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Qualitative Risk Management in Space Activities
A risk analysis method explored

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Abstract
Risk management is the human activity which integrates recognition of risk, risk assessment, developing strategies to manage risk, and mitigation of risk using managerial resources. Risk management is an essential element of project management. In a project, risk analysis should be performed to identify which risks could occur and, knowing these risks, a project manager can then affect measures to control them. However, the effect of those measures must be assessed regularly throughout the life of the project. More often than not, qualitative risk analysis instead of quantitative risk analysis is used for risk management, because qualitative methods in general consume much less time and demand less specific theoretical knowledge of risk analysis. While other risk management techniques are available, it is considered that the RISMAN-method would be highly suitable for space projects, due to its applicability throughout a whole project. This paper describes qualitative risk management, based on the RISMAN-method.
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Introduction
Space projects, such as developing and building satellites and launch systems (space rockets), need a risk assessment tool that can be used in every phase of the project to produce quick visibility of project risks and their potential impact.

In every phase of a (space) project, risk analysis is the core element of risk management. Risk management begins with a risk analysis to systematically identify the risks within the project. A once only stocktaking of risks, at the beginning of the project, is not enough since projects tend to develop and change over time. Also, risk control measures taken during the project, can change the risks themselves. Consequently, risk management must be a cyclical process that has to be carried out continuously. (See Figure 1)

The RISMAN-method[1] is a technique to conduct risk analysis and is very well suited to be used in long duration space projects, as it can be utilized throughout the whole project. The RISMAN-method was initially developed as a risk analysis tool in the 1990s by the Dutch Ministry of Waterways and Public Works to assess the risks in planning large infrastructural projects. Using the RISMAN-method, the risks are made clear in a systematic way and from a variety of perspectives and measures to control these risks identified. It is possible to conduct qualitative and/or quantitative interpretations with the RISMAN-method. More often than not, qualitative risk analysis instead of quantitative risk analysis is used for risk management, because qualitative methods in general consume much less time and demand less specific theoretical knowledge of risk analysis.

In qualitative analyses, step approaches in cyclic processes often can be distinguished. The RISMAN-method consists of four steps which are described below. (See Figure 2) Different activities required to conduct an analysis will be examined and supporting aids and technologies covered. Based on this information, a full risk analysis can be achieved.

The RISMAN-analysis uses:

- A risk matrix through which risks can be identified systematically;
- Graphs to clarify the relationships between, and mutual influences of, the identified risks;
- Calculation programmes to determine the feasibility / practicability of the planning estimates and – if desired – perform a full quantitative risk analysis.

Scope of paper
Risk analysis is a part of the cyclical process of risk management and can be performed either qualitative or quantitative. Because qualitative risk analysis is much more utilized than quantitative risk analysis, this paper focuses on qualitative risk analysis based on the RISMAN-method and describes the four steps of this method.

Step 1. Determine goals

The most important goal is to identify the key risks that could adversely impact upon a project. There are other goals that may play a part, such as stimulation of risk awareness amongst project staff, or to conduct a risk analysis to aid decision making.

The risk analysis can be focused on the control aspects of time, money or quality, or, an integrated analysis could be performed on all aspects at the same time. With a risk analysis on time or money, special attention is of course given to any risks that would delay the delivery date or increase project costs. With an analysis on quality, risks would need to be identified which threaten such quality aspects as environment, safety, strength, reliability, life span, maintainability, and even aesthetics.

Risk analysis can be targeted at any phase or product within the total project. For example, one could only look into the risks of loading a satellite with hydrazine, but it might be wise to look at the whole process of loading substances into the satellite. Specific (sub) phases or (sub) products could influence, or be a risk to, other phases or products. Therefore it makes sense to always look at the complete process. For many risks, the source of the problem is found in an earlier phase to that where it actually manifests itself. Also, control measures applied can introduce risks in other (sub) phases or (sub) products.

Every risk can, in every phase of the project, threaten the end result, by affecting project schedule, time, cost and/or quality. At the beginning of every new phase in a project, it must be clear which risks could influence this phase or the end result of the project and which of those risks might manifest themselves again in a following phase. The risk analysis focuses firstly on the risks that could endanger the end result of the project and thereafter on those threatening the end result of the phase involved. Risk management encompasses the following phases. (See Figure 3):

- Initiative Phase. In this phase in which the initiative to start a project originates, usually the end result of the project is not yet fully defined. Some element of planning or estimation is still required. Additionally, decisions taken in this phase could create risks in later phases of the project. Therefore, a risk analysis will need to be conducted differently from the other phases. Risk management in this phase supports the decision-making process regarding the organization of the project.
- Preliminary Study Phase. In this phase risks could lead to failed goals, such as the starting point (start note) or project plan, in the allotted time. Risk management in the preliminary study phase focuses on control of decision-making aspects; aspects outside ones own control and project organizational aspects such as lack of capacity in the project team.
- Trajectory Study Phase. In this phase measures can be taken to involve third parties in consultations. It is important to know what influence these parties may have on the project and what demands they can make. Risk management in this phase should ease the decision process between all concerned parties.
- Plan Execution Phase. In this phase the requirement plan and marginal values are determined. These relate to risks in later phases. Risks could be project organizational aspects such as shortage of capacity, supplementary demands, etc. Risk analysis in this phase shows the reliability of earlier planning estimations and from this, a project budget can be approved.
- Specification Phase. In this phase, it is determined which risks can be eliminated or reduced to an acceptable level within the project itself and which risks need to be insured against. Risk management in the specification phase mainly concentrates on risks that manifest themselves during the execution phase.
- Tender Phase. Measures taken to control risks taken in this phase will influence the control of schedule and cost of the whole project. When contemplating the different tenders it is very important to be able to accurately estimate the different risks involved. Risk management in this phase mainly involves the estimation of the execution risks for all tenders.
- Execution Phase. In this phase the emphasis of risk management lies mainly with risks that could occur within the technical execution of the project. Important issues are quality and capacity control, avoidance of disasters and logistics control.
- Control Phase. In the beginning of this phase the responsibility for the project result shifts from the project team to the controller. This controller will be confronted with risks that could be the result of choices made during earlier phases. Possible risks in this phase are disappointing exploitation yield, shorter life span than planned, higher cost for maintainability, unplanned necessary modifications, etc.

Choosing between a qualitative or quantitative risk analysis is a balance between costs and benefits. A quantitative analysis provides more insight into the risks and uncertainties than a qualitative analysis does. However, a quantitative analysis demands much more specific knowledge of risk analysis and consequently consumes much more time than a qualitative analysis. In every step of the RISMAN-analysis something extra has to be done. The most important difference is that in a quantitative analysis the risks and uncertainties are not only described in words, but also in terms of probabilities (expressed in a figure between zero and one) and effect (expressed for example in cost or time).

Finally, in step 1, one should decide on the desired depth of the risk analysis as well as who is going to do the analysis and when. To perform a good risk analysis, a complete and current knowledge of the project is essential.

Based on the RISMAN-method a so called Quick-Scan has been developed (but not described here). The difference between the comprehensive RISMAN-analysis and the Quick-Scan is that with the latter, in a short period of time (two half days) and relatively little effort, a first and quick insight in the risks of planning a project can be obtained. The results of the Quick-Scan are inherently more global than the comprehensive RISMAN-analysis.

Step 2. Map the risks

In this step the risks must be identified and structured. It is essential that the project is looked at from different perspectives to, as best as possible, identify all risks. The following activities must be performed: analyse the risk information available; create a risk matrix; display the risks in a risk graph.

In practice often the necessary information is not available or the information is out-of-date. In this case, the risk analysis could enable the project team to generate or update this information. The planning and the assessment should be looked at for completeness, topicality and the starting points.

- Completeness and topicality. Checking of the completeness of the information could be executed by looking backwards from project results through the relevant activities required to reach those project results. Likewise it has to be checked whether the planning and estimation are sufficiently up-to-date and all changes processed.
- Starting points. To get every starting point clear, with every planned activity two questions must be answered: “What must go right?” and “What could go wrong?” The purpose of this is to research which uncertainties have already been taken into consideration when the plan or assessment was drawn up.

To map the project process, one could use aids such as input-output process diagrams, but this is only possible when we have good insight into the project and all its’ activities. Each main activity is then looked at as a component of the total process and subdivided into (sub) activities also seen as separate components.

An aid to identifying risks is the risk matrix. This is a table in which risks can be drawn up and displayed as shown in Figure 4. The different components of the project are shown in the vertical axis and the perspectives from which you can look at the project in the horizontal axis. The way of organizing the matrix is indicative of the quality (depth and completeness) and tempo of the risk analysis. There are other methods to map risks, such as Failure Mode and Effect Analysis (FMEA), Hazard and Operability (HAZOP) and Structured What If Technique (SWIFT), but these are not addressed here.

After the axes of the matrix have been organized, the matrix can be used to identify the risks. Here risk is defined as the possibility of an event occurring that will have an impact on the achievement of objectives (time, cost, and quality).

Risk graphs have then to be drawn up to visually display the risks. Examples of such graphs are error trees or event trees. Error trees depict causes that could lead to unwanted events and therefore contain risks. An event tree depicts how an event could lead to certain (unwanted) effects. Risk matrices and graphs visualize risks and make them better comprehensible.

Step 3. Determine important risks

In this step the risks identified in step 2 are assessed and the most significant risks determined. These are the risks for which control measures must be defined in step 4. Available control measures are best focused on controlling the most important risks. It is certainly not practical to try to control all risks at the same time. Step 3 could be performed qualitatively (prioritizing in degrees of risk likelihood and level of impact) or quantitatively (detailed calculations required for each individual risk). Because qualitative risk analysis is much more utilized than quantitative risk analysis, in this paper the qualitative approach is explained.

There are various methods to prioritize the risks, such as:

- Get the risks into the right order [numbers]. Every participant places the risks in a table in descending order of significance, as he sees them, numbering each risk. The resulting lists of the participants are then combined into one list which shows the risks from the most important to the least important.
- Judge risks with words, tokens or labels. In the matrix, risks are given descriptions such as big, average, small, very small, or are given labels such as ++, +, –, – –.
- Divide a total of 100 points over all the risks. The points are divided (by a minimum of five people who have a good knowledge of the project) over a minimum of five and a maximum of twenty risks. (See Table 1) For each risk the points are then added up and the risks prioritized from high to low. The result is a list of the most important risks. According to table 1, risk number 3 is the highest; risks 7 and 8 are the lowest. The RISMAN-method uses this method mostly because the combining of assessments is relatively straightforward and simple.
- Judge probability and effect separately. The risk is broken up into ‘probability’ and ‘effect’ and the overall risk = probability x effect. The magnitude of the probability and the effect can be estimated on a scale of 1 to 5 (or 10 etc) in which 1 has the smallest value and 5 has the greatest value. The risks are then placed in sequence by as shown in Table 2. The opinions of participants are combined by adding the amount of points allotted by the participants to each risk (Table 1) and prioritize the risks again from high to low.

These different methods of prioritization each have their own limitations. In Risk Management literature this is known as Measurement Theory. This theory deals with the assignment of numbers to objects, also called measuring the objects. This can be done using different measuring scales. The most important scales are, in declining order of value and level of detail, the ratio or relation scale, the interval scale, the ordinal scale and the nominal scale.

Step 4. Map the control measures

In the preceding steps the most significant risks that could threaten the project have been identified. In the fourth step, measures to control these risks are mapped. Enforcing these control measures contributes to risk reduction and improved control of the project.

Activities that should be initiated are:

- Identify the control measures – there are many kinds of control measures used to control risks, but essentially there are only two:

1. Measures in which the risks are born internally by the project or project team. Here the key words are: avoiding, decreasing by cause-directed or outcome-directed measures, or risk acceptance.
2. Measures in which the risks are transferred to another party. Transferring risks does not lead to removal of the possible cause of the risks, but to a risk reduction. One expects (or hopes) that the other party is capable of managing that risk. The risks could be transferred to the client or to an insurer. Possible damage arising from these transferred risks would be compensated, but other (adverse) effects (such as delay in the project) would remain present. This specific measure is agreed on and implemented before the occurrence of the risk, but would be put into action after its occurrence.

- Show likely effects of the control measures – map the cost / effort necessary for the execution of the control measures and the expected effects / benefits. This again can be done both qualitatively and quantitatively.

If one maps the effects of control measures, one has to assess the expected effort or cost of the measure in terms such as big, small, low, high, and the expected effect of the measures, likewise, in terms such as big or small. (See table 3)

The result of this step is a survey in which, for every designated risk, the measures which could possibly be applied to control each risk are shown, and the likely effect of each measure.

Concluding remarks

Effectively managing the risks in planning processes in space endeavours, using the proper tools, improves the balance of costs, time and quality, and safety of the project.

The RISMAN-method has been developed as a risk analysis tool in the 1990s and used as a successful risk reduction tool in many large projects. Over the years the method evolved from risk analysis to risk management.

By adapting the RISMAN methodology for space projects, a universal and structural tool for risk management in this (high risk) sector of industry was developed and was successfully utilized in different projects.[2]

Fig. 1 Risk management, a cyclic process.

Fig. 2 The risk analysis four step approach.

Fig. 3 Risk management in project phases.

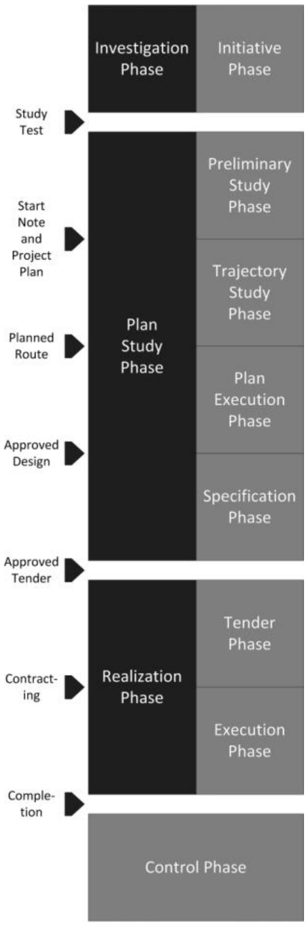

Fig. 4 Risk matrix

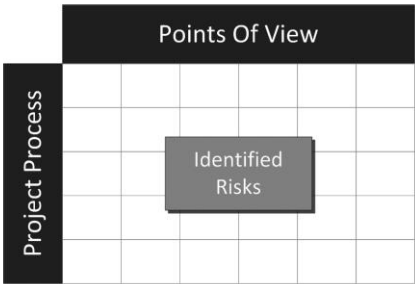

Table 1 - Risk matrix according to the RISMAN-method.

Risks / Partici-pants	1	2	3	4	5	6	7	8	9	10	Points
A	20	5	0	10	0	0	0	15	30	20	100
B	5	10	30	0	0	20	10	0	25	0	100
C	10	25	15	20	0	0	5	0	5	20	100
D	5	20	17	15	33	10	0	0	0	0	100
E	5	18	20	7	20	30	0	0	0	0	100
	45	78	82	52	53	60	15	15	60	40	500

Table 2 – Probability and Effect matrix

Description of risks	Probability	Effect	Risk	
More design changes than planned	4	1	4	4
More materials needed	3	4	12	1
Extra safety measures	4	2	8	3
Extra testing of hardware	2	5	10	2

Table 3 – Effects of Control Measures

Risk	Possible Measures	Effort	Cost	Effect
◘	◙	●High/Low	○High/Low	♦Big/Small
◘	◙	●High/Low	○High/Low	♦Big/Small
◘	◙	●High/Low	○High/Low	♦Big/Small
◘	◙	●High/Low	○High/Low	♦Big/Small

References

[1] Well-Stam, D. van; Lindelaar, F.; Kinderen, S. van; *Risk Management for Projects. The RISMAN method applied.* Het Spectrum, 2003 (in Dutch).

[2] ribs Space Consultancy & Insurance / Data Banking & Control, 1984 – 2007.