QUALITATIVE RISK ANALYSIS METHODS IN AVIATION PROJECTS

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This paper provides information to project managers and project teams that will help with their risk management efforts in the following ways: provide a consistent methodology for performing project risk management activities, provide techniques and tools for project risk management, identify data requirements for risk analysis input and for output, and provide guidance on how to proactively respond to risks.

The research will outline a few of the qualitative methods commonly used in project risk management and also accomplishes the comparative evaluation of different methods using multi-criteria analysis. Understanding of project risks will better enable project teams to contribute to the fulfillment of public service through assessing project risk and uncertainty to aide in making decisions regarding aviation project development and delivery. These decisions contribute to public safety and the projects we deliver add value on many levels.

Qualitative risk analysis assesses the impact and likelihood of the identified risks and develops prioritized lists of these risks for further analysis or direct mitigation. The team assesses each identified risk for its probability of occurrence and its impact on project objectives. Project teams may elicit assistance from subject matter experts or functional units to assess the risks in their respective fields.

Key words: risk management, aviation project, qualitative analysis

1. INTRODUCTION TO PROJECT RISK MANAGEMENT

Project risk management attempts to anticipate and provide a solution regarding the uncertainties that pose a threat to project objectives and terms, to identify all the foreseeable risks, assessing the chance and severity of those risks, and then deciding what might be done to reduce their possible impact on the project or avoid them altogether.

In some industries risk management and its closely associated discipline of reliability engineering have to be taken particularly seriously because of the potential of project failure on public safety or the environment. High in this list of risk/sensitive projects are all those connected with aerospace and air transport, where a risk event might be anything from missing a flight connection to a catastrophic collision between two fully laden passenger aircraft over a densely populated city.

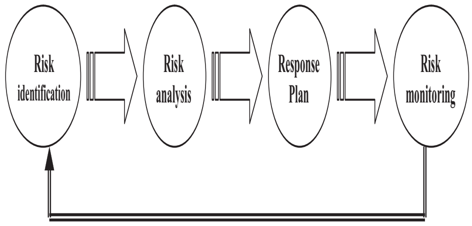

Fig. 1 Cycle of risk management process

Any project, small or complex, needs special attention to risk management [1]. A risk management strategy must be developed, first to identify as many potential risks as possible and then to decide how to deal with them **(Fig.1).**

Project risk management is a complex subject. Even the classification of risks is not straightforward and can be approached in different ways. There are several techniques for assessing and dealing with project risks grouped into two categories: qualitative and quantitative risk analysis. Qualitative risk analysis involves considering each risk in a purely descriptive way, to imagine various characteristics of the risk and the effects that these could have on the project or subsequent operations.

Quantitative risk analysis goes at least one stage further than qualitative analysis by attempting to quantify the outcome of a risk event or to attach a numerical score to the risk that ranks it according to its perceived claim for preventive or mitigating action.

2. CAUSE AND EFFECT IN QUALITATIVE ANALYSIS

The process of qualitative analysis means to evaluate the importance of identified risks and to extend the priority lists of these risks for further evaluation. Risks analysis is about clearly defining them, including weighing the importance of project risk, anticipating an agravating presumed situation, establishing projects sensibility and also the probability of risk materialization.

The concept of qualitative risk analysis is of fundamental importance when it comes to the need for the project management team and or the project management team leader to take the action at the onset or prior to the onset of the project to adequately and appropriately ascertain the approximate level of risk that so may exist in regards to the conduction of the given project and or series of projects. Specifically speaking, the concept of the qualitative risk analysis refers specifically to the project related process of performing a thorough and complete analysis of the overall effect of the complete and total set risks in the entirety of the predetermined list of project objectives that have been set forth by the project management team and or project management team leader.

The qualitative risk analysis can be conducted at any point in a project life cycle, however at least once at the onset it should be conducted. The primary goal is to determine proportion of effect and theoretical response [1,2].

Qualitative Risk Analysis assesses the impact and likelihood of the identified risks and develops prioritized lists of these risks for further analysis or direct mitigation.

To perform the analysis it has to identify the risk, including a thorough description of the risk and risk triggers, it can be characterized in terms of probability of occurrence and the consequence if it does occur.

2.1. FISHBONE DIAGRAMS

This method is commonly used by reliability and safety engineers to analyze or predict faults in design and construction. In project risk management fishbone diagram is usefull to examine risk cause and effect relationships. Fishbone diagrams can also be used to analyze failures or poor performance in project organizations or communications.

In my case, I show how an Ishikawa fishbone diagram might be compiled to analyze the numerous reasons why an Unmanned Air Vehicle (UAV) might lose the communications with control station (**Fig.2**). Many items in this example could be expanded into a complex diagram [3].

This method has numerous advantages: it permits a thoughtful analysis that avoids overlooking any possible root causes for a need; it is easy to implement and creates an easy-to-understand visual representation of the causes, categories of causes, and the need; it focuses the group on the big picture as to possible causes or factors influencing the problem/need; it shows areas of weakness that can be rectified before causing more sustained difficulties. As disadvantages, we can enumerate: the simplicity of the fishbone diagram may make it difficult to represent the truly interrelated nature of problems and causes in some very complex situations; smetimes, it is necessary an extremely large space on which to draw and develop the fishbone diagram, you may find that you are not able to explore the cause and effect relationships in as much detail as you would like to.

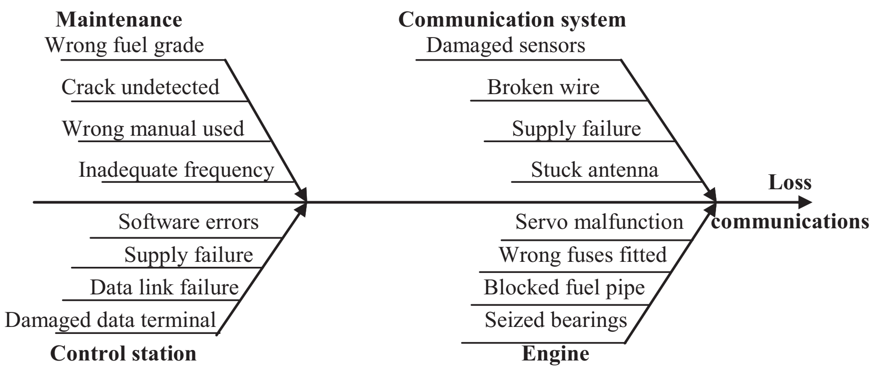

Fig. 2 A simplified fishbone diagram

2.2. FAULT-TREE ANALYSIS (FTA) IN ENGINEERING DESIGN

The fault-tree analysis diagram is an important tool when it comes to quality management that has applications in reliability engineering. This process examines the posibility of component failures in all kinds of engineering systems, with a view to improving safety and reliability.

This enables all those who are involved in the production of a product to be able to understand why these failings and faults have occurred and they can then ensure that the causes of the faults are eliminated. It can also be used within the design process, using design to eradicate faults that have occurred in a product and ensuring that future products are fault free.

One particularly good aspect of the fault tree analysis is that it seeks to get to the root of any fault problem, so it is not about papering over the cracks, but rather seeks to address why the cracks have occurred and making certain that they do not happen again.

The fault tree analysis is very good at looking at a problem from different angles. It requires a very honest approach in order to get to the root cause of problems that result in fault. So human error has to be looked at and also what caused the human error to happen. Was it the result of staff not caring, staff being pressurised in terms of time, or are there issues of staff training that need to be addressed?

The process of getting to the "root cause" for a fault is often quite lengthy, so the fault tree analysis diagram, if it is to be done properly, has to focus on a number of aspects of the production process. Failure to properly identify the root causes and the countermeasures will result in a fault tree analysis that simply fails to elicit improvements. However, when done properly and the root causes and countermeasures are all listed, this analysis can be a powerful catalyst for improvements to production [4].

2.3. FAILURE MODE AND EFFECT ANALYSIS (FMEA)

This method is an established reliability engineering activity that also supports fault tolerant design, testability, safety, logistic support, and related functions. It is particularly helpful to aviation project managers because it starts by considering possible risk events and then attemps to predict all their possible effects.

The FMEA can be performed as either a hardware or functional analysis. The hardware approach requires parts identification from engineering drawings (schematics, bill of materials) and reliability performance data, for example mean time between failure (MTBF), and is generally performed in a part-level fashion (**Table 1**). However, it can be initiated at any level (component/assembly/subsystem) and progress in either direction (up or down) [4]. The recommended method for performing an FMEA is dictated by the equipment life cycle. The early stages of the equipment life cycle represent the region where the greatest impact on equipment reliability can be made.

Item	Failure mode	Cause of failure	Effect	Recommended action
Pilot's automobile	Engine refuses to start	Poor maintenance	Pilot marooned at private hunting lodge with no other means of transport	Ensure good vehicle maintenance. Either keep back up car at hunting lodge or don't go there
New maintenance hangar	Floor over basement collapses during first aircraft engine exchange	Errors in the floor loading calculations when hangar was built	Personal injuries. Damage to engines. Damage to aircraft. Schedules disrupted.	Triple check vital structural calculations
	Floor over basement collapses during first aircraft engine exchange	Floor slabs incorrectly poured	Personal injuries. Damage to engines. Damage to aircraft. Schedules disrupted.	Ensures operatives get good training and instruction

Table no. 1 Part of a FMEA matrix for a new airport
Source: Flouris T., 2009

FMEA provides an organized, critical analysis of potential failure modes of the system being defined and identifies associated causes. It uses occurrence and detection probabilities in conjunction with a severity criteria to develop a risk priority number (RPN) for ranking corrective action considerations.

For each potential failure, a formal estimate is derived to determine potential impact and in some cases the anticipated cost of both making up financially for said failure and also possibly the estimated costs in modifying the project to minimize the risks of this failure [5].

2.4. RISK CLASSIFICATION MATRICES (RCM)

A risk classification matrix or table is a simple way of ranking different potential projects in terms of their potential benefit and the likely risks or costs in implementing them. Some projects may be very attractive in terms of the potential benefits that they offer but have serious implementation difficulties.

Risk matrices are different enough from other topics (such as multivariate classification, clustering, and learning with correct classes provided as training data) to require separate investigation of their properties, in part because "risk" is not a measured attribute, but is derived from frequency and severity inputs through a priori specified formulas such as following:

$$Risk = probability \times impact \quad (1)$$
$$(frequency \text{ x } severity)$$

The use of such risk matrices to set priorities and guide resource allocations has also been recommended in national and international standards: airport safety (**Fig. 3**).

In general, there is no unique way to interpret the comparisons in a risk matrix that does not require explanations about the risk attitude and subjective judgments used by those who constructed it. In particular, if some consequence severities are random variables with sufficiently large variances, then there may be no guarantee that risks that receive higher risk ratings in a risk matrix are actually greater than risks that receive lower ratings [6].

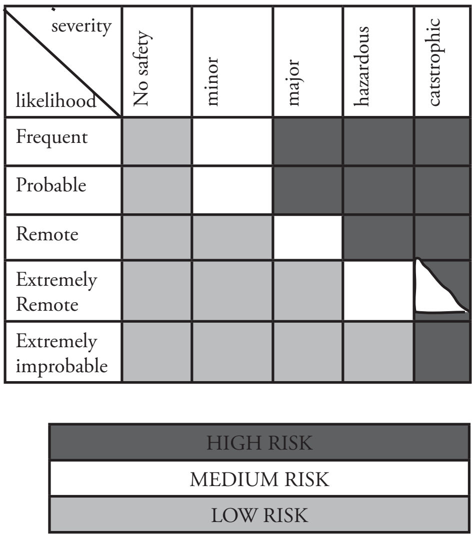

Fig. 3 Predictive Risk Matrix for Federal Aviation Administration
Source: Federal Aviation Administration, 2007

Categorizations of severity cannot be made objectively for uncertain consequences. Inputs to risk matrices and resulting outputs require subjective interpretation, and different users may obtain opposite ratings of the same quantitative risks. These limitations suggest that risk matrices should be used with caution, and only with careful explanations of embedded judgments [7].

3. THE COMPARATIVE METHODS ANALYSIS

For comparative evaluation of qualitative methods of risk analysis in project management of aircraft, we used multi-criteria analysis [8].

Establishing criteria

The criteria considered for this analysis are :

- Consistency (C)
- Aplicability (A)
- Design (D)
- Ability to use in dynamic scenario (S)
- Utility (U)

The share of each criterion

Share of criteria is established on a grid with three values. It compares each and every criterion is assigned a value of 0,5 and 1 in order of importance. Determination is completed with the calculation (table 2) of share coefficient (γ_i) using Frisco method:

$$\gamma_i = (p+m+\Delta p+0{,}5)/(-\Delta p' + N_{crt}/2) \quad (2)$$

where:

p – the sum of points obtained (on line) by the considered item;

m – surpassed the number of criteria considered by the criterion;

Δp – difference between item score and the score taken from the last level element;

-Δp' – difference between item score and the score taken from the top level element;

N_{crt} – number of the considered criteria.

	C	A	D	S	U	Points	Score	Share
C	0,5	1	1	1	0	3.5	2	2.85
A	0	0,5	1	1	0	2.5	3	1.55
D	0	0	0,5	1	0	1.5	4	0.72
S	0	0	0	0,5	0	0.5	5	0.15
U	1	1	1	1	0,5	4.5	1	5.20

Table no.2. The share of each criterion

Identifying alternatives

Among countermeasures for increasing survival of large transport aircraft when the missile self-directed terrorist attacks, we selected the following:

a) Fishbone Diagram (FD)

b) Fault-tree Analysis (FTA)

c) Failure Mode and Effect Analysis (FMEA)

d) Risk Classification Matrices (RCM)

Grant notes

According to the criteria, we gave the following notes to each variant N_i, as we show in **Table 3**.

	FD	FTA	FMEA	RCM
Criterion	N_i	N_i	N_i	N_i
C	7	8	9	7
A	9	7	9	8
D	7	7	8	9
S	6	7	8	6
U	8	8	9	8

Table no. 3. Grant notes

Determination of matrix effects

In order to calculate the matrix of consequences it is graded the product between the grades and the weighting coefficients. Finally, it is calculated the amounts of these products and the final standings are determined (table 4).

	FD	FTA	FMEA	RCM
Criterion	$N_i x \gamma_i$	$N_i x \gamma_i$	$N_i x \gamma_i$	$N_i x \gamma_i$
C	19,95	22,8	25,65	19,95
A	13,95	10,85	13,95	12,4
D	5,04	5,04	5,76	6,48
S	0,9	1,05	4	0,9
U	16,64	41,6	46,8	41,6
Total	**56,48**	**81,34**	**96,16**	**81,33**

Table no. 4. The final standings

4. RESULTS ANALYSIS

The final results demonstrate that FMEA method, as a complete set for identifying and managing failure modes to all assembly levels, provides a balanced approach into aviation risk management projecys.

Top-down methods (such as FTA) are efficient in that they focus on particular areas of safety and certification concern, but do not provide general validation support.

To analyze as possible in a comprehensive manner the various situations of danger and undesirable events, and the causes and their consequences, is required a complete risk appraisal and analysis: qualitative and quantitative.

This approach can create a clear and common reality to promote effective solutions in aviation projects every time.

REFERENCES

[1] Flouris, G.T., Lock (2009) D., *Managing Aviation Projects from Concept to Completion,* Ashgate Publishing Company, Farnham, pp. 304-306.

[2] http://project-management-knowledge.com/ definitions/q/ qualitative-risk-analysis/ accesed on January 22nd, 2011.

[3] Boscoianu, M., Axente, C., Parhonie, R., Some aspects regarding the cooperative control problem for flying wing air vehicles. In: Mathematical Methods and Computational Techniques in Electrical Engineering – MMACTEE'08, Sofia, 2008.

[4] Rother, M., Shook, J. (2003) *Value-Stream Mapping to Create Value and Eliminate,* Lean Enterprises Inst Inc.

[5] http://www.sematech.org/ docubase/ document/0963beng.pdf accesed on December 28th, 2010.

[6] http://project-management-knowledge. com/ definitions/f/failure-mode-and-effect-analysis/ accesed on January 27th, 2011.

[7] Cox, L.A.(2008) *What's Wrong with Risk Matrices,* in Risk Analysis, vol. 28, no. 2,.

[8] Cox, L.A., What's Wrong with Risk Matrices? In: *Risk Analysis,* Vol. 28, No. 2, 2008.

[9] Bobancu, S.,Cozma, R. (1997) *Tehnici de inovare: inventica pentru utilizari practice,* Transilvania University Publishing House.