Development of a Dynamic Risk Management Model Allowing for Holistic Assessment of Identified Risks and Adoption of Preferred Mitigation Strategies Based on a Multi Criteria Decision-Scheme

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Abstract. Current risk management practices are characterized by linear and rigid frameworks, not allowing for periodically assessments of identified risks. The aim of the developed Dynamic Risk Management Model (DRMM) is to allow to periodically assess identified risks from a holistic perspective and to adopt a preferred mitigation strategy using a multi criteria decision scheme. A set of improved assessment criteria is provided to arrange for a more comprehensive assessment of risks. Replacing the traditional Risk Priority Number (RPN) to decide what risks that are subjective to a mitigation, with a set of rules based on the rating of the assessed criteria. A flowchart is provided to form the basis of the risk management process, including 8 phases that should be followed. The flowchart also demonstrates the dynamic aspect of the proposed DRMM. A case study has been performed in a company project to test and validate the DRMM.

Keywords: Dynamic risk management, risk assessment criteria, rules for mitigation strategy

Introduction

The paper focuses on risk management and the importance of this theme in both project management and systems engineering. Risk Management is the process of identifying, assessing and mitigate risks to deal with the uncertainty and its effect on project objectives. The current risk management methods are looked upon as linear and rigid, not allowing for the continuous assessment and identification of risks. It is often looked upon as "fire and forget", performed only one time in the initiating phase of a project. A proper risk management strategy can help identifying potential risks which is hazardous to the project or company. If risks are carefully assessed and analysed, it can reveal weaknesses in specific processes that can be improved. Cost and time overrun is also a realistic problem. Rework and resources bound to poor risk management can cause major impact on project objectives.

Risk Management can also reduce the uncertainty of the final project delivery. A literature review has been done to form a theoretic framework: are there any weaknesses in the literature that can be used to strengthen a new model, and any existing methods with favourable elements that can be used to create a new model? The description of the DRMM has been emphasizing the development of a dynamic model, where the main contribution is set of new assessment criteria and rules to choose a preferred mitigation strategy. The model is tested in a case study at a company. The Conclusion will be followed by Future Research, where suggestions to future validation will be discussed.

Risk management is a tool that is instrumental in managing complex projects. Risk management can save time, money and resources if it is introduced in an early phase of the project. Risk management is a well-known term in both systems engineering and project management. In Project management, risks are managed to avoid negative impacts on project objectives. Actively managing risks is often considered to be a part of the project management plan. Risk management in systems engineering is necessary to avoid risks that may influence the three phases from concept to production to operation (Walden et al., 2015). This is a holistic process, considering the system as whole entity with many branches and disciplines involved. Risks related to both business and technical risks are to be

considered. The importance of doing risk management in a continuous manner is very clearly with a systems engineering point of view, since it focuses on structuring the development and planning throughout the lifecycle of the system.

The goal is to develop a risk management model that is dynamic. Facilitating for systematic follow-ups is central to keep the risk management process continuous. Follow-up is important to the degree that it can be a "measure" on how well the risks are assessed and mitigated, acting as validation over time. It shall accept risks identified in an early phase of a project, as well as risks found as the project develops. Risk assessment criteria will need to be developed to provide new alternatives to the existing criteria. A mitigation strategy for identified risks shall be considered to know how to deal with risks, to take appropriate actions as well as preventive measures. Rules based on the assessment criteria shall build the base for choosing the right mitigation strategy. A flowchart has been developed to create a better understanding on how to use the Dynamic Risk Management Model (DRMM). The main contributions in this paper will be the improved set of criteria and the rules for the mitigation strategies.

Literature Review

Risk. A natural place to start is to define the meaning of the word risk. After all, risk is the "object" the risk management model shall treat. The literature does not seem to see eye to eye on how to define the word risk. One definition of risk, on the more humane side, is that risk is potential unwanted events. And these are events that one would rather not want to occur (Pritchard, 2015). In project risk management, it is said that risk can be described as the probability and severity of adverse effects (Lowrance, 1976). Some argue that risk should handle two factors; calculated risks that are quantified in risk analysis or risks managed by statistics, and also the acceptance of different types of risk by those dealing with them (Hokstad & Steiro, 2006). This is an important aspect of risk, not only do we have to deal with the identified risk – but there is also a need for discussing what impact it has on humans interacting with it.

Since there are so many different variations in the definition of risk, Slovic (1999) stated that; "Whoever controls the definition of risk controls the rational solution to the problem at hand" This is a good point, and it is an indication that one definition of risk is not necessarily the right definition to all cases where risk is to be assessed and managed. He also pointed out that the different risk concepts do have one common element – the distinction between reality and possibility. Risk is often calculated with background of the possibility of it occurring, but the risk is also defined from a real event that can occur. With background in these statements from the literature, the definition of risk in this paper is as following: *"Risk is the effect of uncertainty on project objectives"*

Risk Management and Risk Assessment. There are several definitions of risk management. But there is no absolute definition. Aven (2012) states that the number of existing standards and guidelines to risk management has not yet been able to provide a common understanding of the field. This contributes to the confusion around the definition of risk management. According to ISO 31000:2009 and IEC/ISO 31010:2009 (IEC, 2009), risk management can be defined as "coordinated activities to direct and control an organization with regard to risk". It also says that: risk management is dynamic, iterative and responsive to change. The ISO 31000:2009 describes the project management process to include risk assessment, risk treatment and risk monitoring and review. Some guidelines are provided together with a model to give advice on how a risk management process can be performed. These guidelines are general, so they are not meant to be a specific method of how to do it.

Pennock and Haimes (2002) state in their paper that three questions can be asked in risk management: 1. What can be done and what options are available? 2. What are the trade-offs in terms of all costs, benefits, and risks among the available options? 3. What are the impacts of current decisions on future options? This is interesting because it is necessary to identify all feasible options available to deal

with these are identified risks. Measures to deal with risks may be mitigation strategies such as prevention, reducing or monitoring. This gives an impression of how circumstantial risk management is. And when an option on mitigation strategy has been decided, it is not necessarily a finite solution for handling risk. The trade-off that may be carried out to mitigate one risk may influence the future level of a different risk and the status quo in a system. This can result in a new analysis in the future to prevent a new potentially high risk. It is recommended to run analyses to assess potential changes in the system to avoid surprises. This is interesting since it argues for the need of making risk management more dynamic, allowing to re-assess risks to examine potential risk dependencies.
The definition of risk management used in this paper is *"The process of identifying, assessing and mitigate risks to deal with the uncertainty and its effect on project objectives"*

Risk filtering is proposed to prioritize the most critical risks that is a threat to project objectives. This idea of determining what risks that are considered to be critical in a project is a concept that can be introduced to the development of the new set of assessment criteria in the DRMM. The paper also brings about another interesting concept that is used as an inspiration for the model, described as cascading effects. This is when effects from a serious condition transfers to other parts of a system (Pennock & Haimes, 2002). This idea can be used in the model to identify risks that may have such an effect on other risks. Khakzad, Khan, Amyotte, and Cozzani (2014) mentions in their paper the term "domino effect". This can be considered to be somewhat of the same essence as the cascading effect. They define the domino effect as a chain of accidents where a primary risk increases and trigger other accidents.

Bley, Kaplan, and Johnson (1992) suggested in their paper that the reason one wants to perform risk assessment is that one would like to understand a risk in order to be able to do something about it. This is a good statement for the DRMM, where the results of the assessment of risks will decide if a risk shall be exposed to a mitigation strategy. J. Liu, Jin, Xie, and Skitmore (2017) defines risk assessment as a systematic approach for the assessment of uncertainty or risky future events. This can be seen in compliance with the stated definition for risk used in this paper, where uncertainty is a keyword. As for risk management, the ISO 31000:2009 has defined it as the overall process of risk identification, risk analysis and risk evaluation. Risk identification is not emphasized in this paper, so there will be no further explanation on that. There are several methods of this method described in the standard, and in the PMBOK Guide provided by the Project Management Institute (PMI, 2013). Risk Analysis and risk evaluation is in this paper referred to as risk assessment and risk prioritizing.
The definition of risk assessment that will be used further in the paper is *"shall provide the necessary information to understand the nature of the risk, its effect and provide a basis for the consideration of acceptance or not"*

Limitations of Current Risk Management Practices. (Zwikael & Ahn, 2011) states in their paper that: As size and complexity of projects increase, the effort required for effective risk planning exponentially rises, making current tools difficult to use. This underline the use of a model that is easy to use, with rational set of assessment criteria that is not too difficult to use.

In several risk management methods, whereas the most familiar method is Failure Modes Effects and Criticality Analysis (FMECA), there are three criteria that are emphasized to assess the risk level. It is Occurrence (O), Detectability (D) and Severity (S). These are numbered on a quantitative scale, and then multiplied in order to get a Risk Priority Number (RPN). The risks with the highest RPN will be prioritized for further mitigation. This does not take in to consideration that frequency of risk, possibility of predicted risk and seriousness of risk to the system (occurrence, detectability, severity) will give the same RPN. This emphasizes the need for introducing a new set of criteria combined with a more nuanced decision on what risks that are to be subject to a mitigation strategy. Klein and

Another limitation is the lack of communicative description of the criteria used in assessments. Lipkus (2007) argues the need for a more communicative way of describing the importance of each of these can give a more reliable risk assessment, since it is more likely that there is a better understanding of what the criteria encompass. In many cases of risk management, the consideration of the lifecycle stages are often neglected. There is a need of focusing on different risks that may occur in different phases of the life cycle. And since the stages often are interdependent, risks may occur from the design of the lifecycle process itself (Sage, 1992). This statement explains why the dynamic aspect of managing risks is so important, allowing to re-assessing risks after mitigation strategies are initiated and identification of emerging risks as the project/product prospers.
Hall (2011) Is discussing the fact that a majority of risk management methodologies are using subjective inputs, and there is a lack of formalization in the different methods. This influence the ability to provide risk assessments that are repeatable and comparable in one specific project. Making assessment criteria that are as objective as possible is the goal, to avoid bias from the management or customer trying to lower the price or accelerate the timescale.

Dynamic Risk Management. The DRMM is developed with the goal of being dynamic. This is an up and coming field that is receiving more and more attention. As an example Fehle and Tsyplakov (2005) presented a model to mitigate financial stress, and they made two assumptions on the dynamic aspect: 1) the firm can adjust its use of risk management instruments over time, 2) risk management instruments expire as time progresses and that the available maturity of the risk management instruments is shorter than the life time of the firm. This implicates that a dynamic risk management model is adjusted and adapted as the environment for the company/project changes over time. This seems logic, because over time and in different phases of projects/company life time, things will change – both externally and internally.

G.-F. Liu et al. (2016) did research on how dynamic risk assessment and management could be implemented on rock bursts in drill and blast tunnels. They found that establishing procedures to map early warning signals of risks that may occur, was very helpful. Also, the opportunity to update the model over time, allowing new information or occurrences of risk be taken in to the model when identified, was a positive effect of the dynamic model. Something of interest in this article, which can be used in the DRMM is the introduction of the concept of early warnings. Early warnings are used in this paper to get some kind of warning signal to predict that an event is occurring. This can leave time to identify a mitigation plan in advance of the event/risk occurring. Also, they introduce a sensible statement on risk acceptance criteria that may be interesting to incorporate to the model. This concept deals with reducing risks by submitting them to mitigation strategies. The paper enhances the importance of balancing the risk level against risk costs. This can also be linked to project objectives, whereas risks that are threatening to reach project objectives cannot be tolerated.

Enterprise Risk Management (ERM) is coming up as an advocate for dynamic risk management. It underlines the benefits of making risk management models holistic. Since current management models has a tendency to focus on specific areas, such as finance or technical risk management, it is important to see the whole company as an entity and identifying embedded links between disciplines or branches. (Bharathy & McShane, 2014). This is combined with a dynamic systems approach that allows for feedback and non-linearity argues for a more dynamic way of managing risks, as well as introducing a more holistic view whenever it is appropriate. ERM supports the arguments for the need of a more dynamical risk management. Garvey (2008) ERM shall focus on early and continuous identification, management, and resolution of risks such that the engineering of a system is accomplished within project objectives.

Paltrinieri, Khan, and Cozzani (2015) Stated in their study of coupling advanced techniques for dynamic risk management that quantified risk analysis has been proven effective in process industry, but they lack the dynamic dimension of risk – the ability to learn from new risk notions, experience

and early warnings. Another interesting point in that study was that risks that are not identified or assessed is impossible to prevent or mitigate, and that such risks may be more dangerous than a recognized risk because one is not prepared for this. This is very true, it is difficult to prepare for the unknown. The last interesting finding in this study is the definition of dynamic approach to risk; capability of identifying and assessing emerging, and increasing risks in all aspects of the lifetime of the project. The lifetime management of risks compose one of the key drivers to success with dynamic risk management. That one is aware that things change in different phases, and is influenced by both internal and external factors is very important. The definition of dynamic risk management used in this paper is *"The process of treating risks during the lifetime of the project. Identifying, assessing, mitigating and monitoring risks"*

Description of the Dynamic Risk Management Model

The model is developed with the agenda of making risk management more dynamic, as many of today's models are linear and typically a onetime process. Using the literature research to identify limitations and drawbacks in the current models, has been beneficial to create a model that aim to improve the current methods used in risk management. The DRMM is intended to be of generic nature, and reduce the need for having different methods for different disciplines of a project. An existing assessment method is to calculate a Risk Priority Number (RPN), by multiplying severity, occurrence and detectability. This method is criticised by many, and it does not take in to consideration the individual levels of each criteria. Reworking and adding improved criteria is one of the proposed methods in this model. The assessment criteria used is based on findings in the literature and some are used in existing methods. Adding rules for choosing a mitigation strategy based on the assessment criteria is added to reinforce the model. A case study has been performed to implement the model in a company. The model has been tested by using a case company and their risks as an example. Due to a non-disclosure agreement, the case study is presented in Appendix I.

Following is the description of the proposed Dynamic Risk Management Model. Before explaining the model, it is necessary to explicate some key concepts to ensure proper use of the DRMM. In the literature review, the definitions of risk, risk management, risk assessment and dynamic risk management are discussed. There is a need to determine their definitions in the DRMM, but also other terms used in the model.

- **Risk:** Risk is the effect of uncertainty on project objectives.
- **Risk Management:** The process of identifying, assessing and mitigate risks to deal with the uncertainty and its effect on project objectives.
- **Risk Assessment:** Shall provide the necessary information to understand the nature of the risk, its effect and provide a basis for the consideration of acceptance or not.
- **Dynamic Risk Management:** The process of treating risks during the lifetime of the project. Identifying, assessing, mitigating and monitoring risks is essential. Monitoring the risks and continuously perform risk identification and assessment is substantial, and is the key factor in separating risk management and dynamic risk management from each other.
- **Risk Identification:** This is the process of finding risks and recognizing and determining their influence on project objectives.
- **Risk Mitigation Strategy:** A responsive strategy where the goal is to reduce impact or occurrence of a risk, to an acceptable level.
- **Holistic Assessment:** Signify that risks of any certain nature, such as cost, schedule and technical, may be assessed using equal criteria.
- **Risk Acceptance Criteria:** Defines what level of risk that is acceptable, and what level of risk that is unacceptable in terms of the project definition.
- **Contingency Plan:** Part of mitigation, whereas a planned strategy is executed when a risk occurs.

Flowchart for the Dynamic Risk Management Model

The flowchart presented in figure 1 is the suggestion for a Dynamic Risk Management Model. The flowchart is the conceptual model, and provides guidance on how the processes may be executed. When initiating risk management in a project, it is essential to have defined the project and its objectives. The dynamic contribution in the model is that the flowchart explicitly says that if the project is not finished, the work with identifying, assessing and mitigating risks is continuous.

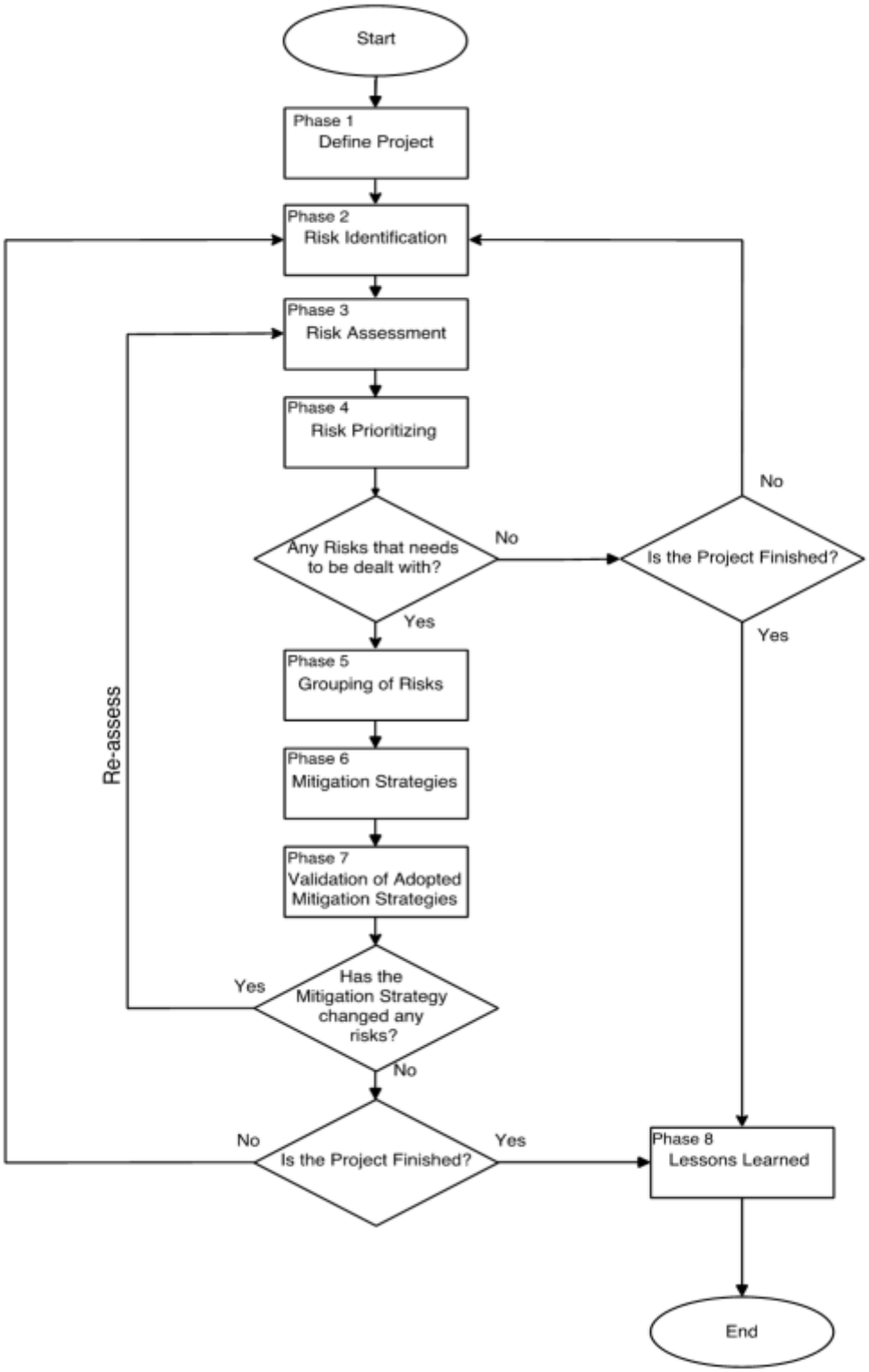

Figure 1: Flowchart describing the phases of the DRRM

The questions are a reminder to secure the continuous work. The periodically assessment is carried out in an interval, decided and agreed upon by the participants in the project. The main contribution, in addition to the dynamic aspect, is that it emphasizes the need for new assessment criteria and suggestive rules to choose a mitigation strategy.

Phase 1: Define Project concerns determining project scope, deliverables and constraints. This may be communicated in terms of cost, schedule, product or other important project objectives. If this description is vague, there is a possibility that assumptions will be made, this can be a source of potential causes of risks (PMI, 2013). Therefore, the need for being thorough is important. The project definition can function as a risk acceptance criteria on what risks are acceptable and which ones is not, in terms of how they impact scope, deliverables and constraints.
Phase 2: Risk Identification is the act of finding risks that may impact the project objectives defined in phase 1. The DRRM is concentrated on identifying risks that is considered a threat to the project objectives, and have negative impacts. There are several approaches to identify risks, such as documentation reviews and different information gathering methods. Many companies have sets of internal generic risk policies that may be embedded into the process at this stage. In addition, the ISO 31000:32009 contains several techniques on how to carry out the risk identification.

Phase 3: Risk Assessment and how it is performed is one of the main contributions in this paper. A set of criteria is formulated to reinforce the assessment phase. Where the focus on risk priority number (RPN) traditionally has had a major influence on how risks have been assessed and further on mitigated, there is now an improved set of assessment criteria and rules for choosing the preferred mitigation strategy. The results of the assessment shall provide a realistic picture of the risk level, and further be used to select a preferred mitigation strategy. A thorough description of each acceptance criteria is found in the section *Criteria for Risk Assessment*.
Phase 4: Risk Prioritizing is the phase of deciding if any risks and their respective effects on project objectives, are of such a serious nature that they should be subject to a mitigation strategy. The rules suggested for a possible mitigation strategy are shown in the section *Rules for Mitigation Strategies*. The rating of the criteria after the assessment phase, is the reference for prioritizing the risks to ensure they are subjected to the preferred mitigation strategy.

After phase 1-4 is carried out, the question is if there are any risks that needs being dealt with, if any risks are of such severity that it may threaten the project objectives. If this is the case, one continues to phase 5: grouping of risks. If there are no risks that needs to be dealt with, at least for now, and the project is not finished, then continue with phase 2: risk identification. This is to control if any new risks have emerged as the project prospers. This is part of adding dynamism in to the model, by continuously identifying and assessing risks periodically. If the project is finished, then enter phase 8: lessons learned.

Phases 5 and six is considered to be concurrent. **Phase 5: Grouping of Risks** is meant to be a helpful resource to have a better overview of risks that have been assessed and assigned to equal rules, and therefore may be subjected to the same mitigation strategy. A preliminary identification of strategies is done first, then one can group risks according to the suggested mitigation strategies. This shall prevent initiating a number of mitigation strategies, resulting in many similar risks being mitigated isolated when they instead could have been subject to a similar strategy.
Phase 6: Mitigation Strategies is the phase where the aim is to prevent, reduce or plan contingency for an assessed risk. One of the main contribution in this paper is the ability to choose a preferred mitigation strategy based on a multi-criteria decision scheme, which is described in the section rules for mitigation strategies. Final adoption of strategy may differ from the preliminary identification of strategies, as mentioned in phase 5, and is to be chosen as seen fit for the risk.

Phase 7: Validation of Adopted Mitigation Strategies means that if the mitigation strategy has changed a risk - or several - in terms of the given criteria, the need for a re-assessment is required. New risks may have emerged, and existing risks may have changed. This implies that one should go through phase 3 – 6 again, and if then there are no changes, one can proceed to the last question. This is to avoid the model being used as a "fire and forget" risk management process. If the effects of the mitigation are not controlled, the possibility that emerging and existing risks will cause unwanted effects on objectives increases. This is also a validation of the chosen mitigation strategy, to confirm the goodness of it and if it has worked as planned. If not, other mitigation plans may have been created or there is a need to create one.

Phase 8: Lessons Learned is the phase where the participants of the project describes how the work was conducted, how it worked and what they learned, for a potential future risk management process. The lessons learned are very valuable, and can contribute a great deal to making improvements to other risk management projects. Creating a database where this can be accessed by all involved in the project, and future projects, is beneficial for reusing the knowledge gained.

Criteria for Risk Assessment

The criteria presented for the different assessment methods are described in general. For different projects and/or companies, it is possible to alter the descriptions to get a more realistic use of the model. Before commencing the work with risk assessment, the project shall be defined and acceptable levels of risk impact should be stated (risk acceptance criteria). The ratings described for each criterion should be linked to risks (preferably use both numbers and the word, since the rules for mitigation strategy uses numbers for each criteria), and listed in a sheet/table. This will be used to choose a preferred mitigation strategy in line with the rules for mitigation. All risks shall be assessed in accordance to the following criteria:

a) Risk Impact:

Risk impact is the outcome of an event affecting project and/or company objectives and goals. Risk impact is one of the most critical criteria in the risk assessment. This criterion describes the seriousness of the effect a risk, if it is to occur, may have. The rating and description of risk impact is shown in table 1.

Table 1: Risk Impact

Rating	Description
Severe (4)	If the risk occurs, it will have a catastrophic effect: - Loss of life - More than 50% increase of scheduled time - More than 50% increase of project and product cost - Market/customer does not accept product - Unable to attain multiple critical key milestones - Under-resourced project team
Significant (3)	If the risk occurs, it will have a serious effect: - Physical/mental harm to humans - Between 20 – 50% increase of scheduled time - Between 20 – 50% increase of project and product cost - Market/customer demands rework on product - Missing one critical milestone - Capability gap in the project team
Moderate (2)	If the risk occurs, it will have a limited effect: - No harm to humans - Between 5 – 20% increase of scheduled time - Between 5 – 20% increase of project and product cost - Market/customer demands minor changes to product - Delay on non-critical milestones - Loss of competence in the project team
Minimal (1)	If the risk occurs, it will have minimum effect: - No harm to humans - 0 – 5% increase of scheduled time - 0 – 5% increase of project/product cost - Market/customer accept product - No notably delay on milestones – critical and non-critical - Inadequate training of project team.

b) Likelihood of Occurrence:

Likelihood of occurrence is defined as the chance of something happening, it can be defined, measured or described mathematically. The likelihood of occurrence is described verbally, since numbered probabilities may be difficult to estimate upfront, and may differ from project to project. Table 2 shows the descriptions of the different ratings for Likelihood of Occurrence.

Table 2: Likelihood of Occurrence

Rating	Description
Very Likely to Occur (4)	The probability of the risk materializing is far more certain to happen, than not to happen
Likely to Occur (3)	The probability of the risk materializing is slightly more certain to happen, than not happen
Somewhat Likely to Occur (2)	The probability of the risk materializing is slightly less certain to not happen, than happen
Unlikely to Occur (1)	The probability of the risk materializing is far less certain to not happen, than happen

c) Detectability:

Detectability describes how likely the project team members is to discover that a risk has actually materialized, and is described by the likelihood of discovery before critical milestones and the delay in project timescale. If a risk is difficult to detect, it is harder to fully know its impact. This is because it is difficult to predict what phase of a project it may impact, and some phases of a project may be considered more vulnerable than others in relation to something specific occurring. The consequence of the detectability is described in terms of how likely it is to discover before critical milestones, and how it affects the project timescale as shown in table 3.

Table 3: Detectability

Rating	Description
Very Difficult to Detect (4)	Unlikely to discover before critical milestones, causing significant delay in project timescale
Difficult to Detect (3)	Less likely to discover before critical milestones, causing delay in project timescale
Detectable (2)	Somewhat likely to discover before critical milestones, causing slight delay in project timescale
Very Detectable (1)	Very likely to discover before critical milestones, not causing delay in project timescale

d) Recoverability:

Recoverability describes how likely a project/company is to recover if a given risk materializes. As seen in table 4, this should be assessed with the project objectives in mind, describing how likely it is to recover. Is the effect of the risk of such a severe nature that it threatens the ability to recover from it and prevent the reach of the project objectives?

Table 4: Recoverability

Rating	Description
Low (3)	Recovery is not very likely; high safety, cost and technical critical issues that cannot be re-attained
Moderate (2)	Recovery is likely; medium safety, cost and technical issues that can be re-attained
High (1)	Recovery is very likely; low safety, cost and technical issues that is certain to be re-attained

e) Triggering Effect:

Triggering effect describes the scenario if a risk materializes, it increases the likelihood of other risks occurring (table 5). A risk with a triggering effect is referred to as the primary risk, and may cause the occurrence of secondary or higher order risks. For the triggering effect, secondary and higher order risks are defined as following:

- *Secondary risks*: risks assessed to have a Risk Impact ≤ 2
- *Higher order risks*: risks assessed to have a Risk Impact ≥ 3

Table 5: Triggering Effect

Rating	Description
Severe (3)	Increases the likelihood of higher order risks to occur
Moderate (2)	Increases the likelihood of secondary risks to occur
Minor (1)	There is no effect on other risks

f) Immediacy:

Immediacy is described as the time it takes from a given risk occurs, to the impact materializes. Immediacy can give valuable information on how much time we have to take action, to mitigate or reduce impact. In table 6 immediacy is described with words, but may be altered to contain specific numbered values if preferred.

Table 6: Immediacy

Rating	Description
High (3)	The impact of the risk, if it occurs, is immediate and will need to be reduced or eliminated as soon as possible
Moderate (2)	The impact of the risk, if it occurs, is close and will need to be reduced or eliminated within the time left until it materializes
Low (1)	The consequence of the risk, if it occurs, will leave time to prepare and initiate mitigation strategy

g) Early Warnings:

Early warnings are signals one can get in advance of a risk occurring. Are there anything that can imply that a risk is emerging, so that one can be prepared to take actions in time to prevent an unwanted impact? As seen in table 7, the ratings for early warnings is set to yes/no.

Table 7: Early Warnings

Rating	Description
Yes	If the risk is to occur, there are early warning signs that leaves time to prepare for impact
No	If the risk is to occur, there are no early warning signs that can leave time to prepare for impact

Rules for Mitigation Strategies

Mitigation strategies are chosen with background in the multi criteria decision-scheme described below by seven main rules and two general rules. The rules are based on the assessment criteria, and their ratings after the assessment. With every rule, there is a preferred mitigation strategy that suggests where the focus for risk treatment should be. For the rules, the numeric scale of the ratings in the assessment is used. And Yes/No for the early warnings. The numbers are collected from the sheet/table where the results of the risk assessment are stated.

Mitigation strategies shall aim to prevent, reduce, monitor and/or create contingency plan for unacceptable levels of risk, that may interfere with the project objectives. Mitigation strategies shall seek to find solutions that are feasible and well reflected. The difference between these mitigation strategies and how to apply them are given under "General Guidelines". There are seven main rules that are considered to be the most important combinations one should be especially aware of. They mainly describe situations where the risk impact is rated as significant or severe. This is because the impact of the risk is considered to be the most critical factor, due to the effects it may have on the project objectives. Suggestions for a preferred mitigation strategy for each of the seven main rules are given in the rationale provided in for each rule. Of course, there are several other possible combinations formed by the assessment criteria. To encompass risks with other combinations of criteria, general guidelines are provided. There are two general guidelines, General Rule A and General Rule B, described below.

General Guidelines:

The general guidelines are created to comprehend the cases where the combination of assessed criteria does not specifically apply to any of the seven main rules. Risks that are assessed and have combinations of criteria that is not compatible with the rules must be evaluated against the defined risk acceptance criteria. Since different projects/companies may have different policies on what is accepted, and how the risk affects the project objectives. This must be decided by the user of the model. But in general, risks that are assessed to have criteria with combinations of ratings *not* stated in the rules below, neither main or general rules, may be accepted. If there are any uncertainties, a contingency plan for these risks can be made, leaving time, money and resources to manage risks of this nature. The different mitigation strategies are stated below:

Mitigation Strategies:

a) *Prevention:* This mitigation strategy seeks to initiate measures to eliminate the risks that are considered to have serious effect on project objectives. May be necessary to change project objectives, change requirements or project objectives. For risks that have a very serious effect on project objectives, a contingency plan should be worked out, in case prevention is not feasible (schedule and cost) or fails. Also, if the prevention is not viable, the next strategy could be seeking to reduce the risk. Prevention is especially interesting when Risk Impact ≥ 3 is combined with Triggering Effect = 3 and/or Recoverability =3 and and/or Immediacy = 3 have a serious rating

b) *Reduction:* Reduce risk impact and/or other critical criteria that is assessed to a higher rating than one is comfortable with. This strategy is most likely to be successful if actions are taken as early as possible, since mending effects of a risk in retrospect may not be feasible.

Especially interesting when Risk Impact ≥ 3 and/or Likelihood of Occurrence is ≥ 2 and/or Immediacy ≥ 2 and/or Recoverability ≥ 2.

c) Contingency: A plan whereas a strategy is executed when a risk occurs. This is not necessarily a mitigation strategy that is used isolated. As mentioned in both the prevention and accept strategies, a contingency plan can be used as security if a strategy fails, is not feasible or a risk emerges after being assessed as acceptable.

d) Monitoring: A mitigation strategy where risks considered to not be a serious threat, in the present, are to be observed. Especially risks with Risk Impact ≤ 2 combined with Detectability ≥ 3 and/ or Immediacy = 3 and/or Triggering Effect = 3 may be subjected to this. Risks like this do not have a severe impact but effects other unwanted, serious criteria if it were to occur.

e) Accept: Acknowledge that the risk is existing, but not act on it until it occurs. As for now, there is no impact on project objectives. But as the project prospers, these risks may change. This can be a result of changes in the project objectives or in the external forces. Therefore, a contingency plan where time and resources are included can be beneficial.

In "General Rule A", Risk Impact ≥ 3 and Triggering Effect ≥ 2 are given a higher relevance
For each of these, conditional criterion is stated. This is to underline the serious consequences of the Triggering Effect, since it is more likely that higher order risks are to occur. An already serious risk causing one or more several risks that is also serious in terms of Risk Impact, is not desirable.

General Rule A:
If Risk Impact is ≥ 3 and Triggering Effect ≥ 2 is combined with;
(Likelihood of Occurrence ≥ 2 and/or Detectability ≥ 3 and/or Immediacy ≥ 2 and/or Recoverability ≥ 2 and/or Early Warnings = No) then there is a need for initiating a mitigation strategy. This general rule encompasses so many combination of rules, that an individual preferred mitigation strategy has to be chosen from the list of strategies, some guideline are provided under *prevention, reduction* and *monitoring,* as to what risks should be subjected to what mitigation strategy.

General Rule B:
If Risk Impact is ≤ 2 is combined with the following:
(Detectability ≥ 3 and/or Immediacy = 3 and/or Triggering Effect = 3) then the mitigation strategy shall focus on *monitoring* the risk. This is a relative low Risk Impact, but it may have a severe effect on the other three criteria. The possibility of causing more severe risks to occur, and ignoring risks with immediate effects that may be difficult to detect is in need of being controlled.

Main Rules:
The main rules for choosing a preferred mitigation strategy are stated below:

Rule 1:

If Risk Impact is ≥ 3, Detectability is ≥ 3, and Immediacy is ≥ 2, and Early Warnings = No
Rationale: This is a risk that, if it materializes, has a considerably high impact, that is difficult to detect and gives no early warnings. Risks with this combination of criteria shall be subject to a mitigation strategy that focuses on *reducing* the risk level, especially the risk impact. When detectability and early warnings are rated such as this, it is difficult to discover if the risk has materialized. The impact of the risk is high, which means that a severe risk may materialize without being detected. If reduction is not feasible, a *contingency plan* shall be prepared.

Rule 2:

If Risk Impact is ≥ 3, Likelihood of Occurrence is ≥ 3 and Recoverability = 3

Rationale: This is a risk that, if it materializes, has a considerably high impact, is likely to occur and is severe in terms or recoverability. When dealing with a risk with such critical severity to recoverability combined with the likelihood of occurrence being this high, the mitigation strategy shall focus on *preventing* the risk. When it is considered to be not very likely to recover, it has to be eliminated. If this is not at all feasible, risk *reducing* shall be done, and a contingency plan shall be prepared regardless.

Rule 3:

If the Risk Impact is ≥ 3, Likelihood of Occurrence is ≥ 2 and Immediacy is = 3

Rationale: This is a risk that, if it materializes, has a considerably high impact, is somewhat likely to occur and is immediate. The mitigation strategy shall focus on *reducing* the risk, by especially focusing on impact. If there are any measures that can be taken to reduce impact, they should be initiated as soon as possible. Since the immediacy is moderate to high, there may not be sufficient time to come up with a strategy to reduce the impact. A *contingency plan* is suggested to have as a backup due to the immediacy.

Rule 4:

If the Risk Impact is ≥ 3, Immediacy is = 3, Early Warnings = No and Triggering Effect is = 3

Rationale: This is a risk that, if it materializes, has a considerably high impact, has a high immediacy, gives no early warnings and has a severe triggering factor. It is a risk that materializes immediately, not leaving much time to prepare for a mitigation strategy. The Triggering Effect is of such a severe nature that it increases the likelihood of other risks with considerably high Risk Impact. The mitigation strategy shall seek to eliminate the risk, using the *prevention* mitigation strategy. If not a prevention is feasible, a risk *reduction* strategy shall be prepared.

Rule 5:

If the Risk Impact is ≥ 3, Detectability is ≥ 3 and Early Warnings is = No

Rationale: This is a risk that, if it materializes, has a considerably high impact, is difficult to detect and gives no early warnings. Risks that are assessed with this combination of criteria, shall be subjective to mitigation by *monitoring*. The monitoring shall focus on keeping the likelihood of occurrence low, by tracking this risk. This is because the risk is difficult to detect and gives no early warnings to predict that it is about to occur.

Rule 6:

If the Risk Impact is = 2 and Triggering Effect is = 3

Rationale: This is a risk that, if it materializes, has a moderate risk impact and has a severe triggering effect. These risks are important to keep under control, since the risk impact easily may be neglected due to the relative low rating. The severe triggering effect is an indicator that if the risk is to materialize, the probability of other higher order risks occurring is increased. In this combination of assessed criteria, the mitigation strategy shall be to *monitor* closely this risk to prevent triggering of higher order risks to be more likely to occur. The risks impact in itself is not considered to be catastrophic, but if it materializes it might have an unwanted effect on reaching project objectives.

Rule 7:

If the Risk Impact is ≥ 3, Immediacy = 1 and Recoverability ≥ 2

Rationale: This is a risk that, if it materializes, has a considerably high impact, is not immediate and is possible to recover from. It does not within the typical combination of the risk reducing mitigation strategy, but it is a risk that is important to bring in to the main rules. This is because Risk Impact is rated considerably high, but Immediacy is very low and recoverability is likely. Risks like these are possible pitfalls due to the combination of criteria, and neglecting them is not beneficial since the risk impact is at this level. The mitigation strategy shall aim to *reduce* the risk impact, so that the risk can be classified as an accepted risk. A *contingency* plan shall be prepared customized to accepted risks like this, since the impact is considerably high.

Conclusion

Presented in this paper is a Dynamic Management Model that aims to make risk management more dynamic by allowing to periodically assess risks from a holistic perspective. The proposed DRMM provides a flowchart to show 8 phases and how they can be executed to achieve a dynamic risk management. Re-assessment to observe the effect of initiated mitigation strategies and identification of risks in the project duration substantiate the dynamic aspect. An improved set of assessment criteria is provided and a multi criteria decision scheme in the form of rules based on the assessment of the criteria. The model is qualitative, using words and terms to describe the assessment criteria.

The DRMM has encompassed several of the limitations and drawbacks of the current risk management practices, by making the process dynamic and not linear, as so many of the current models have a one-time "fire and forget" approach. Using several criteria instead of the traditional Risk Priority Number (RPN) and creating a new way of choosing a preferred mitigation strategy is believed to provide a more reliable source to mitigation, but a complete validation will have to be carried out. Even if this is a model that is meant to fit any project or company, it should be noted that some of the elements in the proposed model might vary in use in the industry. This is due to individual company policies and strategies. The criteria are assessed using qualitative descriptions, and may be altered to get a more realistic use of the model.

The proposed DRMM is tested using a case study in a company project. The case study seeks to show the use of the model in an active project, with real risks. Phases 1 – 6 described in the paper are applied to the company, but due to the nature of the Systems Engineering Management Plan (SEMP), phases 7 and 8 will have to be performed along with the progression of the project. The testing of the assessment criteria and rules for mitigation strategies are tested preliminary in the case study. The results of the provided mitigation strategies will have to be validated over some amount of time. So far, the assessed risks combined with the rules are giving mitigation strategies that is believed to be suitable for the chosen risk. Due to a Non-Disclosure Agreement, the case study is separated from the paper and enclosed in Appendix I.

Future Research

Due to the limited time in the Systems Engineering Management Plan (SEMP) of this project, a further validation of the model is needed. There is a need to test the complete 8 phases over a substantial manner of time, to fully see the effects of the DRMM. The validation of the dynamic aspect, especially phase 7: validation of adopted mitigation strategies, is beneficial to complete to see how the mitigation strategies affects the overall risk level.

Another important aspect, is to establish objectivity. With a qualitative analysis like this, subjective opinions may bias the assessment of the risk to initiate mitigation strategies that has less cost or is less time-consuming. Going further in finding criteria and mitigation strategies that is objective may be a necessary contribution for the future, to ensure that no decisions are made just to suit wants, but suits the actual needs.

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