Multidimensional Risk Management at NASA and its Potential Use at NATO Allied Command Transformation

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ABSTRACT

Effective project management relies on the meticulous and precise quantification of risks. According to Kaplan and Garrick (1981), risk is probability and impact [9]. However, impact is frequently multidimensional including a schedule dimension, safety dimension, financial dimension, or technical dimension, etc. This paper intends to introduce the use of statistical science to merge multiple risk dimensions into one value. A multidimensional risk tool called MRISK is used in numerous projects at the National Aeronautics and Space Administration (NASA) to assess and prioritize risks and mitigations. Moreover, this paper will summarize current risk management guidelines at NATO Allied Command Transformation (ACT) and will inform potential ways NATO ACT can benefit from statistical science in risk assessment and management.

The MRISK tool was developed by Booz Allen Hamilton at NASA Langley Research Center. I worked as a developer on MRISK and through this paper, I aim to raise awareness of quantitative risk assessment and present on its potential application at NATO ACT. The original MRISK paper written by Booz Allen Hamilton is proprietary to NASA and resides within the NASA Scientific and Technical Information (STI) Repository [8]. Opinions expressed in this paper are solely my own and do not express the views or opinions of my former or current employers.

1.0 INTRODUCTION

All projects, regardless of their organization, complexity, timeframe, or objectives, will have risks. The Project Management Institute defines a risk as "an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more objectives" [12]. A positive risk is considered an opportunity, whereas a negative risk is considered a threat. Most often risk management implies threat management. Given that, it is impossible to avoid project threats, effective project management must comprise ways to successfully manage it. Especially considering that deficiencies in risk mitigation ultimately cost the Alliance extensive money, and potential lags in warfare capability development and progress, it proves to be a vital component of project management.

Risk management encompasses risk identification, risk assessment, and risk response. The objective of the risk assessment stage is to evaluate the probability and impact of risks qualitatively and/or quantitatively [3]. Traditionally, a risk assessment is done qualitatively, meaning it is dependent on judgement about the probability and impact of the individual risks. Judgement can be based on information from past experiences, comparable projects, or expertise in the project's subject area. Risk assessment done in this way can fall on one person, or within a team setting with various stakeholders and experts. Nevertheless, a risk assessment done solely qualitatively is not always adequate.

If the primary objective of the risk assessment is to prioritize risks to determine which ones warrant further research and response, then a qualitative assessment is likely sufficient. Conversely, if the risk assessment demands high precision and a more conclusive evaluation, then a quantitative assessment in conjunction with the qualitative assessment would be of benefit to the project [11].

To advance accuracy and precision in risk management, this paper will predominantly focus on risk assessment, specifically emphasizing the benefits of a quantitative risk assessment methodology. The risk management process at NATO ACT will be reviewed and a potential area for improvement in risk assessment will be highlighted. Lastly, as an example of best practices, the risk management method and tool employed at NASA will be reviewed.

2.0 BACKGROUND

NATO ACT has long recognized the need for establishing effective risk management as a pillar of project management. According to the ACT Risk Management Directive (ACT Dir 20-3.2), "Risk Management is an essential and integral component of all ACT activities and is to be executed at all levels of management and leadership. Management and decision making without considering risk will inevitably lead to ineffective and/or inefficient decisions' [2].

The NATO ACT risk management process outlined in Figure 2-1 shows a 5-step process;

1. Risks are **identified** as threats and opportunities.

2. Risks are **assessed** in terms of probability, impact, and proximity, and to evaluate the net aggregated effect.

3. Risk responses are **planned** to remove or reduce the threats and to maximize opportunities.

4. Risk responses are **implemented** and monitored for their effectiveness.

5. Risk management is **communicated** throughout the project to ensure steps 1-4 occur as often as possible and effectively within the project team.

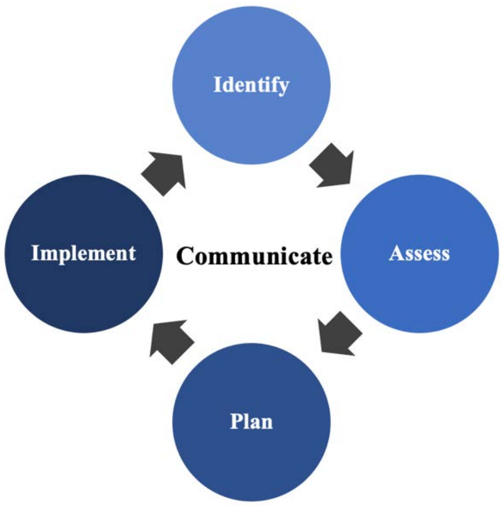

Figure 2-1: NATO ACT Risk Management Process.

At Step 2, the assessment stage encompasses assigning Likert scale values of 1-5 to probability, impact, and proximity of risks via a risk register to estimate their net aggregated effect. The ACT Project Management Office maintains the risk register dashboard for NATO ACT. The risk register enables project teams to document all identified risks and their assessment values. Risks are then ranked and visualized on a probability-impact grid. It is recommended that every project have a risk owner, risk actionee, and risk specialist responsible for managing and controlling risks, carrying out risk responses, and trained in risk management practice, respectively. Most often, these obligations all fall on the project director (PD) in charge of the project and is a challenge to manage in conjunction with the PD's myriad other duties.

In addition to ACT's framework, the risk assessment stage can be further described in two parts: performing qualitative risk assessment and performing quantitative risk assessment [12]. Frequently at NATO ACT, we are skilled in qualitative evaluations, but lacking in sufficient data and information to be able to perform quantitative assessments. This is primarily due to working on the early stages of acquisition projects. Nonetheless, even when we are privy to adequate data, we are uncertain of the appropriate quantitative risk analyses to perform. Projects vary extensively in complexity, and given the broad range of nationalities, education, and breadth of experiences of project team members, we have difficulties in down-selecting methodologies and tools. Due to time constraints, we frequently satisfy requirements and populate the probability, impact and proximity fields of the risk register based on collective qualitative assessments only. Even though a probability-impact grid contains numbers, it is still considered a qualitative risk assessment method. Although this is often satisfactory for projects, there are ways we can evolve our methodologies to reflect greater insight and precision into the risks that threaten our projects [4].

3.0 MULTIDIMENSIONAL RISK

While analysing risks in terms of probability, impact and proximity is effective and straightforward to understand, in practice, risks have consequences (impact) that are multidimensional. Consequences recurrently include a schedule dimension, safety dimension, financial dimension, or technical dimension, etc. All too often, one dimension can have impacts across the other dimensions [4]. When these consequences interact, they produce a consequence greater than the sum of their individual values. By quantifying these dimensions, we can capture an all-encompassing aggregated effect. Ultimately, the value of following such a methodology is a more precise quantification of the impact of a risk. We can capitalize on statistical science and the development of algorithms to produce risks assessments that are superior in accuracy and consistency.

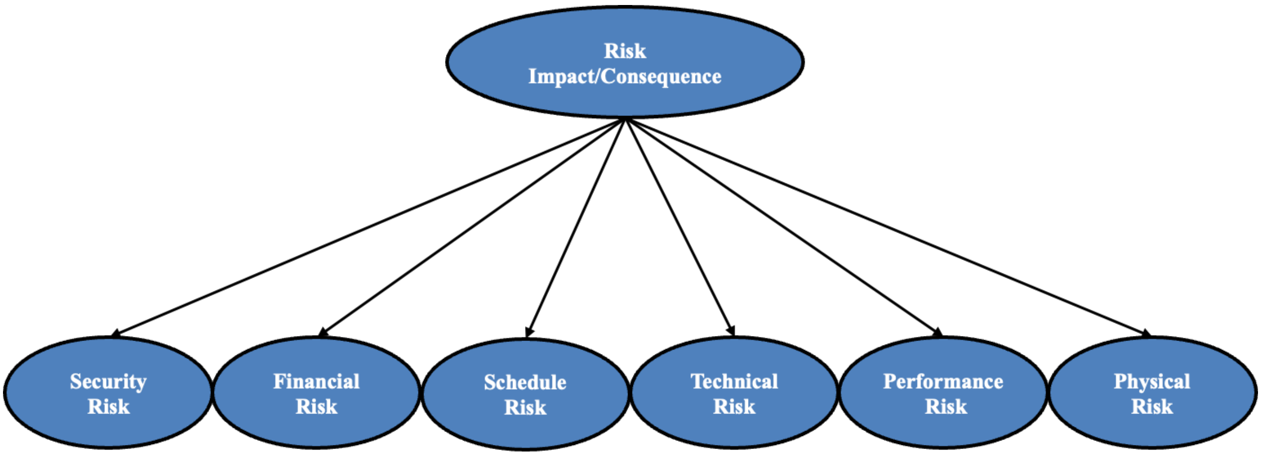

Figure 3-1: Examples of Impact Dimensions

At ACT, risk management is most noticeably completed as a project team. We value collaboration and consensus amongst personnel with differences in nationality, education, and military expertise with the aim of achieving the optimal result. Through a joint effort, we follow a qualitative process to assign values for probability, impact and proximity as risks are identified through the project life cycle. Although this is often sufficiently effective in capturing risks, it is in the benefit of the Alliance to make a concerted effort to reduce the subjective nature of scoring risk probabilities and impacts. Projects vary in complexity as do their risk impact dimension categories as well as dimension values. It is imperative to differentiate risk evaluations between projects [1]. The magnitudes of the dimension values are unique to each project and must be evaluated as such. To accurately quantify risk for a project, we must customize and thoughtfully choose dimensions and develop impact ranges depending on the project's structure, setting and objectives. In other words, a risk scorecard must be developed to capture scores by the various dimensions that affect the impact score. Thus far, this is still a qualitative process because it involves the project team collectively creating a risk scorecard by choosing impact dimensions and range values.

Quantitative risk assessment begins as we develop an algorithm to represent the relationship between the impact dimensions. Breaking out the impact into multiple dimensions helps to prioritize and analyse the risks. As projects grow and become more complex, their risks grow as well; it becomes increasingly challenging to identify effective mitigation strategies. Risk prioritization also proves more difficult when there are multiple risks with the same risk score. By evaluating risks through multiple dimensions, and using a consistent and defendable aggregation algorithm, it is possible to determine the higher priority risks efficiently and accurately. This process requires further dedication and resources in risk management in the form of risk managers that are part of the project team throughout the project life cycle. This is especially challenging for ACT given that project oversight changes as the project moves through the NATO acquisition life cycle. There will always be a requirement for qualitative risk assessments; however, quantitative assessments can increase precision by accounting for the complex relationships of a project's impact variables [13].

4.0 RISK MANAGEMENT AT NASA

The National Aeronautics and Space Administration (NASA) uses statistical science to merge multiple risk dimensions into one value using the Multidimensional Risk (MRISK) tool. The MRISK tool is used in many projects at NASA to assess and prioritize risks and mitigations [8]. Legacy methods have difficulty distinguishing between similar impact scores. Therefore, using multiple dimensions and a meticulous aggregation algorithm helps to determine which risks are higher priority than others. NASA employs risk managers to work alongside project risk owners to identify risks, and to capture and update risks in the MRISK tool to ensure data integrity and continuous risk management through up-to-date risk information [8].

It is the risk manager's role to help facilitate the risk management process: identify, assess, plan, and implement. At each step of the process, the risk manager communicates, documents, and facilitates the dialogue around project risks. At NASA, the risk management process is essentially two stages: creation and execution. During the creation stage, the risk manager will focus on forming the risk scorecard and formally documenting the risk management plan, which outlines the risk management strategy for the project. The risk management plan may be updated throughout the project life cycle. During the execution stage, the risk manager is accountable for documenting risks and the project team discussions surrounding them. It is normal for the risk manager to schedule one to three meetings per month to create risk reports identifying the number of current risks and detailed risk information such as creation date, status, action type required, list of mitigations, etc. Risks may need to be filtered or clustered based on a variety of features, and these features change depending on the project owners and stakeholders. Additionally, each risk requires an in-depth analysis, which can be challenging using a spreadsheet tool like Excel. To combat many of these analysis and organizational challenges in risk management, risk managers at NASA use MRISK [8].

5.0 MRISK TOOL

The MRISK tool has many management and control benefits of serving as a risk repository and risk report generator; however, this section will focus on the statistical science of the tool to combine multiple dimensions together into one risk metric. As noted previously, at ACT, the standard practice is to translate qualitative assessments into a numerical Likert scale for the risk impact measure. A Likert scale is a measure of one to five, with one being associated with the least threatening impact and five being associated with the most threatening impact. Likewise, the MRISK tool uses Likert scale data, although it is applicable to all forms of numerical data. It is worth mentioning that if the scoring inputs used within MRISK are inexact then MRISK will be no better than any other method. The MRISK tool is not for defining a risk score assessment process, rather it is designed for accounting for the covariance amongst the multiple impact dimensions [8]. Project team members at ACT would still need to produce qualitative risk assessments and undoubtedly probe deeper to select impact dimensions and assign risk scores for use in MRISK. By accounting for the covariance in dimensions, it allows for discerning when and why certain risks should take priority over others. In other words, it resolves the interdependencies of impact dimensions, providing a clearer depiction of risks.

The Euclidean distance is one of the oldest and most popular mathematical models used to visualize variables in two-dimensional space. It is a commonly used method to calculate the straight-line distance between two points [6]. The Euclidean method is intended for multidimensional situations; however, it is flawed in that it assumes the dimensions occupy the same plane, which is not accurate for risk assessment.

MRISK is developed based on the Mahalanobis distance. In his 1936 paper, On the Generalized Distance in Statistics, P.C. Mahalanobis introduced his innovative method to measure the distance between a vector and a distribution. It measures how many standard deviations away from a distribution a given point is; Mahalanobis also generalized the concept to multiple dimensions. [8]

The three advantages of this method are:

- Accounting for correlation between variables
- Using normalized Euclidean distance when correlation doesn't exist or when vectors occupy the same plane
- Can be scaled to infinite dimensions, meaning the technique will never lose validity as the number of dimensions grow

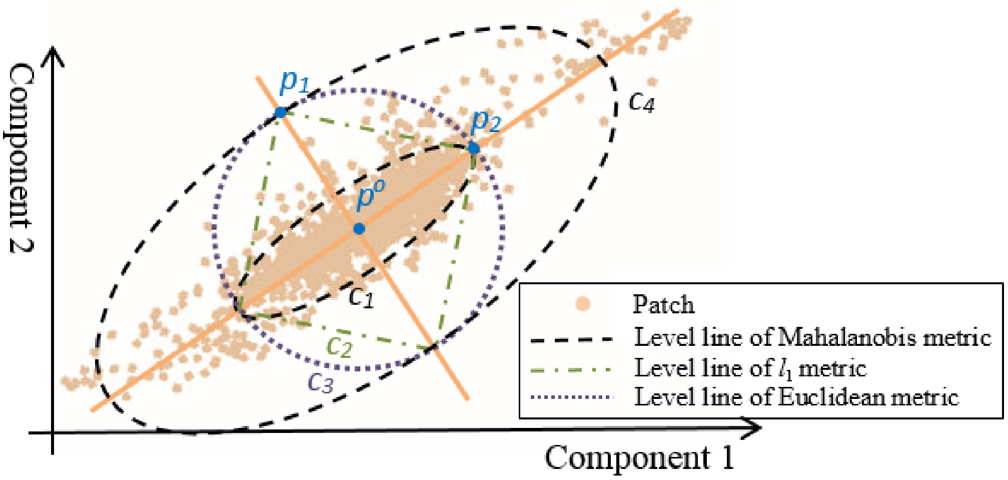

Figure 5-1: Mahalanobis vs. Euclidean Distances

Since the Mahalanobis distance is the distance between a point and a distribution (not between two distinct points), and better accounts for covariance at a greater scale, it is effectively a multivariate equivalent of the

Euclidean distance [6]. By using the Mahalanobis method, MRISK can merge multiple risk factors into a single metric that properly accounts for correlation between dimensions [10]. Multidimensional risk assessment done in this way is growing. NASA has expanded impact to directly account for cost, schedule, and technical dimensions (NASA/SP-2011-3421). Other subjects such as finance frequently use five dimensions and the Department of Homeland Security (DHS) National Infrastructure Protection Plan (NIPP) and sector specific plans include three dimensions and may add a fourth resilience dimension [8].

6.0 CONCLUSION

Although the ACT Risk Management Directive identifies a risk owner, risk actionee and risk specialist, in practice, every project is not assigned such team members. A great deal of risk management responsibilities falls on project team members who have key responsibilities in other areas of the project and are not necessarily experienced or focused on risk management. No team member is exclusively working in project risk management in the form of a risk manager. We need to devote more resources in the form of risk managers and employ advanced tools to ensure greater consistency and accuracy in risk assessments. The employment of risk managers and the MRISK tool at NASA is one example of the room for improvement in risk management.

Employing a tool like MRISK requires a considerable investment in developers to build and maintain, as well as risk managers to utilize and keep up-to-date risk data within it. However, it would serve as a complementary process to the current risk management framework at ACT. In other words, it would be an enhancement to the status quo. Project team members would still be required to perform qualitative assessments; however, these assessments would need to be in greater depth examining the impact dimensions and values of their projects. Ultimately, it would serve as a more sophisticated and organized approach to better perform these assessments and the employment of a risk manager to produce a more complete and accurate risk management practice.

7.0 REFERENCES

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