HMC's personnel and presents the format of the risk register survey.

B.1. INTERVIEW QUESTIONS

The interview questions for the interviews with the project managers and the interviews with the former risk team members are presented below. The type of questions are linked to the research framework as presented in chapter 1 (figure 1.3), and the framework of evaluation as described in chapter 2.6. Both the related literature and the related research area is indicated. Since the interviews are semi-structured the presented questions can differ from the conducted interviews.

B.1.1. INTERVIEW QUESTIONS TO PROJECT MANAGERS

PRM Theory, HMC's Current PRM Procedure, and HMC's Current PRM practice

1) How do you start the PRM at the start of a project?
2) How is the risk workshop, at the start of the project, done?
3) Who is invited for the risk workshop?
4) How do you identify the risk events?

Theory – Practice Qualitative Risk Assessment, HMC's Current PRM Procedure, and HMC's Current PRM practice

5) How is the risk assessment done?
6) What do you think of people's different risk perception when using a probability and impact matrix as HMC does?

PRM Theory, HMC's Current PRM Procedure, and HMC's Current PRM practice

7) How and when do you decide on how to treat a risk event?
8) How do you choose the risk owner?
9) How are you communicating the risk events to whom?
10) How do you get an idea of the project risk?
11) At which frequency is there a PRM review with the current PRM procedure?
12) What is the link between the PSR and the PRM?
13) What is the link between the HAZID/HAZOP and the PRM?
14) What do you think of a pre-listed risk register with project specific risk events as input for the PRM?
15) Do you have feedback on the PRM after the project is finished?
16) Is there, according to you, currently something missing in the PRM method of HMC?

PRM Theory, HMC's Former PRM Practice, and HMC's Current PRM practice

17) How did the risk workshop differ at the time there was a specialized risk team?
18) At which frequency was there a PRM review with the former PRM procedure? What was done during those meetings?
19) What did you think of the facilitating role of the team in the PRM?

Theory – Practice Quantitative Risk Assessment, HMC's Former PRM Practice, and HMC's Current PRM practice

20) What was the value of the additional MC simulations as done by the risk team?
21) Did you made use of the MC simulation results? Did the MC simulation results ever surprised you?
22) Did you trust the MC simulation results?
23) Did the former method have a better performance than the current method?/What do you think of the former method?
24) How would you think of a new PRM method including quantitative risk analysis?

B.1.2. INTERVIEW QUESTIONS TO THE FORMER RISK TEAM MEMBERS

Theory – Practice Quantitative Risk Analysis, HMC's former PRM in practice, and HMC's current PRM in practice

1) When did HMC start with the quantitative risk analysis?
2) What was the reason to expand the PRM activities with quantitative risk analysis?
3) What was the input for the MC simulation?
4) With whom did you prepare the MC simulation input on project basis?
5) Which risk events were taken in account?
6) What was done with the output of the MC simulation?
7) Was the MC simulation output truthful with respect to both time and cost estimations? i.e., where both opportunities and exposures taken in account? Where correlations between risk events taken in account?
8) What was the project manager's attitude towards the MC simulation? Did the project managers use the results?
9) On portfolio level; where the MC simulation results used to see the direct knock-on effect on previous outcomes?
10) When did HMC abandoned the risk team?
11) Why did HMC abandoned the quantitative risk analysis?
12) What did you think of using MC simulations in the PRM?

PRM Theory, HMC's former PRM in practice, and HMC's current PRM in practice

13) What was the attitude of the project managers to the facilitating role of the risk team? i.e., the first risk assessment workshop and the monthly PRM update meetings?
14) What is your thought about the abandonment of the facilitating role of the risk team?

B.2. RISK REGISTER SURVEY

The interviewees are asked to fill in two unfinished risk registers of two project cases (see next pages). The first case is a relatively simple transportation and installation (T&I) project and the second case is a more complex engineering and installation project. This is done to compare the risk perception of the interviewed project managers.

The cause, effect and mitigation actions of the risks are already presented in the risk register. The participant has to point out the positive (+) or negative (-) consequence, or leave the specific consequence open when there is no or a neutral relation. They are also asked to fill in the likelihood and impact score using HMC's Risk Evaluation Matrix.

Case 1; Jacket Installation (T&I)

- Critical lift
- Fabricator in Europe
- Reliable client
- Soil conditions
- Piling/grouting
- Lump sum contract with client

Case 2; Installation and Engineering Pipelines Deep-water

- Installation
- Engineering of the pipes
- Lump sum contract with client

Case 1; Critical Jacket Installation (T&I)

	Cause	Effect	Consequence +/-		Likelihood /Impact Score		Mitigation Actions
1.	Plans out of phase between interfacing contractors Cause - Lack of interfaces (HMC is not responsible for the fabrication of the jacket)	- Weight increase to unacceptable level - CoG moved to unacceptable location - Lifting points at incorrect locations - Inadequate lifting points	Schedule Costs Revenues Reputation				B: Interface responsible appointed at HMC B: Correspondence register with fabricator B: Client involvement in interfaces B: Interface register and procedure B: Regular interface meetings
2.	Uncontrolled mooring lines Cause: - Incorrect use of mooring lines - Too high tension on mooring lines	- Personnel hit by mooring lines (injury/death) - Damage to equipment	Schedule Costs Revenues Reputation				M: First aiders M: Emergency response plan B: Weather forecast B: Define weather limitations for mooring operations B: Use experienced personnel
3.	Sea transport inadequately prepared Cause: - Ballast pump failure - Undesired movement - Grounding/inadequate water depth - Weather forecast not consulted - Inadequate sea fastening	- Collision - Loss of cargo - Loss of lives	Schedule Costs Revenues Reputation				B: Inspection certificate M: Redundancy in capacity of ballast pumps B: Proper fabrication of see fastening B: Proper design of sea fastening M: Emergency tow line in place M: Emergency procedures in place B: Sail only when weather conditions are acceptable B: Inspections/maintenance B: Consider spare ballast pump B: Pre sail-away checklist completed
4.	Support systems not working or not working properly Cause: - Inadequate planning and detailing of support systems	- Extended duration of installation - Safety hazard during installation	Schedule Costs Revenues Reputation				B: Yard visit to check arrival of supporting system B: Test/trial of support systems on board Thialf B: Equipment list containing all supporting systems
5.	Rupture of rigging Cause: - Incorrect size of rigging - Incorrect design of rigging	Uncontrolled release of equipment - Damage to equipment - Injury/death to personnel	Schedule Costs Revenues Reputation				B: Use of certified slings B: Pre-sail yard inspection of rigging B: Correct design of rigging

Case 2; Installation and Engineering Pipelines Deepwater (T&I)

	Cause	Effect	Consequence +/-		Likelihood /Impact Score		Mitigation actions
1.	Multiple cut outs on collar welds	When a collar is lost, or a pipe length, we have to replace this pipe with a new pipe. - Time consuming to replace	Schedule				B: Design collar for multiple cut outs M: Know why the defect is there M: Know where the defect is
			Costs				
			Revenues				
			Reputation				
2.	Late ordering of long lead items	- Delayed start of the project - More cost in quick transport	Schedule				B: Analysis of long lead items B: Check with 3rd parties for adequate analysis B: Build float in schedule to overcome non performance
			Costs				
			Revenues				
			Reputation				
3.	Damaging a LIFE PIPELINE	- Pollution	Schedule				B: Proper protection by matresses
			Costs				
			Revenues				
			Reputation				
4.	Inexperienced pipeline engineers could result in not achieving engineering milestones	- Additional material or equipment - Additional man-hours	Schedule				B: Engineering ahead of schedule B: Get experience in team
			Costs				
			Revenues				
			Reputation				
5.	- Unreliable soil data (HMC did take contractual responsibility)	- Misjudgments of design(s)	Schedule				B: Sizing of foundation piles to allow for contingency, installation off the critical path B: Potential spare piles for walking anchors B: Install well ahead of time when it is really needed
			Costs				
			Revenues				
			Reputation				

APPENDIX C: INTERVIEWS HMC

In table C.1 all the interviewees are presented. Only the meetings directly related to the case study are mentioned, additional meetings have occurred. Underneath all the interviews are elaborated by presenting the question with the corresponding answer. This is not literally copied but is summarized.

Nr	*Function*	*Department*	*Date*	*Time*
C.1.	Project Manager & Former Risk Team Member	PM Legal	10/02/11	15:00 – 16:00
C.2.	Project Manager	PM	16/03/11	13:30 – 14:30
C.3.	Project Manager	PM	18/03/11	10:00 – 11:00
C.4.	Project Manager	PM	21/03/11	16:00 – 17:00
C.5.	Project Manager	PM	23/03/11	13:30 – 14:30
C.6.	Project Manager	PM	25/03/11	11:00 – 12:00
C.7.	Project Manager	PM	29/03/11	09:00 – 10:00
C.8.	Project Manager	PM	30/03/11	10:00 – 11:00
C.9.	Project Manager	PM	01/04/11	14:00 – 15:00
C.10.	Project Manager	PM	06/04/11	13:00 – 14:00
C.11.	Project Manager	PM	18/04/11	09:00 – 10:00
C.12.	Project Manager	PM	18/04/11	14:00 – 15:00
C.13.	Project Manager	PM	28/04/11	09:00 – 10:00
C.14.	Project Manager	PM	06/05/11	13:00 – 14:00
C.15.	Former Risk Team Member	Legal	13/05/11	10:00 – 11:00
C.16.	Manager Planning & Head Planner	PLAN	18/05/11	11:00 – 12:00
C.17.	Former Risk Team Member	Legal	20/05/11	14:00 – 14:30
C.18.	Vice President of Project Management	PM	16/06/11	15:00 – 16:00

Table C.1: Case Study Interviewees

The interviews' elaborations are not available in the public version of this master thesis

Appendix D: Risk Assessment Workshop HMC

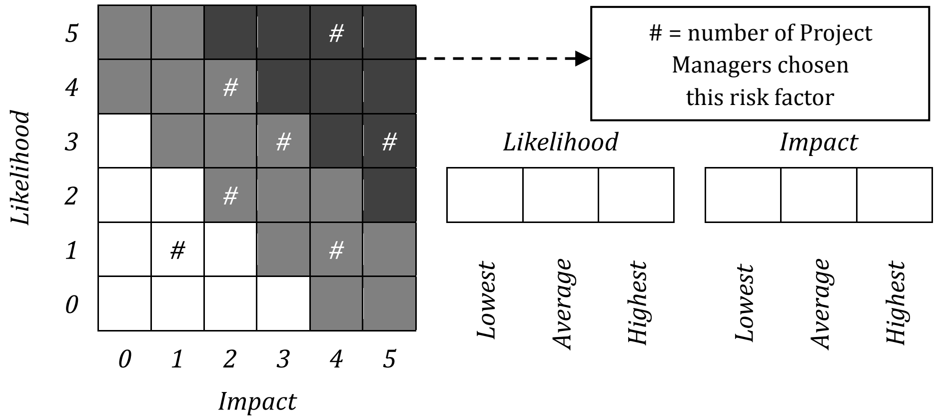
In this Appendix the risk assessment workshops attended are presented. Table D.1 shows the workshops with the corresponding phase. Underneath the workshops are summarized.

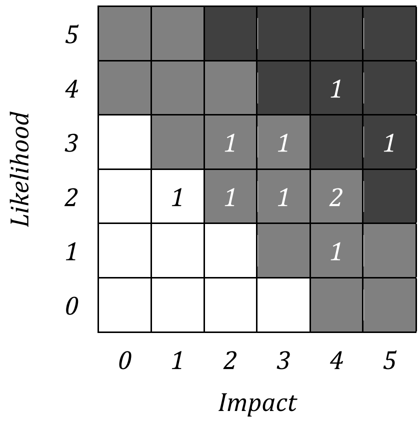
Nr	*Project*	*Phase*	*Date*	*Time*
1	I/0376 Valemon	Project	13/01/2011	09:00 – 12:00
2	I/0383 South Arne	Project	29/03/2011	12:30 – 14:00
3	Brent Alpha	Study	21/04/2011	09:00 – 12:00

Table D.1; Risk Assessment Workshop Attended

The risk assessment workshops' elaborations are not available in the public version of this master thesis

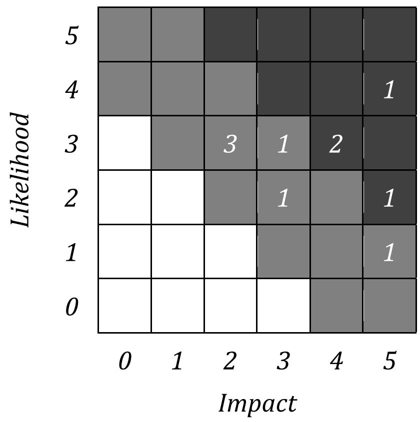
APPENDIX E: RESULTS RISK REGISTER SURVEY





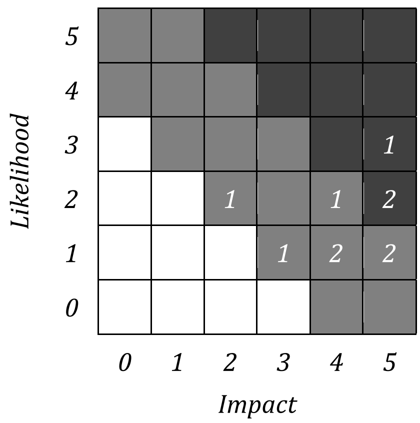
Case 1, Risk event 1

Likelihood			*Impact*		
1	***2,4***	*4*	*1*	***3,2***	*5*



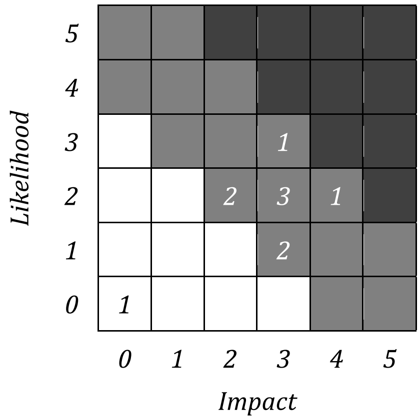
Case 1, Risk event 2

Likelihood			*Impact*		
1	***2,7***	*4*	*2*	***3,5***	*5*



Case 1, Risk event 3

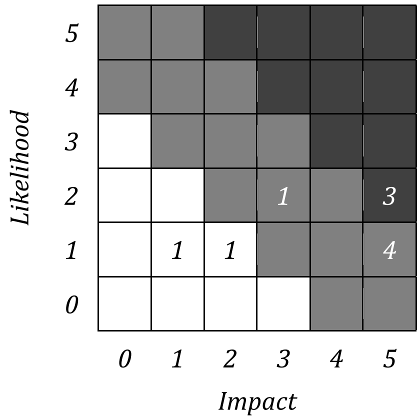
Likelihood			*Impact*		
1	***1,6***	*3*	*2*	***4,2***	*5*



Case 1, Risk event 4

Likelihood		
1	***1,7***	*3*

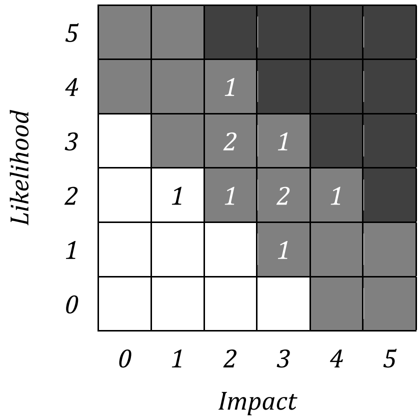
Impact		
0	***2,6***	*4*



Case 1, Risk event 5

Likelihood		
1	***1,4***	*2*

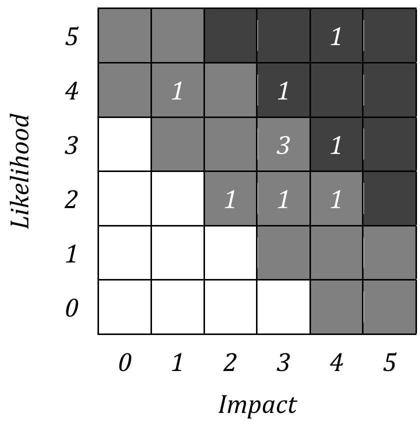
Impact		
1	***4,1***	*5*



Case 2, Risk event 1

Likelihood		
1	***2,4***	*4*

Impact		
1	***2,5***	*4*

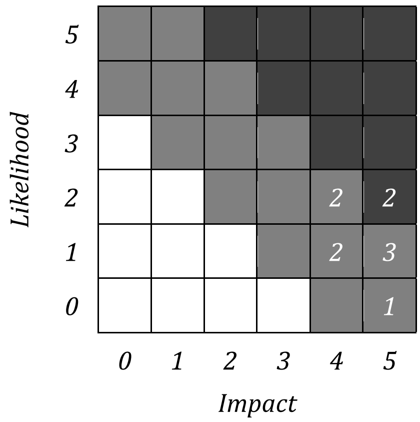


Case 2, Risk event 2

Likelihood		
2	***3,1***	*5*

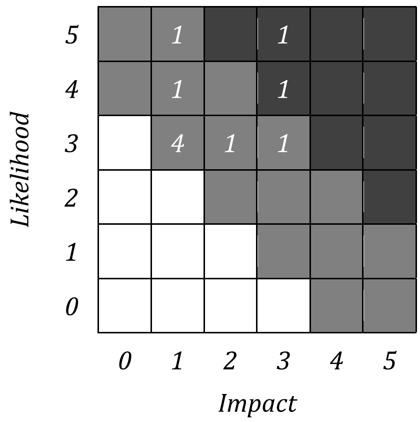
Impact		
1	***3***	*4*

Case 2, Risk event 3



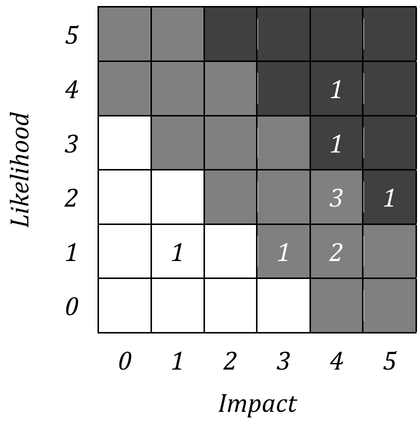
Likelihood			Impact		
0	***1,3***	*2*	*4*	***4,6***	*5*

Case 2, Risk event 4



Likelihood			Impact		
3	***3,6***	*5*	*1*	***1,7***	*3*

Case 2, Risk event 5



Likelihood			Impact		
1	***1,9***	*4*	*1*	***3,7***	*5*

<table>
<tr><td rowspan="2">Case 1:
Critical Jacket Installation</td><td colspan="4">1</td><td colspan="4">2</td><td colspan="4">3</td><td colspan="4">4</td><td colspan="4">5</td></tr>
<tr><td colspan="2">Consequence +/-</td><td colspan="2">Likelihood /Impact Score</td><td colspan="2">Consequence +/-</td><td colspan="2">Likelihood /Impact Score</td><td colspan="2">Consequence +/-</td><td colspan="2">Likelihood /Impact Score</td><td colspan="2">Consequence +/-</td><td colspan="2">Likelihood /Impact Score</td><td colspan="2">Consequence +/-</td><td colspan="2">Likelihood /Impact Score</td></tr>
<tr><td rowspan="4">1.</td><td>Schedule</td><td>-</td><td rowspan="2">2</td><td rowspan="2">1</td><td>Schedule</td><td>-</td><td rowspan="2">2</td><td rowspan="2">5</td><td>Schedule</td><td>-</td><td rowspan="2">2</td><td rowspan="2">5</td><td>Schedule</td><td>-</td><td rowspan="2">2</td><td rowspan="2">3</td><td>Schedule</td><td>-</td><td rowspan="2">1</td><td rowspan="2">5</td></tr>
<tr><td>Costs</td><td>-</td><td>Costs</td><td>-</td><td>Costs</td><td>+</td><td>Costs</td><td>+</td><td>Costs</td><td>+</td></tr>
<tr><td>Revenues</td><td>+</td><td colspan="2" rowspan="2">3</td><td>Revenues</td><td>-</td><td colspan="2" rowspan="2">7</td><td>Revenues</td><td>-</td><td colspan="2" rowspan="2">7</td><td>Revenues</td><td>+</td><td colspan="2" rowspan="2">5</td><td>Revenues</td><td>-</td><td colspan="2" rowspan="2">6</td></tr>
<tr><td>Reputation</td><td>-</td><td>Reputation</td><td>-</td><td>Reputation</td><td>-</td><td>Reputation</td><td>-</td><td>Reputation</td><td>-</td></tr>
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<tr><td>Costs</td><td>-</td><td>Costs</td><td>-</td><td>Costs</td><td>-</td><td>Costs</td><td>-</td><td>Costs</td><td>-</td></tr>
<tr><td>Revenues</td><td>?</td><td colspan="2" rowspan="2">8</td><td>Revenues</td><td>N</td><td colspan="2" rowspan="2">9</td><td>Revenues</td><td>N</td><td colspan="2" rowspan="2">7</td><td>Revenues</td><td>N</td><td colspan="2" rowspan="2">6</td><td>Revenues</td><td>N</td><td colspan="2" rowspan="2">7</td></tr>
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<tr><td>Costs</td><td>+</td><td>Costs</td><td>+</td><td>Costs</td><td>+</td><td>Costs</td><td>+</td><td>Costs</td><td>+</td></tr>
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<tr><td>Reputation</td><td></td><td>Reputation</td><td>-</td><td>Reputation</td><td>-</td><td>Reputation</td><td></td><td>Reputation</td><td>-</td></tr>
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<tr><td>Revenues</td><td>+</td><td colspan="2" rowspan="2">6</td><td>Revenues</td><td></td><td colspan="2" rowspan="2">7</td><td>Revenues</td><td>+</td><td colspan="2" rowspan="2">8</td><td>Revenues</td><td></td><td colspan="2" rowspan="2">5</td><td>Revenues</td><td></td><td colspan="2" rowspan="2">7</td></tr>
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</table>

Case 1: Critical Jacket Installation	1				2				3				4				5			
	Consequence +/-		Likelihood /Impact Score		Consequence +/-		Likelihood /Impact Score		Consequence +/-		Likelihood /Impact Score		Consequence +/-		Likelihood /Impact Score		Consequence +/-		Likelihood /Impact Score	
6.	Schedule	-	2	4	Schedule	-	3	4	Schedule	-	1	4	Schedule	-	2	3	Schedule	-	1	5
	Costs	-			Costs	-			Costs	-			Costs	-			Costs	-		
	Revenues		**6**		Revenues		**7**		Revenues		**5**		Revenues		**5**		Revenues		**6**	
	Reputation				Reputation	-			Reputation	-			Reputation				Reputation	-		
7.	Schedule	-	3	3	Schedule	-	3	2	Schedule	-	2	2	Schedule	-	2	2	Schedule	-	1	1
	Costs	-			Costs	-			Costs	-			Costs	-			Costs	-		
	Revenues	+	**6**		Revenues		**5**		Revenues		**4**		Revenues	+	**4**		Revenues		**2**	
	Reputation				Reputation	-			Reputation	-			Reputation				Reputation	-		
8.	Schedule	-	2	2	Schedule	-	1	5	Schedule	-	1	5	Schedule	-	3	3	Schedule	-	1	2
	Costs	-			Costs	-			Costs	-			Costs	-			Costs	-		
	Revenues	+	**4**		Revenues	-	**6**		Revenues	-	**6**		Revenues	-	**6**		Revenues	-	**3**	
	Reputation				Reputation	-			Reputation	-			Reputation				Reputation	-		
9.	Schedule	-	2	3	Schedule	-	3	2	Schedule	-	1	4	Schedule	-	2	2	Schedule	-	2	3
	Costs	0			Costs	-			Costs	-			Costs	-			Costs	-		
	Revenues	0	**5**		Revenues	0	**5**		Revenues	0	**5**		Revenues	0	**4**		Revenues	0	**5**	
	Reputation	-			Reputation				Reputation	-			Reputation	0			Reputation	-		
10.	Schedule	-	1	4	Schedule	-	2	3	Schedule	-	2	4	Schedule	-	1	3	Schedule		2	5
	Costs	-			Costs	-			Costs	-			Costs	-			Costs			
	Revenues	+	**5**		Revenues		**5**		Revenues		**6**		Revenues		**4**		Revenues		**7**	
	Reputation	-			Reputation	-			Reputation	-			Reputation	-			Reputation			

Case 2: Installation and Engineering Pipelines Deepwater	1				2				3				4				5			
	Consequence +/-		Likelihood /Impact Score		Consequence +/-		Likelihood /Impact Score		Consequence +/-		Likelihood /Impact Score		Consequence +/-		Likelihood /Impact Score		Consequence +/-		Likelihood /Impact Score	
1.	Schedule	-	1	3	Schedule	-	5	4	Schedule	-	2	5	Schedule	-	5	3	Schedule	-	2	4
	Costs	+			Costs	+			Costs	+			Costs	+			Costs	+		
	Revenues	-	**4**		Revenues	-	**9**		Revenues	-	**7**		Revenues	-	**8**		Revenues		**6**	
	Reputation				Reputation	-			Reputation	-			Reputation	-			Reputation	-		
2.	Schedule	-	2	2	Schedule	-	2	2	Schedule	-	1	5	Schedule	-	3	1	Schedule	-	4	4
	Costs	-			Costs	-			Costs	-			Costs	-			Costs	-		
	Revenues	N	**4**		Revenues	N	**4**		Revenues	-	**6**		Revenues	?	**4**		Revenues	?	**8**	
	Reputation	-			Reputation	-			Reputation	-			Reputation	-			Reputation	?		
3.	Schedule	+	4	2	Schedule	+	3	3	Schedule	+	2	4	Schedule		5	1	Schedule	+	3	4
	Costs	+			Costs	+			Costs	+			Costs	+			Costs	+		
	Revenues		**6**		Revenues		**6**		Revenues	+	**6**		Revenues		**6**		Revenues		**7**	
	Reputation				Reputation				Reputation	-			Reputation	-			Reputation			
4.	Schedule	-	3	2	Schedule	-	3	4	Schedule		2	4	Schedule	-	3	3	Schedule	-	2	4
	Costs	-			Costs	-			Costs				Costs	-			Costs	-		
	Revenues		**5**		Revenues		**7**		Revenues		**8**		Revenues		**6**		Revenues		**6**	
	Reputation				Reputation	-			Reputation	-			Reputation				Reputation	-		
5.	Schedule	-	2	3	Schedule	-	2	3	Schedule	-	1	5	Schedule	x	3	1	Schedule	-	1	1
	Costs	-			Costs	x			Costs	-			Costs	-			Costs	-		
	Revenues	x	**5**		Revenues	x	**5**		Revenues	x	**6**		Revenues	x	**4**		Revenues	+	**2**	
	Reputation	-			Reputation	-			Reputation	-			Reputation	x			Reputation	x		

Case 2: Installation and Engineering Pipelines Deepwater	1				2				3				4				5			
	Consequence +/-		Likelihood /Impact Score		Consequence +/-		Likelihood /Impact Score		Consequence +/-		Likelihood /Impact Score		Consequence +/-		Likelihood /Impact Score		Consequence +/-		Likelihood /Impact Score	
6.	Schedule		2	3	Schedule	-	3	3	Schedule	-	1	5	Schedule		3	2	Schedule	-	2	4
	Costs	-			Costs	-			Costs	-			Costs	-			Costs	-		
	Revenues		**5**		Revenues		**6**		Revenues		**6**		Revenues		**5**		Revenues	+	**6**	
	Reputation				Reputation				Reputation	-			Reputation				Reputation			
7.	Schedule	-	3	3	Schedule	-	2	4	Schedule	-	1	4	Schedule	-	3	1	Schedule	-	1	3
	Costs	-			Costs	-			Costs	-			Costs	-			Costs	-		
	Revenues		**6**		Revenues	+	**6**		Revenues	-	**5**		Revenues		**4**		Revenues		**4**	
	Reputation	-			Reputation				Reputation	-			Reputation	-			Reputation	-		
8.	Schedule	-	2	1	Schedule	-	4	1	Schedule	-	0	5	Schedule		3	1	Schedule	-	1	4
	Costs	-			Costs	-			Costs	-			Costs	-			Costs	-		
	Revenues	-	**3**		Revenues	-	**5**		Revenues	-	**5**		Revenues		**4**		Revenues	-	**5**	
	Reputation				Reputation				Reputation	-			Reputation				Reputation			
9.	Schedule	-	3	2	Schedule	-	3	3	Schedule	-	1	4	Schedule	0	4	1	Schedule	-	1	4
	Costs	-			Costs	-			Costs	-			Costs	-			Costs	-		
	Revenues	0	**5**		Revenues	0	**6**		Revenues	0	**5**		Revenues	0	**5**		Revenues	0	**5**	
	Reputation	0			Reputation	0			Reputation	-			Reputation	0			Reputation	-		
10.	Schedule	-	2	4	Schedule	-	4	3	Schedule	-	2	5	Schedule	-	4	3	Schedule	-	2	5
	Costs	-			Costs	-			Costs	-			Costs	-			Costs	-		
	Revenues		**6**		Revenues		**7**		Revenues	-	**7**		Revenues		**7**		Revenues	-	**7**	
	Reputation				Reputation	-			Reputation	-			Reputation				Reputation	-		