Comparative Risk Assessment in Applicative Aerospace Projects using different approaches

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Abstract: *Certification of the quality management system for aviation, space and defense organizations, according to EN 9100: 2016 / AS 9100D standard requires compliance with the operational risk management requirement. This article proposes the risk assessment for an applicative aerospace project, using three different approaches. The first method for the risk assessment is described in SR EN 16601-80: 2015 standard - Space Project Management. Part 80: Risk management. The second method for performing the risk analyzes proposes the use of the FMEA (Failure Mode and Effect Analysis) technique described in SR EN 31010: 2010 standard - Risk Management. Risk assessment techniques. The third approach presented is based on the risk assessment and quantification using Risk Management Guidance Material from IAQG - International Aerospace Quality Group, section 7.3.2.*

***Key Words:** risk, EN 9100: 2016/ AS 9100D, EN 16601-80: 2015, SR EN 31010: 2010, SR EN 60812:2006, FMEA, FMECA, IAQG*

1.INTRODUCTION

Certification of the quality management system for aerospace, space and defense organizations according to EN 9100: 2016/ AS 9100D requires compliance with the operational risk management requirement in the projects.

The development of applicative aerospace projects takes place within a regulated quality management system, aiming not only at satisfying the explicit customer requirements described in the contractual and regulatory clauses, but also in the implicit ones by identifying, evaluating, treating and monitoring the risks related to each project.

This article proposes the comparative assessment of risks within an applicative aerospace project using the following approaches:

A. the method described in SR EN 16601-80: 2015 standard;
B. FMEA technique, as described in SR EN 31010: 2010 standard and SR EN 60812:2006;

C. the approach regarding the risk assessment and quantification using Risk Management Guidance Material from IAQG materials, section 7.3.2.

Within the risk management process, available risk information is produced and structured, facilitating the risk communication and management decision-making. The results of the risk assessment and reduction and the residual risks are communicated for information and follow up, as illustrated in figure 1. [4]

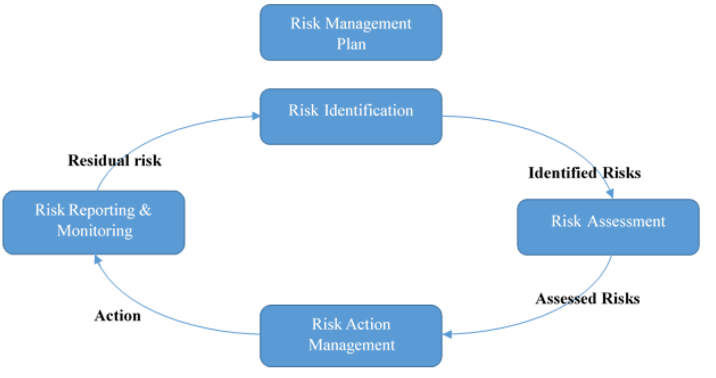

Fig. 1 - Risk management process [4]

2. PRESENTATION OF RISK ASSESSMENT APPROACHES

A. The method described by the standard SR EN 16601-80: 2015 – Space Project management. Part 80: Risk Management

To assess the risks, the scoring schemes are established for the severity of the consequences and the likelihood of occurrence for the relevant tradable resources as shown in the examples given in table 1 and table 2.

Table 1- Example of a severity-of-consequence scoring scheme [1]

Score	**Severity**	**Severity of consequence: impact on (for example) cost**
5	Catastrophic	Leads to termination of the project
4	Critical	Project cost increase > x %
3	Major	Project cost increase > y %
2	Significant	Project cost increase < z %
1	Negligible	Minimal or no impact

Table 2 - Example of a likelihood scoring scheme [1]

Score	**Likelihood**	**Likelihood of occurrence**
E	Maximum	Certain to occur, will occur one or more times per project
D	High	Will occur **frequently**, about 1 in 10 projects
C	Medium	Will occur **sometimes**, about 1 in 100 projects
B	Low	Will occur **seldom**, about 1 in 1000 projects
A	Minimum	Will **almost never** occur, 1 in 10000 or more projects

The next step is to establish the risk index scheme to denote the magnitudes of the risks of the various risk scenarios as shown, for example in table 3. The establishment of scoring and risk index schemas is performed with the full coordination between the different project disciplines to ensure complete and consistent interpretation.

Table 3 – Example of risk index and magnitude scheme [1]

Likelihood | **Risk index: Combination of Severity and Likelihood**

E	Low	Medium	High	Very High	Very High
D	Low	Low	Medium	High	Very High
C	Very Low	Low	Low	Medium	High
B	Very Low	Very Low	Low	Low	Medium
A	Very Low	Very Low	Very Low	Very Low	Low

Severity

Table 4 presents an example of establishing the criteria for actions to be taken on risks of various magnitudes and the associated risk decision levels in the project structure.

Table 4. Example of risk magnitude designations and proposed actions for individual risks [1]

Risk index	**Risk magnitude**	**Proposed actions**
E4, E5, D5	Very High risk	Unacceptable risk: implement new team process or change baseline – seek project management attention at appropriate high management level as defined in the risk management plan.
E3, D4, C5	High risk	Unacceptable risk: see above.
E2, D3, C4, B5	Medium risk	Unacceptable risk> aggressively manage, consider alternative team process or baseline – seek attention at appropriate management level as defined in the risk management plan.
E1, D1, D2, C2, C3, B3, B4, A5	Low risk	Acceptable risk: control, monitor – seek responsible work package management attention.
C1, B1, A1, B2, A2, A3, A4	Very Low risk	Acceptable risk: see above.

Complete a risk register, taking into account:

- Severity (S) - Severity is a numerical subjective estimate of how severe the customer (next user) or end user will perceive the effect of a failure.

- Likelihood (L), **- Occurrence (O)** is a numerical subjective estimate of the likelihood that the cause of a failure mode will occur during the design life, or during production in the case of a Process FMEA.

In order to assess the risks the following steps are taken:

- determine the severity of consequences for each risk scenario;
- determine the likelihood of each risk scenario;
- determine the risk index for each risk scenario;
- use the available information sources and application of suitable methods to support the assessment process;
- determine the magnitude of risk of each risk scenario;
- determine the overall project risk through an evaluation of identified individual risks, their magnitudes and interactions, and resultant impact on the project [1].

The risk register of the purchasing process within a simulators project is presented in table 5.

Table 5. Risk register example [1]

<table>
<tr><td colspan="15">RISK REGISTER</td></tr>
<tr><td colspan="4">Project: Simulators</td><td colspan="4">Organization: INCAS</td><td colspan="4">Source:
Controlled by:
Supported by:</td><td colspan="3">Date:
Issue:</td></tr>
<tr><td colspan="15">RISK SCENARIO and MAGNITUDE</td></tr>
<tr><td colspan="2">No.</td><td colspan="13">Risk scenario title: Not understanding customer needs.Customer implications if I deliver late? Is this a new market leader? (PURCHASING)</td></tr>
<tr><td colspan="15">Cause and consequence:</td></tr>
<tr><td colspan="5">Severity (S)</td><td colspan="5">Likelihood (L)</td><td>Risk index</td><td>RED</td><td>YELLOW</td><td>GREEN</td><td>Risk domain</td></tr>
<tr><td>Negligible 1</td><td>Significant 2</td><td>Major 3</td><td>Critical 4</td><td>Catastrophic 5</td><td>Minimum A</td><td>Low B</td><td>Medium C</td><td>High D</td><td>Maximum E</td><td></td><td></td><td></td><td></td><td>Plan</td></tr>
<tr><td></td><td></td><td></td><td>X</td><td></td><td></td><td></td><td>X</td><td></td><td></td><td></td><td></td><td>X</td><td></td><td></td></tr>
<tr><td colspan="15">RISK DECISION and ACTION</td></tr>
<tr><td colspan="7">Accept risk ■</td><td colspan="8">Reduce risk □</td></tr>
<tr><td colspan="3">Risk reduction measures:
Responsible selection of the equipment supplier</td><td colspan="3">Verification means:</td><td colspan="9">Expected risk reduction (severity, likelihood, risk index):</td></tr>
<tr><td colspan="6">Action:</td><td colspan="9">Status:</td></tr>
<tr><td colspan="12">Agreed by project management:

Name: Signature:
Date:</td><td colspan="3">Risk rank:</td></tr>
</table>

In order to have an overview of the project risks, table 6, the ranked risk log, should be filled in.

Table 6. Ranked risk log [1]

<table>
<tr><td colspan="3">Project: Simulators</td><td colspan="5">Organization: INCAS</td><td>Date:
Issue:</td></tr>
<tr><td>Rank</td><td>No.</td><td>Risk scenario title</td><td>Red</td><td>Yellow</td><td>Green</td><td>Risk domain</td><td colspan="2">Actions and status</td></tr>
</table>

Soft	1	Not understanding customer needs. Customer implications if I deliver late? Is this a new market leader?		X		Plan	Responsible selection of equipment supplier
Hard	2	Dependence on technology breakthrough. Does my current technology permit me to be competitive? Can R&D provide improvements to my current process to meet cost objectives?			X	Cost	Request additional budget to maintain the equipment performance

B. Method FMEA (Failure Mode and Effect Analysis), described in the standard SR EN 31010:2010 - Risk management. Risk assessment techniques

Failure Mode and Effect Analysis (FMEA) is a technique used to identify the ways in which components, systems, or processes can fail in the initial fulfillment.

The FMEA steps for the project are described in figure 2.

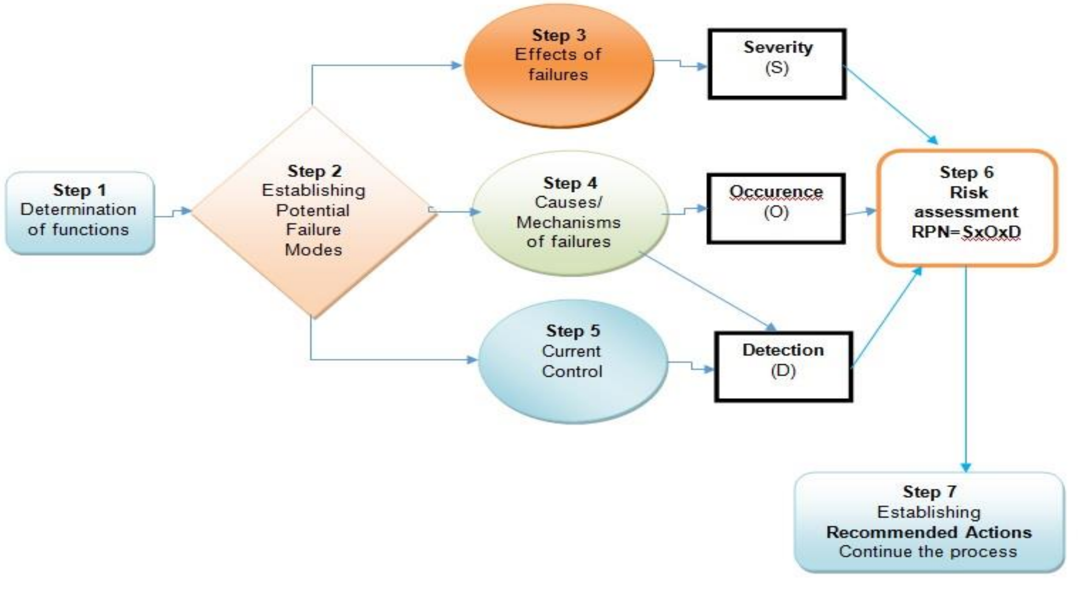

Fig. 2 - FMEA steps for the project [5]

FMEA methodology can be applied from the early selection phase of its design concept, to be upgraded and refined progressively as design evolves.

It is useful for identifying all possible causes of failure, including the underlying causes and for determining the relationships between them.

The reasons for undertaking Failure Mode Effects Analysis (FMEA) or Failure Mode Effects and Criticality Analysis (FMECA) may include the following:

- to identify those failures which have unwanted effects on system operation, e.g. preclude or significantly degrade operation or affect the safety of the user;

- to satisfy contractual requirements of a customer, as applicable;
- to allow improvements of the system's reliability or safety (e.g. by design modifications or quality assurance actions);
- to allow improvement of the system's maintainability (by highlighting areas of risk or nonconformity for maintainability). [3]

FMEA identifies:

- all potential failure modes in different parts of a system (a failure mode indicates a malfunctioning or a defective component);
- the effects that failures can have on the system;
- failure mechanisms;
- how to avoid malfunctions and / or limit the effects of system failures.

By definition, the failure or the system breakdown is the termination of a system's ability to perform its specific function.

Also, the difference between the concept of fault and failure, the fault being generally a local effect and the failure a higher order event with a high degree of generality. Figure 3 illustrates the types of failures.

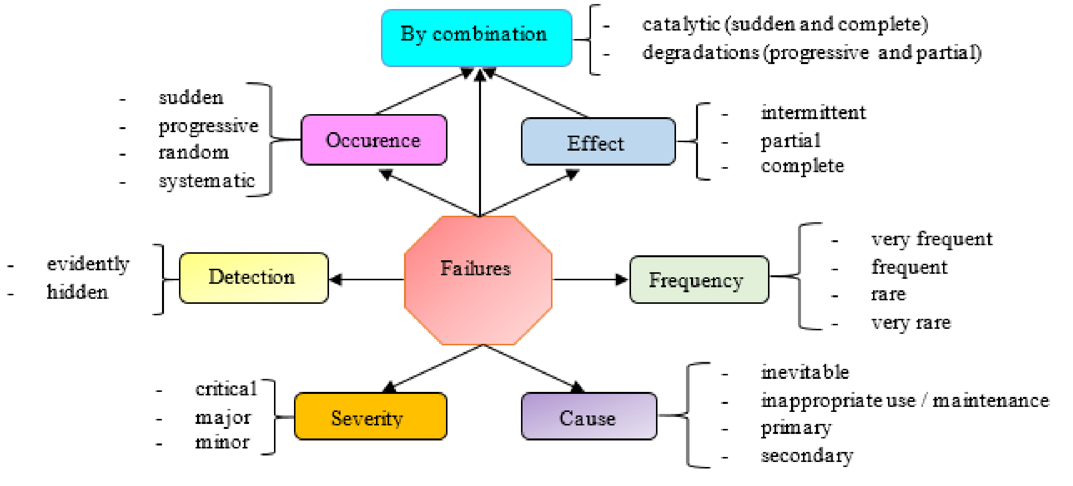

Fig. 3 - Types of failures [5]

FMECA (Failure Mode, Effects and Criticality Analysis*)* indicates that failure mode analysis includes criticality analysis.

Determining the criticality involves the addition of qualitative measures of the extent of the failure mode.

One of the methods of quantifying criticality is the Risk Priority Number. [3]

Most common way, Risk Priority Number is calculated by multiplication of 3 indexes: Severity, Occurrence, and Detection of the failures:

- Severity (S) is ranking of the severity level of the failure mode on a 1 to 5 scale. A higher severity ranking indicates higher severe risk;
- Occurrence (O) is ranking of occurrence potential of the failure mode cause on a 1 to 5 scale. A higher Occurrence rank reflects higher occurrence potential;
- Detection (D) is ranking of detection potential of the failure mode cause on a 1 to 5 scale.

  A higher Detection rank reflects worse detection potential.

So RPN's formula looks like below:

Risk Priority Number (RPN) = Severity (S) X Occurrence (O) X Detection (D)

Due to the multiplication of the three factors, the evaluation errors of the parameters will have a disproportionate effect on the RPN (one unit change of one of the factors will lead to the increase/ decrease of the RPN with the same value as the product of the other factors) [5].

Conclusions regarding method B:

- FMEA considers only the three factors S, O, D, and does not take into account other factors of influence;
- the process of evaluating the parameters is difficult and inaccurate;
- the relative importance of the three factors is neglected and is based on the assumption that they contribute equally to determine the priority of the fault modes;
- the same value of RPN is obtained by different combinations of factors S, O, D, which leads to different implications on the risks;
- the mathematical model for defining the priority of defects is sensitive to the variation of the factors evaluation. [5]

During the assessment of the value of the risk indices, the following observations were made:

- the assessment scales recommended by the standards used in the aerospace industry cannot be applied to any process, it is necessary to define a customized staircase, depending on the specificity of the project;
- in the absence of concrete data on the probability of failure occurrence and the probability of detecting the cause / defect mechanisms, the evaluation of the occurrence and the detection have a highly subjective character;
- the way the severity is expressed does not allow a precise assessment and in many cases the severity is overvalued to ensure that important failure modes are not neglected;
- due to the relative equal importance of S, O, D parameters, the failure modes with the same RPN can have completely different meaning.

In order to have an uniform evaluation scale for the risk assessment, we proposed the following risk matrix, illustrated in figure 4, with the legend:

Green – acceptable;

Yellow – monitoring;

Red – need corrective action.

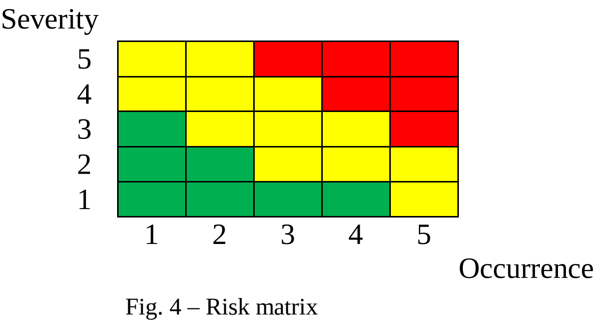

Fig. 4 – Risk matrix

Table 7 contains the risk register and the risk mitigation plan according to FMEA technique.

Table 7 - Failure mode and effects analysis (FMEA)

Risk register													Risk mitigation plan			
Risk ref:	**Stage**	**Detection date**	**Risk category**	**Risk description**	**Impact**	**Subassembly / affected stage**	**Severity**	**Likelihood**	**Detection**	**RPN**	**Status risk**	**Risk prevention**	**Risk mitigation action**	**Due date**	**Owner**	**Status**
1	Advanced simulators for vehicle integration issues in unsegre-gated airspace SOFT	17.03.2016	Plan	Not understanding customer needs.Customer implications if I deliver late? Is this a new market leader?	The delay of some stages or the project	soft	4	4	1	16	Open	Timely compliance by suppliers (friendly customs procedures)	Responsible selection of equipment supplier	27.04.2016	INCAS	Closed
2	Advanced simulators for vehicle integration issues in unsegre-gated airspace-HARDWARE	23.03.2016	Cost	Dependence on technology breakthrough.Does my current technology permit me to be competitive? Can R&D provide improvements to my current process to meet cost objectives?	Affect-ing the equip-ment perfor-mance	hardware	3	1	1	3	Open	Compliance with the financing contract (amounts, deadlines)	Request additional budget to maintain the equipment performance	27.10.2016	INCAS	Closed

C. The approach presented in the IAQG materials, section 7.3.2

The third method developed is based on the types of risks on activities from developing a project, using the IAQG International Aerospace Quality Group materials, section 7.3.2.

Within a project, each process contributes to the project's risk level, as illustrated in figure 5.

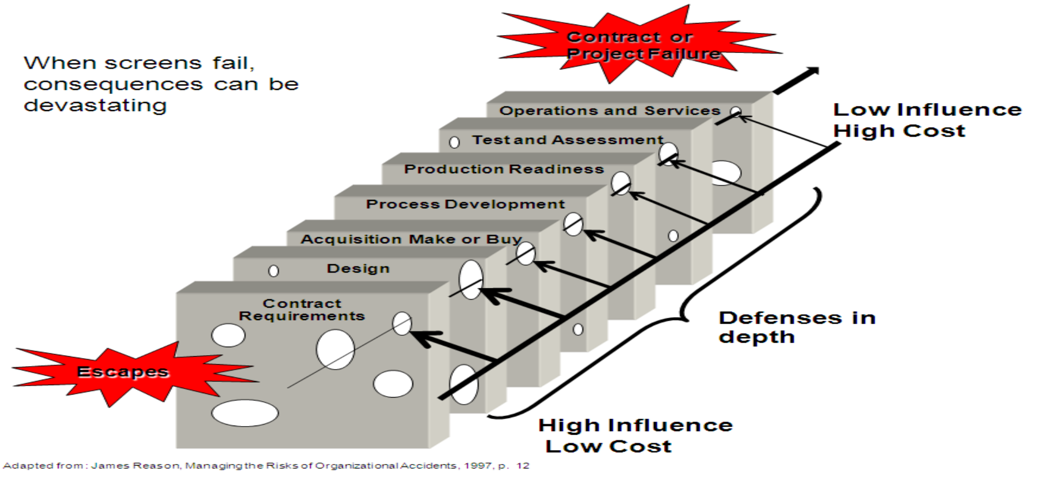

Fig. 5 – Risks and their affects on a project [4]

In figures 6-12 are summarized the processes that influence the level of risk of a project.

The figures below illustrate the own contribution of potential risks that may occur for each process during a project.

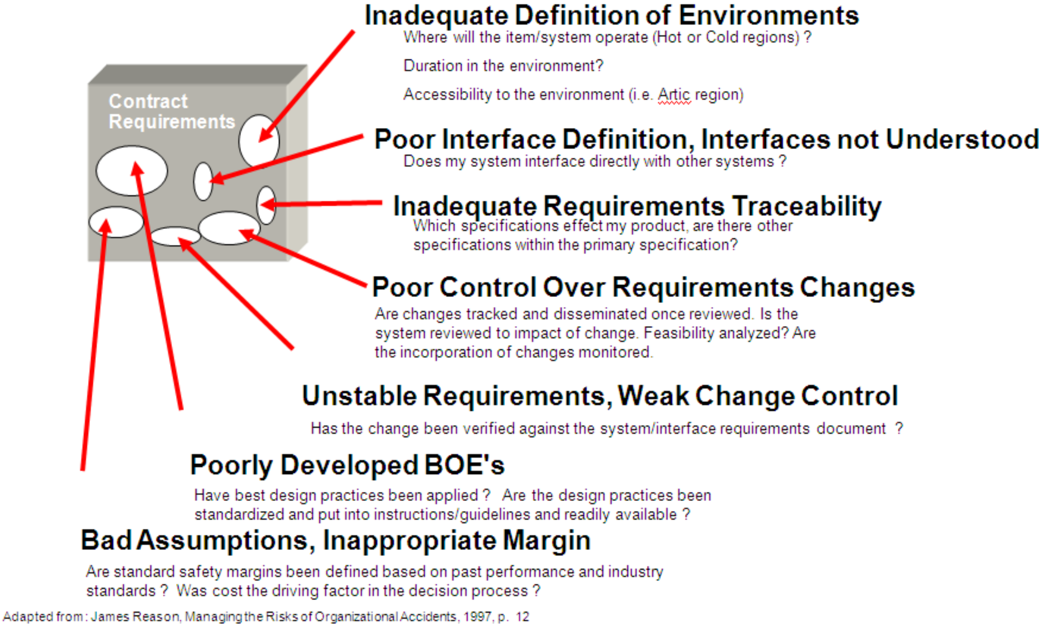

Fig. 6 - Contract requirements risks [4]

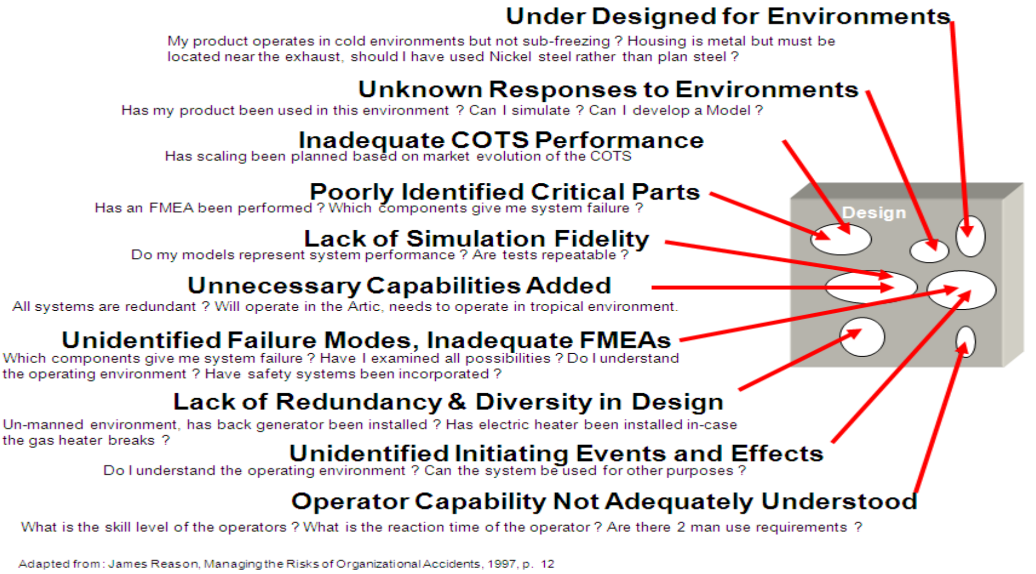

Fig. 7 – Design risks [4]

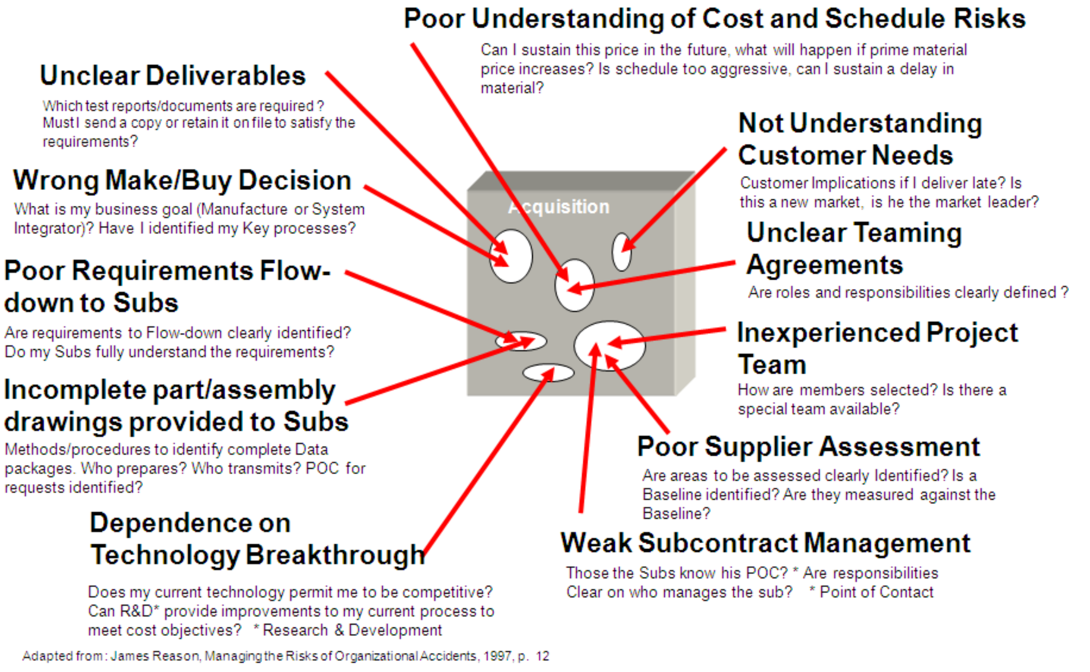

Fig. 8 - Acquisition Risks [4]

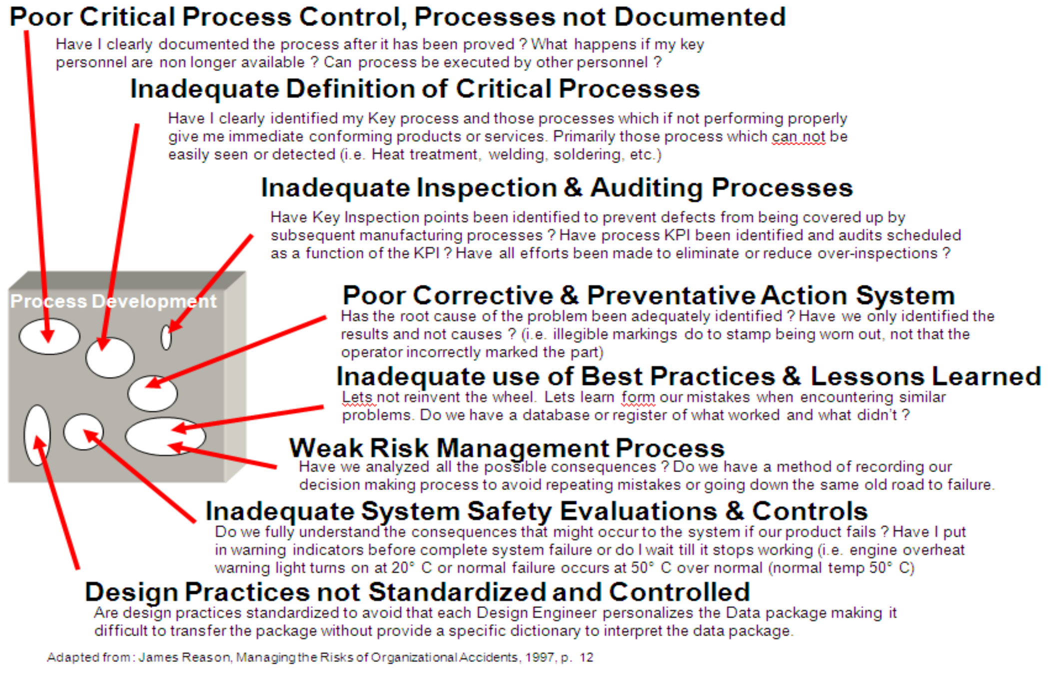

Fig. 9 - Process Risks [4]

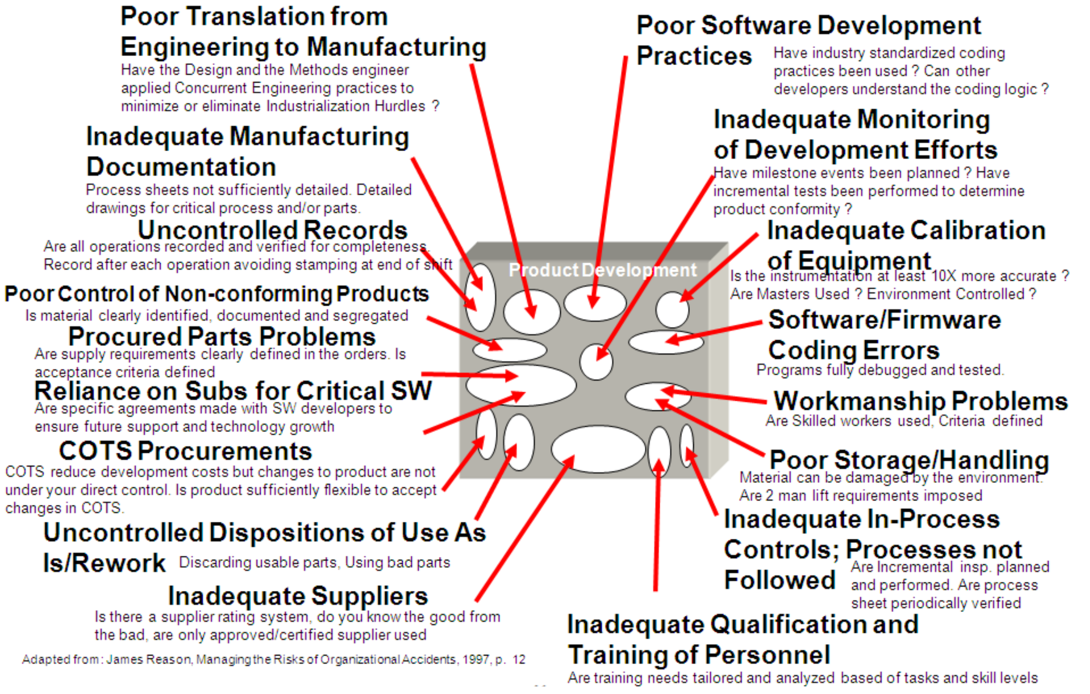

Fig. 10 – Product Development Risks [4]

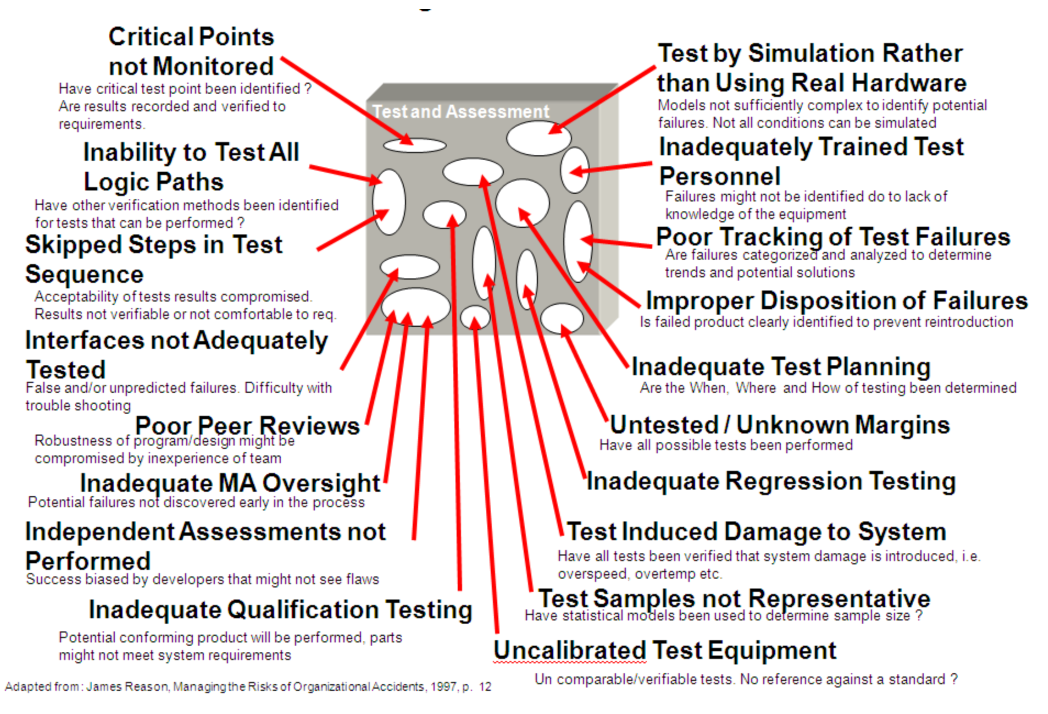

Fig. 11 - Test and assessment risks [4]

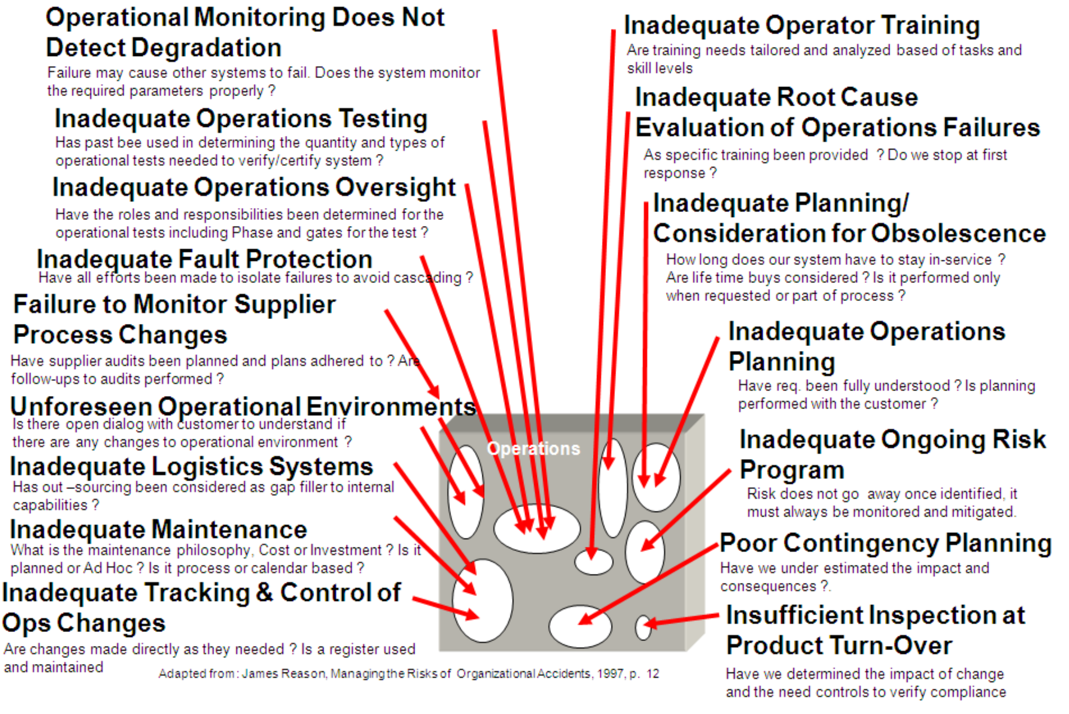

Fig. 12 – Operations risks [4]

In the simulators project, a spreadsheet mentions the risks in the procurement process. An optimal risk value is defined in the procurement process (based on the previous experience of performing the risk analysis by one of the two above mentioned methods).

Table 8 – Risk evaluation

Risk	Evaluation	Optimal value
Unclear deliverables. Which test reports /documents are required? Must I send copy or retain it on file to satisfy the requirements? Which test reports /documents are required? Must I send copy or retain it on file to satisfy the requirements?	5	6
Wrong make/buy decision. What is my business goal (manufacture or system integrator)? Have I identified my key processes?	6	6
Poor requirements flow-down to subs. Are requirement to flow-down clearly identified? Do my subs fully understand the requirements?	7	6
Incomplete part/assembly drawings provided to subs. Methods/ procedures to identify complete data packages. Who prepares? Who transmits? Point of contact for requests identified?	8	6
Dependence on technology breakthrough. Does my current technology permit me to be competitive? Can R&D provide improvements to my current process to meet cost objectives?	4	6
Poor understanding of cost and schedule risks. Can I sustain this price in the future what will happen if prime material price increases? Is schedule too aggressive can I sustain a delay in material?	6	6
Not understanding customer needs.Customer implications if I deliver late? Is this a new market leader?	6	6
Unclear teaming agreements. Are roles and responsibilities clearly defined?	7	6

Inexperienced project team.How are members selected? Is there a special team available?	7	6
Poor supplier assessment. Are areas to be assessed clearly identified? Is a baseline identified? Are they measured against the baseline?	7	6
Weak subcontract management. Those the subs know his point of contact. Are responsibilities clear on who manages the sub?	7	6

The risk assessment is completed as follows:

- if the note is higher than the optimal value, it will be colored in red and corrective action will be establish;
- if the note is equal to the optimal value, it will be colored in yellow and the risk will be monitored;
- if the note is less than the optimum value, it will be colored in green and it will be considered as acceptable risk.

3. CONCLUSIONS

Risks are a threat to project success because they have negative effects on the project cost, schedule and technical performance, but appropriate practices of controlling risks can also present new opportunities with positive impact [1].

The advantages of the FMEA are the following:

- identification of design deficiencies and avoidance of additional costs;
- identification of secondary failures;
- integration of FMEA with other quality management tools and instruments (analysis based on fault tree-FTA);
- fixing product liability, security, or non-compliance issues with regulatory requirements;
- ensuring that the testing program in the development process can detect potential failure modes;
- establishing a proper preventive maintenance program;
- supporting the design of fault isolation sequences and establishing plans for alternative modes of operation and reconfiguration.

The FMEA limitations are:

- FMEA is effective when applied to analyzing elements that cause a total failure of the entire system or a major system function;
- the inability to provide a measure of the overall system reliability, the inability to provide improvement measures and choice of design [3].

The process benefits of risk management are:

- increase the likelihood of achieving objectives;
- be aware of the need to identify and treat risk throughout the organization;
- improve the identification of threats;
- establish a reliable basis for decision making and planning;
- effectively allocate and use resources for risk treatment / handling;
- improve operational effectiveness and efficiency;
- cost of risk management is typically less than the cost of issue management [4].

The authors' contributions are:

- the presentation of the potential risks related to the processes within a project, using Risk Management Guidance Material from IAQG;
- the exemplification of the assessment and quantification of purchasing process risks for an applicative project.

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