Juraj GRENČÍK, Peter VOLNA

RISKS AND SAFETY IN THE OPERATION OF RAILWAY VEHICLES

Abstract

The need for continuous improvement of product quality, reliability and safety arises from product specifications, government regulatory requirements, agency recommendations, legal implications and above all a company's desire to improve its market position and customer satisfaction. These issues require product manufacturers to perform risk analyses that identify and minimize part/system failures throughout the product's life cycle. The FMEA methodology is one of the risk analysis techniques recommended by international standards. It is a systematic process to identify potential failures to fulfil the intended function, to identify possible failure causes so the causes can be eliminated, and to locate the failure consequences so the consequences can be reduced. As an example, FMECA of railway freight tank wagon has been done on which the most critical parts and are addressed, consequently measures to reduce the risk of failure mode in operation are proposed.

INTRODUCTION

It is well known fact that European railways are the safest mode of land transport. The safety level has improved at impressive pace over the past decade and the railway industry can be proud of its achievements, mostly achieved through technical advances. However, although extremely rare, catastrophic, multi-fatality have a heavy impact on the confidence of passengers, customers, public funders and investors. As well as the human cost, every accident, whether they result in injuries or not, represents a significant business cost in a highly competitive environment. Catastrophic accidents have the potential to close otherwise viable businesses and reduce services altogether.

EU member states have until now developed their safety rules and standards mainly on national lines, based on national technical and operational concepts. Simultaneously, differences in principles, approach and culture have made it difficult to break through the technical barriers and establish international transport operations.

Directive 91/440/EEC, Directive 95/18/EC on the licensing of railway undertakings and Directive 2001/14/EC on the allocation of railway infrastructure capacity and the levying of charges for the use of railway infrastructure and safety certification provide the first steps towards regulation of the European rail transport market by opening the market for international rail freight services. However, the provisions on safety have proved to be insufficient and differences between safety requirements remain, which affect the optimum functioning of rail transport in the Community. It is of particular importance to harmonise the content of safety rules, safety certification of railway undertakings, the tasks and roles of the safety authorities and the investigation of accidents.

Important role in railway operation safety was recognised in the area of maintenance. Therefore ERA (European Railway Agency) is responsible for certification of ECM (Entities in Charge of Maintenance) with the aim of enhancing maintenance system, in the first stage, of freight wagons, focused on risk reduction by properly managed and executed maintenance works. Each freight wagon has to have its ECM registered who is responsible for its maintenance.

1. METHODS FOR SAFETY EVALUATION ON EUROPE RAILWAYS

Differences in the assessment and acceptance of changes in the railway system have been an obstacle to cross border operations and approval of railway products in different Member States. A risk based approach with a harmonisation of assessment methodologies will contribute to improving mutual recognition.

This CSM gives a harmonised framework for the risk assessment process through the prescription of Hazard Identification, Risk Analysis and Risk Evaluation. The regulation gives a broad framework for the use of risk assessment methodologies to assess changes to the railway system. It allows the proposer, without prescribing any order of priority, to use interchangeably among three risk acceptance principles already in place such as acknowledged codes of practice and reference systems, or explicit risk estimation for the acceptance of the risks related to the change.

The CSMs describe how the safety levels, the achievement of safety targets and compliance with other safety requirements are assessed, including, where appropriate, through an independent assessment body, by elaborating and defining:

a) the risk evaluation and assessment methods;
b) the methods for assessing conformity with requirements in safety certificates and safety authorisations issued;
c) the methods for supervision to be applied by national safety authorities and the methods for monitoring to be applied by railway undertakings, infrastructure managers and entities in charge of maintenance;
d) the methods for assessing the safety level and the safety performance of railway operators at national and Union level;
e) the methods for assessing the achievement of safety targets at national and Union level; and
f) any other methods covering a process of the safety management system which need to be harmonised at Union level.

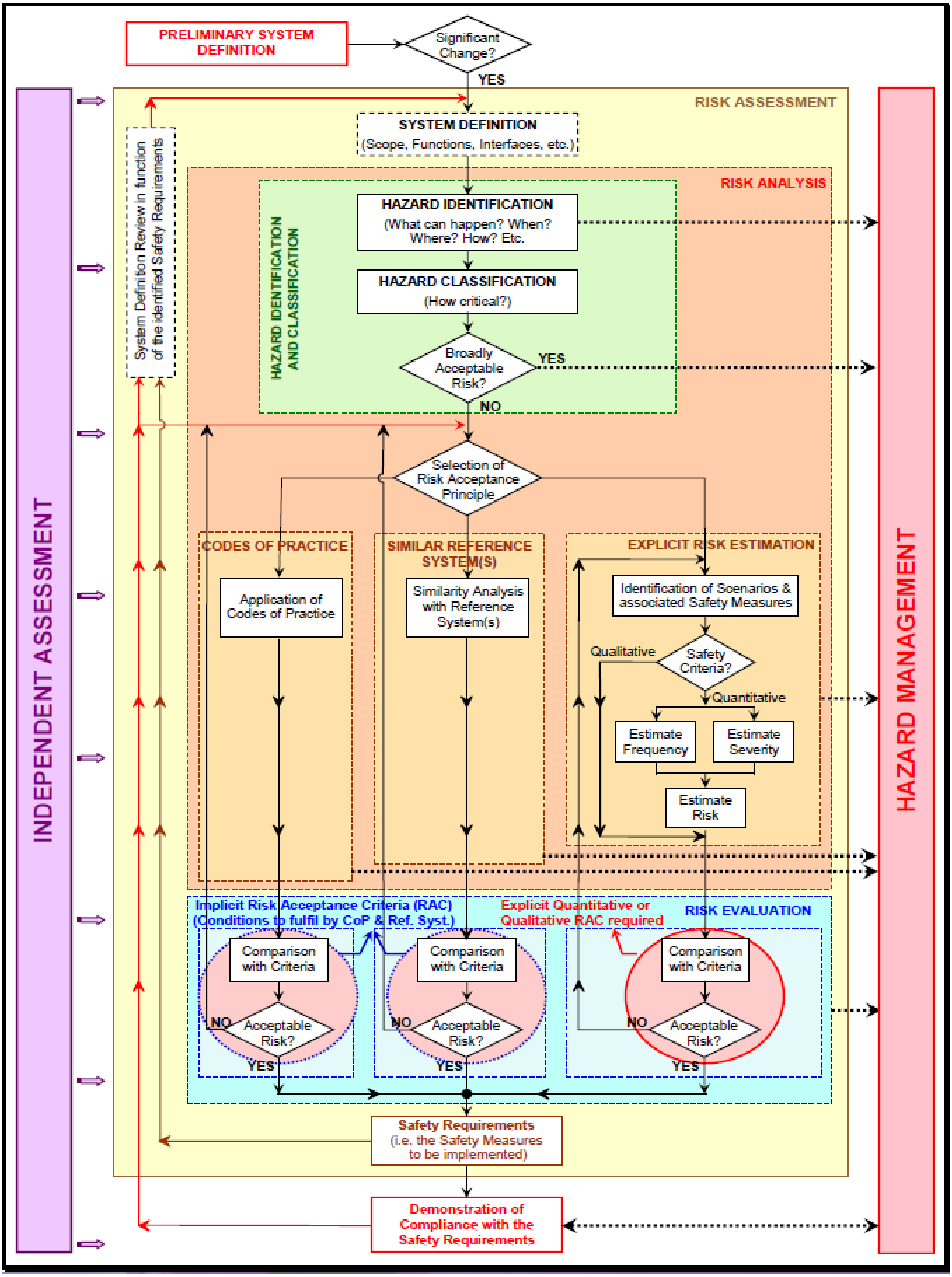

Fig. 1 *Risk management framework in the CSM Regulation [1]*

2. RISK ASSESSMENT

For the technical condition diagnosing of machinery, different diagnostic methods are being used. These methods can give different results. We cannot use certain methods for different machines and different operating conditions because the results can often be distorted or misleading.

Risk analysis contributes to improved security. The risk analysis process depends on the experience, knowledge, imagination, creativity and skills of the team (individuals) engaged in this analysis. Only application of these procedures cannot ensure a proper and thorough risk analysis results without teamwork of competent staff.

An equally important step is to choose an appropriate risk assessment methods. Risk assessment assesses the seriousness of the estimated magnitude of the risk and the need for its reduction based on the risk analysis.

There are various methods for risk assessment. These methods are used in various steps of risk management processes, or they can also be combined. Risk assessment methods can be divided:

- according to the valuation method:
  - qualitative,
  - quantitative,
  - semi quantitative.
- according to sources of information:
  - deductive,
  - inductive.

Example of commonly used methods:

- WHAT IF
- HAZOP(Hazard and operability)
- FMEA(Failure Mode and Effects Analysis)
- ETA/FTA (Event Tree Analysis)/(Fault Tree Analysis)
- HRA(Human Reliability Assessment)
- PHA(Preliminary Hazard Analysis)
- MOSAR (Method Organized for Analysis of Risk)

3. APPLICATION EXAMPLE OF RISK ASSESSMENT METHODS

Tank wagons are significant part of all freight wagons. Therefore we have chosen railway freight tank wagon type Zacns with 88m^3 capacity and L4BH container type.

Fig. 2 *Railway freight tank wagon (type Zacns 88 m^3)*

Selected four-axle tank wagon Zacns is designed for transport of liquid petroleum products. The service time of the vehicle is calculated for 35 years. Vehicle design and manufacturing technology are selected such that the functional and operational characteristics of the vehicle are maintained at all times between two technical inspections.

4. CREATING FMEA STRUCTURE

APIS PRO 6.5 programme was used to develop FMEA analysis of railway freight tank wagon with analysis of the criticality of nodes, including functional and fault networks. The first step is the creation of a system structure. Functions and failures are necessary to be provided for individual elements of the structure. A failure mode is defined as an effect by which the failure of the element is observed. It is important to create a list of all possible or potential failure modes of system, which is the basis of FMEA method – figure 3. Then failure networks, or failure interrelations, can be created, that is description of the mutual cause - effect relations in sense of failures – figure 3.

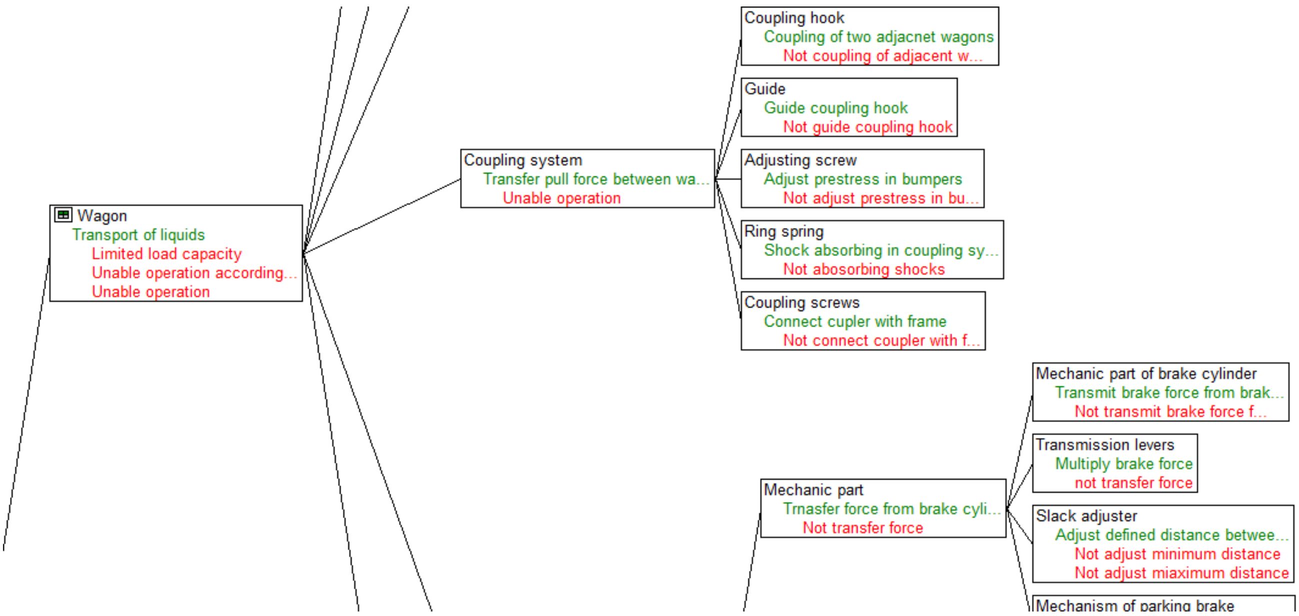

Fig. 3 *View of part of the railway freight tank wagon (type Zacns 88 m3) structure*

5. RISK EVALUATION

Creation of FMEA forms is the main task in the third step. Its result is knowledge of the risk of failure creation. To risk assessment of the system at the design and planning step available measures to limit failures occurrence and to improve their detection are assigned.

The measure of this evaluation is an indicator – RPN – Risk priority number, which consists of three factors, where the level of risk is expressed by their mathematical product.

$$RPN = S \times O \times D \qquad (1)$$

Where:

S – severity – the importance of the seriousness of the occurrence of failure causes, (value is the number between 1 and 10, where 10 is the most important).

O – occurrence – the probability of occurrence failure causes, (10 means, that causes of failure surely happen)

D – detection – the probability of detection causes of failures (it is result, where 10 means, that cause of failure we cannot detect).

Example of risk's form assessment (RPN) is shown in figure 4.

Effects	S	C	Failure Mode	Causes	Preventive Action	O	Detection Action	D	RPN	R/D
System Element: Wagon										
Function: Transport of liquids										
Limited load capacity	5		Limited load capacity	Partly trnasfers longitudinal and transversal forces	Initial State: 29.10.2015					
					none	10	Visual check of local damage and measurement of dimensions every 6 years	2	100	
				Wear of side bearers	Initial State: 29.10.2015					
					none	10	Visual inspection of bearer plates every 6 years	2	100	
Unable operation according to railway regulations	9		Unable operation according to railway regulations	Unable to transport material	Initial State: 29.10.2015					
					none	10	Visual inpection of superstructure before each run	4	360	
				Unable operation according to railway regulations	Initial State: 29.10.2015					
					none	10	Visual check before each run	3	270	

Fig. 4 FMEA form of risk assessment

6. RISK VALUES (RPN) OF CURRENT MAINTENANCE SYSTEM

After making FMECA analysis of railway freight tank wagon and the subsequent compilation of FMEA forms and associated values for each degree of risk factors we need to determine the permissible risk values (RPN), that we are willing to accept and which show that the selected detection measures are sufficient. Acceptable risk value (RPN) will not have any impact on the function of the railway freight tank wagon or on the human safety. Therefore there is no need to perform any preventative measures.

The maximum permissible value of the RPN has been determined to 300. All values located below this value (RPN<300) are acceptable. However, the values situated above (RPN≥300) are not eligible.

We have found 12 values in the range 350-700 RPN. It is necessary to reduce these 12 values to acceptable value.

After making statistical evaluation of RPN values, Pareto analysis form (Fig. 5) is created where RPN values are sorted in descending order from largest to smallest. Failure modes and detection measures are also indicated in the graph, too.

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Pareto Analysis — 30.9.2016

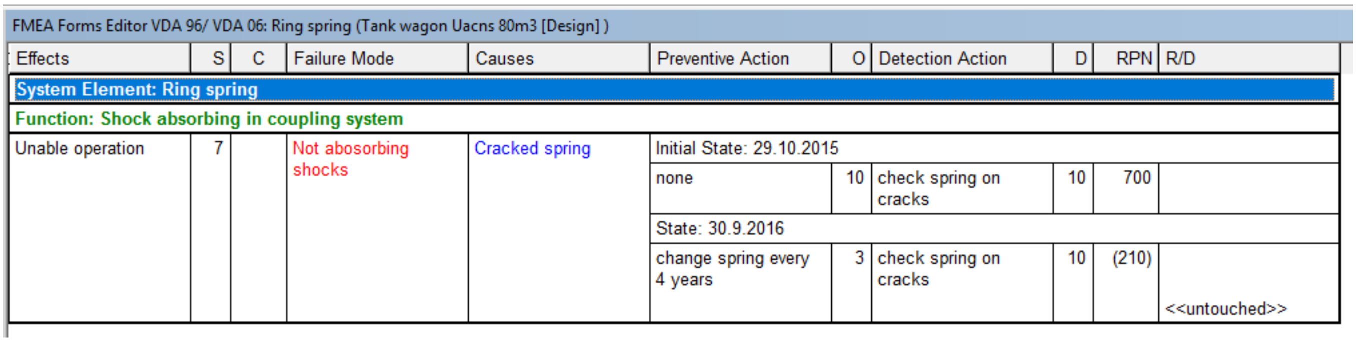
6 Forms: Bumping system; Coupling system; Ring spring; Ring spring; Superstructure; Wagon

No.	FMEA Form	System Element	%	RPN	S	O	D	Function	Failure	Effects	C	Causes	Preventive Action	Detection Action
1	Coupling system	Coupling system	9,93	700	7	10	10	Transfer pull force between wagons	Not transfer forces between wagons	Unable operation		Not abosorbing shocks	none	Check integrity of ring spring
2	Bumping system	Bumping system	6,38	450	9	10	5	Transfer lush forces	Not tranfer forces	Unable operation according to railway regulations		Not guide coupling hook	none	Check the guide during maintenance work

Fig. 5 Pareto analysis form

7. PROPOSAL DETECTION AND PREVENTIVE MEASURES

In the next step, creation of preventive measures for the risk values that exceed acceptable levels RPN will be done. It is important to take such measures so that the RPN value of the falls below a specified maximum accptable value. All measures for the selected tank wagon are designed on the basis of the maintenance plan for tank wagons. Individual preventive measures are based on a medium revision maintenance which is carried out every 4 years. After imposing additional preventive measures to the FMEA forms for vidual RPN values of risks not meeting the specified values, the new reduced RPN values can be plotted in a chart with individual values before and after implementation of these preventive measures. The graph in Fig. 7 shows in red the original values of RPN that were not acceptable (over 300) and green shows the RPN values after implemnting preventive measures to FMEA form for individual units.



FMEA Forms Editor VDA 96/ VDA 06: Ring spring (Tank wagon Uacns 80m3 [Design])

Effects	S	C	Failure Mode	Causes	Preventive Action	O	Detection Action	D	RPN	R/D
System Element: Ring spring										
Function: Shock absorbing in coupling system										
Unable operation	7		Not abosorbing shocks	Cracked spring	Initial State: 29.10.2015					
					none	10	check spring on cracks	10	700	
					State: 30.9.2016					
					change spring every 4 years	3	check spring on cracks	10	(210)	<<untouched>>

Fig. 6 *Example of result forms with preventive measures*

View of analysis forms of the resulting differences with includes various preventive measures are shown in figure 6.

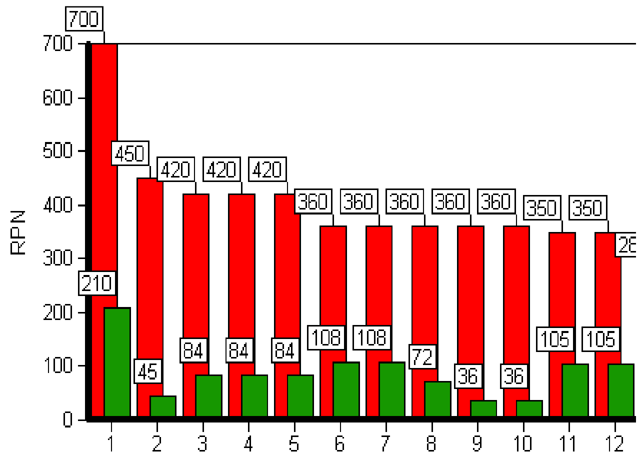


Fig. 7 *RPN values for existing and proposed maintenance system*

CONCLUSIONS

Enhancing safety is the current trend of last years and the railway sector is not excluded. Important safety factor is maintenance and this is expressed in the system of ECM certification. The certification is currently compulsory only for the freight wagons, but the prospects of extending it to passenger coaches or locomotives and diesel and electric units are envisaged. ECM certification is an important means of increasing the safety of rail transport and a tool for risk reduction.

Risk assessment is a means for achieving greater safety. There are several methods used in the various steps of the risk management process and they can be combined, too. The risk analysis process is largely dependent on the choice of appropriate methods and teamwork by professionals who are familiar with the examined system, and largely depends on their experience, knowledge, imagination, creativity and skills.

Rail freight wagons often transport hazardous substances and therefore it is essential to pay due attention to the technical condition of the rolling stock as a whole, as well as the individual parts in terms of reliability and safety of railway operations. Using the example of a selected tank-wagon series Zacns 88 m^3, the importance of identifying critical nodes has been introduced, which can give rise to failures, smaller or more severe consequences, and preventive maintenance measures by which these consequences can be prevented. From FMEA analysis the most critical units are those with the highest RPN values, so measures (preventive methods, detection) must be found to reduce them to acceptable values.

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Authors:

doc. Ing. **Juraj Grenčík**, PhD. - Department of Transport and Handling Machines, Faculty of Mechanical Engineering, University of Zilina, Univerzitná 1, 010 26 Žilina, Slovakia, Tel: +421 41 513 2553, juraj.grencik@fstroj.uniza.sk

Ing. **Peter Volna -** Department of Transport and Handling Machines, Faculty of Mechanical Engineering, University of Zilina, Univerzitná 1, 010 26 Žilina, Slovakia, Tel: +421 41 513 2680, peter.volna@fstroj.uniza.sk