THE INTERSUBJECTIVE KNOWLEDGE OF EFFECT FOR FMEA ANALYSIS

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I. *Abstract*

Objectivity is an essential requirement in the practice and sciences. On safety science or quality engineering where human subject cannot be completely excluded, objectivity cannot be created and sometimes use of this notion can also be misleading. During risk assessment one of uncertainty's sources is the intersubjectivity of estimators. In this study the authors are planning to raise the attention on this question with the help of concrete examples.

II. INTRODUCTION

In engineering science objectivity is a basic requirement. However on interdisciplinary areas such as safety science or quality issue, where human factor appears in technological systems as part of the system, this human subject cannot be completely excluded. In these areas objectivity cannot be created and the use of the notion itself can be misleading sometimes in certain situations. In this article we are planning to highlight the above mentioned with the help of an Failure Mode and Effect Analysises (FMEA) applied and used on the same tools, a ball-point pen of ordinary use. On the basis of the results of experiments our statement, which appoints notion of intersubjective should be implemented and used in certain areas of engineering instead of the objective, may not seem exaggerated.

II. THE INTERSUBJECTIVE

Objectivity is the basic requirements of scientific acknowledgement and experience. The extent of objectivity is an important distinction between artistic and scientific creations. Therefore 'clean' objectivity has become the basic requirement of scientific acknowledgment. Its basic is the 'clean', neutral rationality that is free from values and emotions, further elimination and oppressing subjectivity including neutralization of effect of subjective deformation on acknowledgment processes and results, writes Farkasová [1]. This expectation presented in nature sciences and technological sciences has gradually influenced social sciences and therefore can be found in interdisciplinary sciences such as safety science and one may come across it in risk assessment, too.

If objective acknowledgement was completely possible then we would acquire not objective but absolute knowledge. As opposed to this we only had limited knowledge even about the simplest things, since we can describe and get to know them from certain aspects on the basis of models construed by us. (In engineering sciences it is absolutely true) In case acknowledgment is not the perfect though passive 'reflection' in the aspect of subject of the object but the subject and object receive similar constructive role then it can be considered intersubjictivity, writes Hankovszky [2]

For instance, correlation used in general mechanical thermodynamics

$$pv = \mathrm{R}T \quad (1)$$

is using the unified gas law in gas dynamics, where the density of the agent and not its specific capacity is important and used according to the followings:

$$\frac{p}{\rho} = \mathrm{R}T \quad (2)$$

Intersubjective of another professional group has at once appeared in connection with the same physics correlation, considered objective.

In our view in engineering in certain situations when there are no concrete, relatively objective, measureable features then by introducing several scales we can create quasi objective situations. However this could be misleading by suggesting objectivity! The situation is the same with Failure Mode and Effect Analysis methodology.

III. DESCRIPTION OF MICRO EXPERIMENT

The first micro experiment:
We had the opportunity to inspect and examine one of the products of a firm which produces faucets made of ceramic components. Two member of group experts was carried analysis by the manual of QS9000 and by the manual of FMEA VDA 4 compare the product of RPZ and RPN values.
The second micro experiment:
The micro experiment has been carried out by 6 expert gropes including 3 members by each. All members of the groups have acquires further education certification and are currently taking part in quality insurance training as a second degree. When setting up the groups we select members with the same or very similar qualifications. The subject of the analysis was a simple ball-point pen. The groups have carried out the FMEA analysis of the same ball-point pen consisting of the same particles All the groups have stated all the possible but the same 15 failures RPN numbers. In order to make scaling easier all the groups received the same written instruction guide.

IV. FAILURE MODE AND EFFECT ANALYSIS

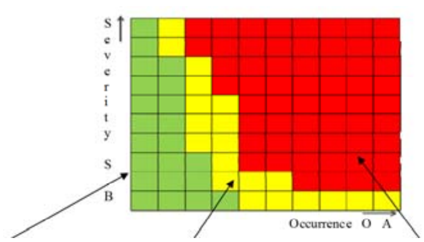
Failure Mode and Effect Analysis abbreviated as FMEA in English-language scientific literature was developed in the USA; Boeing Company and Martin Mariette Company published an engineering manual on the general method even in 1957. The method was successfully employed quite early within the frame of Apollo Moon land-

ing program after astronauts Grissom, White and Chaffee had died on board Apollo 1 during a ground test.
FMEA is a systematic method for development and control including actual and possible errors as well as the examination of their causes and consequences. The aim of FMEA is to produce better products in a more economic way by means of gradual and usual error detection [3].
FMEA can be employed in non-producing areas as well. For instance, it can be used in the risk analysis of an administrative process or a security system. In general, FMEA is applied to detect potential errors in those product designing processes and production processes where its advantages are obvious and potentially significant.
The aim of the analysis is to detect possibilities of failure in the earliest stage in the life cycle of a product, to prevent failures and correct possible errors, which, on the one hand, results in saving in costs, and on the other hand, preserves the company's good reputation.
Not only can the method be employed in the case of processes before production, but it can be employed in the case of already functioning systems and processes.
The purpose of constructional FMEA is to detect and rectify faults and fault possibilities deriving from constructional solutions and regulations designed by the designer.
The purpose of process FMEA is to explore and avoid fault possibilities and risk sources deriving from technological indiscipline, faulty materials, faulty machinery and faulty tools during manufacturing, that is from procurement to delivery of packaged goods.
FMEA according to QS 9000 Manual [4]
According to the manual, detecting failure modes in each FMEA process requires technical language. Furthermore, the analysis of fault effects must be carried out from the customer's point of view. Knowing the customer needs the causes of faults must be evaluated according to three aspects [6]:
Severity (S)- How does the fault affect the customer?
The significance of a fault: we establish the rate at which the consequences of a fault influence the customer. The extent of the effect is the slightest when the customer does not perceive the fault. The extent of the effect is the highest when the fault endangers the customer's safety. Measuring significance requires only one number referred to one fault considering the most severe consequence. The characterizing quality can be indicated under separate headings (e.g. critical, significant, etc.). The evaluation is made on a scale from 1 to 10 where point 10 refers to the most severe one.
Occurrence (O) – How often does the given fault occur?
The occurrence of the cause of the fault: the occurrence refers to the probability that the fault will occur because of a certain defined cause. Each cause of a fault has a specific value.
The occurrence of faults is also evaluated on a scale from 1 to 10 depending on the rate at which the given fault can occur.
Detection (D)- At which rate does the employed control/analysis detect the fault?
Detection of a fault: detection is aimed to examine what probability a fault caused by a certain identified cause under current controls gets to the customer. We must postulate that the fault has occurred and we also must estimate the ability of error determination. The evaluation is also made on a scale from 1 to 10 depending whether the control does not explore the fault or it does *with great certainty*. Each cause of a fault has a specific value.
During a risk analysis the risk priority number can be calculated:

$$RPN = S \cdot O \cdot D \tag{1}$$

Its size extends from 1 to 1000.
Despite the previous editions the manual does not suggest the automatic use of this kind of calculation in order to set the priority of measures. The reason for this is that RPN is deceptive because a high-risk fault may have a lower RPN value (e.g. 10 x 2 x 2 = 40), while a fault at lower risk may have a high RPN value (e.g. 4 x 5 x 3 = 60). There exists no compulsory RPN limit in spite of the previous suggestions. We must focus on ''real" problems. Therefore the value of RPN is important information for the team, however its limits must have a rateable value for each team member.
When defining measures the aim is the suggested priority: severity (its value can be decreased with the help of revising the plan), occurrence (revision) and detention (validation, designing experiments, tests, employing reliability analysis). One must make sure about the results of the changes.
FMEA according to VDA
VDA Volume 4 defines and describes the phases of FMEA in an acronym model called DAMUK [5].
This manual lays emphasis on process, and it prescribes the FMEA employment of a product and process.
D – Definition
Definition serves as an effective and efficient basis of realization of FMEA, designed specifically for the next analysing phase. In this phase, VDA Volume 4 lists examples for priority criteria, and decision-making techniques (8D Process, QFD, FTA, etc.). It also discusses how to form a team, and the conditions imposed on an FMEA moderator and team members. The chapter dealing with supportive methods gives examples, and in order to clearly distinguish risks it also presents the grades of severity, which are: 0- there is no risk, 1 – there is a slight risk, 3 – there is a risk, 9 – there is an extremely grave risk.
A – Analysis
The *analysis phase* consists of a full range of acceptability, the ability of verification, the ability of validation, and their risks. The analysis phase is a part of the decision-making process.
The German language area applies the following marks in FMEA chart:
B - The significance of fault consequences (Bedeutung).
S - Significance.
K - Possible fault cause.
A - Fault cause occurrence probability (Auftretenswahrscheinlichkeit).

O - Occurrence.
E - The probability of detecting the occurred fault cause (Entdeckungswahrscheinlichkeit).
D - Detecting.
RPZ- Risk Priority Number (Risikopriorität)= B x A x E, the equivalent of RPN.
The above evaluation of risks – RPZ (RPN)- is not always appropriate to estimate the size of the risk as the value can be low even though the significance and severity of the fault gets 9 or 10 points (e.g. 10 x 2 x 1 = 20). Therefore the volume also suggests alternative marks besides RPZ calculations.
These ones have various sorts:
the product of Value B and Value A
the product of Value B and Value E
the sum of Value B and Value A
the sum of Value B and Value E
to arrange the three digit numbers formed from Values B, A and E, and also the two digit numbers formed from Values B and E in descending order of magnitude
risk matrix with end values for B, A and E.
The matrix fields were created in such a manner that the expert team, having known the customer needs and regulations, sets an end value referring Values B, A and E. Afterwards, they select all the B-values bigger than the end value, then, out of these they select the bigger ones than the end value A, and out of the group all bigger ones than the end value E. Finally, they place each fault cause in the corresponding places of the matrix.
In the name of the matrix in the chart:



Green Field	Yellow Field	Red Field
There is no need to act.	There is no obligation to act because the risks can be reduced applying proper measures.	The risks must be reduced applying proper measures.

Fig. 1 Risk Assessment matrix

Manual QS 9000 FMEA does not contain this kind of risk matrix, which takes two risk factors into consideration, by this means it offers alternative solutions.

M – Decision on measures.

The aim of this phase is to make decisions on possible measures worked out by the team, and also to carry out the required transformations. In the process of decision-making, the costs of previous measures must also be taken into consideration. To understand this and the expenses in connection with FMEA, there is a particular chapter.

U – Realization, execution.

Its aim is to realize measures, and evaluation of efficiency and successfulness.

K – Communication.

Its aim is to represent and forward FMEA results to the employer or the customer, and also is to gain useable knowledge, which is appropriate to avoid making mistakes, and provides knowledge base and experience to solve problems in situations like this. The chapter particularly emphasizes on communication information to the team, cooperation with the customer and the supplier, utilization FMEA, and connections among FMEAs.

V. RESULTS OF THE EXPERIMENT

Having analysed the given product according to Manuals VDA 4 and FMEA, we compared the values of RPZ and RPN. [6]

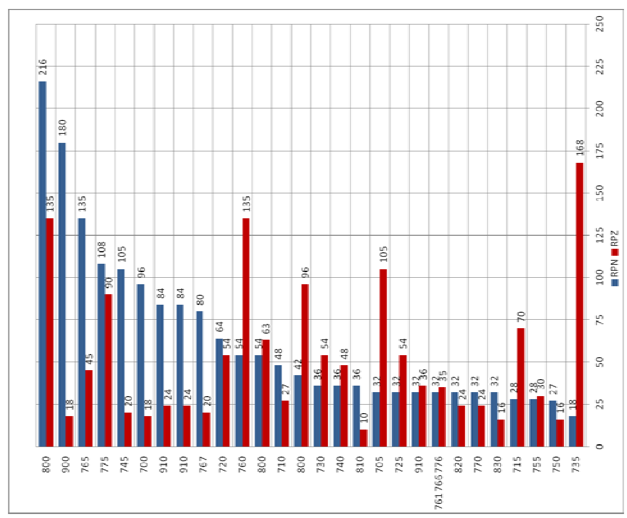


Fig. 2 Pareto diagram of RPN values that also contains RPZ values.

The diagram clearly shows that in most cases, there is a slight difference, while in several cases, there is a significant difference among the values gained from the analysis according to the two methods. As clearly shown on Fig. 2, what QS regarded as the highest risk factor (RPN), VDA did not regard as the risk factor with the highest value. Moreover, interestingly enough, RPZ coordinates the slightest values to the highest RPN values.There can be several reasons for this. One of them occurs because of the calculation of the received value. Both values are the product of three evaluation numbers, which can cause a multiple difference in the case of the minimum difference. This is partly explained by the fact that the point system of evaluation charts are not restricted enough, therefore evaluation experts are given a narrow scope of action. The other essential factor of this kind is the intersubjectivity of the evaluation viewpoints depending on experts. There can be no perfect evaluation, just one of a kind that approaches the suitable level. However, to reach this level it is essential to be familiar with each element of the examined process in every detail, including people doing this work besides machines and activities. Certainly, the two methods differ from one another, which can also cause further differences. The two procedures are identical regarding their contents, although the process of the examinations are totally different.

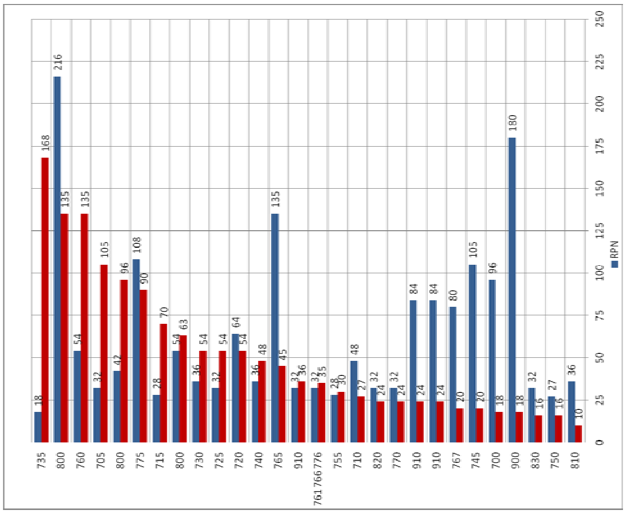


Fig. 3 Pareto diagram of RPZ values that also contains RPN values.

As shown on Fig. 3, risk factors (RPZ) are arranged according to VDA. With reference to the above mentioned subject, it is not surprising that as a general rule the high risk factors (RPN) according to QS 9000 are at the low RPZ values.

We can establish that both methods can have advantages and disadvantages when applied. The two methods are characteristically FMEA methods of two car manufacturers. These two different cultures can also give an explanation for the fact that analysis following the two methods (QS 9000, VDA) produces high risk factor values in the case of different elements. In the course of evaluation, intersubjective knowledge, which uses evaluation charts according to different methods, plays an important role several times.

In the following figures we are presenting the average of S, O, D values given by each group. The figures clearly show that each group found S-severity of failure, O-occurrence of failure and D-Detectability the biggest risk. It is expected that according to similar boundary conditions all the groups would determine similarly the risk of each factor. In other words the average of given number values (S, O, D) will not be significantly different.

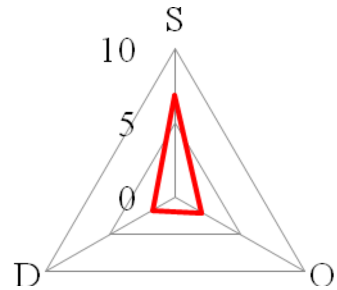


Figure 1. Average of S, O, D values of group 1.

The figure clearly shows that group 1. determines s-severity of failures the most critical. In this case the average of S is 6, 8.

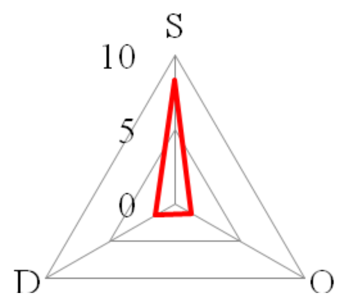


Figure 2. Average of S, O, D values of group 2.

The group 2. also considered S the most critical. The average of the group is 8, 3. The averages of group 1 and 2 are altering with 18% from each other.

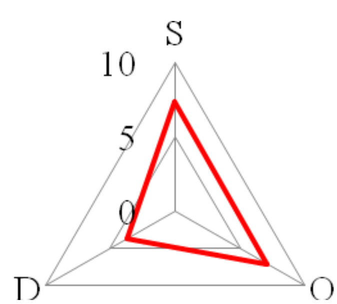


Figure 3. Average of S, O, D values of group 3.

S average of the group is 7, 3. It is placed between the averages of group 1. and group 2. Though it is noticeable that this group described the O-occurrence of failures as a very serious risk. The average of it, 7, 1, is not altering with a great extent from S value.

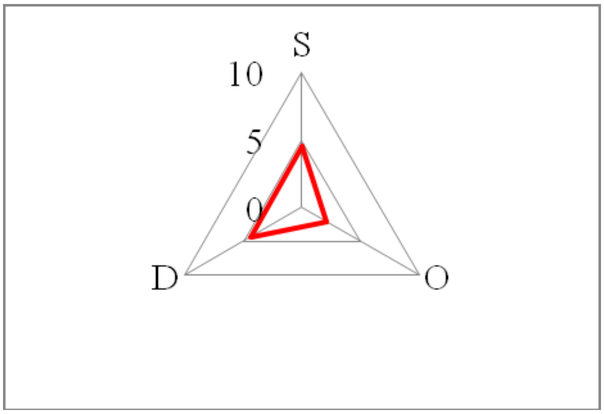


Figure 4. Average of S, O, D values of group 4.

The S average of group 4. is under 5, exactly 4, 5, though it is still the biggest risk factor here, too. This has been the lowest value so far. It is lesser with 46% than the the biggest S value. This is quite big difference. It is also noticeable that this group has determined D-detectability of failure as big risk as the S. Its average value is 4, 4.

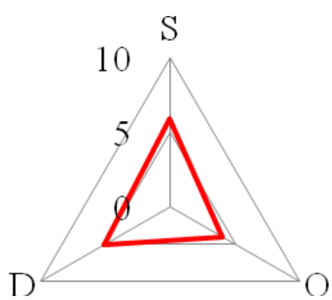


Figure 5. Average of S, O, D values of group 5.

The S average of group 5. is already 5, 9, therefore it is over 5. An outstanding fact is that all the three values of group 5. are showing balanced risks (S 5, 9 O 4, D 5, 1).

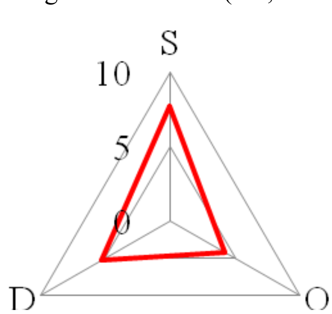


Figure 6. Average of S, O, D values of group 6.

S average of group 6 means the biggest risk according to the group's analysis. Its value is 7, 7. O and D values are similar like the values of group 5. (O 4, 3 D 5, 3).

From the detailed figure we can see that different expert groups are evaluating differently S, O, D points risks. In the aspect of the same boundary conditions it would be different according to former assumptions and expectations.

The following figures are representing different risk analysis of the groups in a more outstanding way.

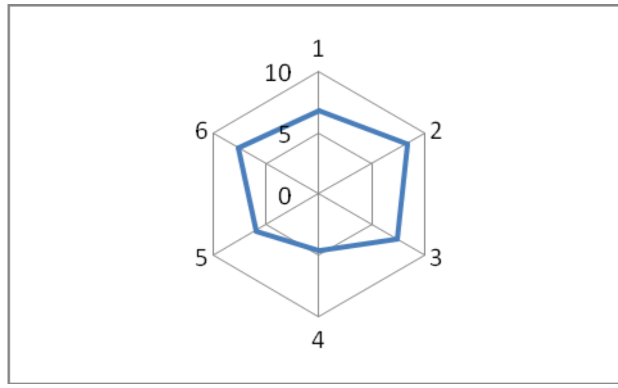


Figure 7. S values of different expert groups

This figure clearly shows that severity of possible failures of given particles had been relatively determined with significant risks by the groups except for group 4.

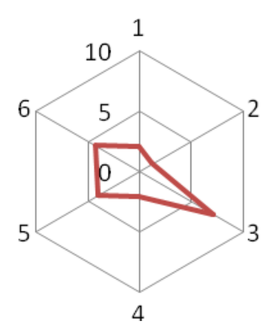


Figure 8. Average of O values by expert group

It can clearly seen from the figure that only expert group 3 has deemed possible occurrence of particles' deficiencies. In our group average value of O is 7, 1. However, it is also noticeable that three groups (1, 2, and 4) found Occurrence negligible. Average value of O 2, 1, at group 1, 1,3 at group 2, and also 2,1 at group 4. Group 3-deemed 5, 5 times riskier occurrence of deficiency than group 2.

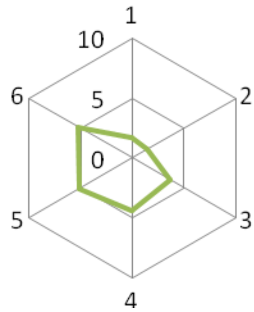


Figure 9. Average of D values by expert group

Average values of D clearly show that none of the groups deemed detectability risky. Average value of group 6 is 5, 3 while value of group 5 is 5, 1. The smallest value belongs to group 2, it is 1, 5. Here the biggest value is 3, 5 times smaller than the smallest value.

Finally let's see average values of Risk Priority Number. All the more these are those values that are used to decide what is, within a product or procedure, as risky as it would demand reduction in the risk of a given particle or procedure step.

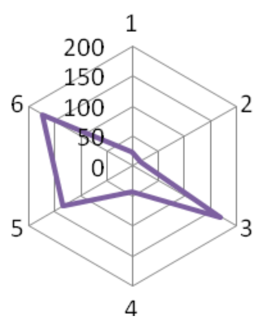


Figure 10. Average of RPN values by expert group

It is clearly seen in the figure that 3 groups relatively deemed the product, the pen in the experiment, critical. The average value of group 6 is the biggest, 173. It is followed by group 3 with 170 RPN. The third riskiest value belongs to group 5, 133. These values are outstanding since as I mentioned before in car industry there was an RPN number recommendation, and when it was exceeded an intervention was launched to reduce risk level.

By now this recommendation has been terminated, however this 125 limit is still invisibly there in the expert knowledge. Therefore interventions are needed on the basis of group 3 in order to set an acceptable risk level. Average numbers of group 1, 2, 3 show that risk level is low at the given product (ball point pen in the experiment). The values are in ascending orders 16 (group 2), 25 (group 1), 43 (group 4). The biggest is tenth times more than the smallest one. The alteration can be considered significant if the alteration is bigger than 50%. In other words in this case RPN value numbers over 139, 5 and under 46, 5 indicate significant alteration.

VI. CONCLUSION

The first micro experiment:

These two different cultures can also give an explanation for the fact that analysis following the two methods (QS 9000, VDA) produces high risk factor values in the case of different elements. In the course of evaluation, intersubjective knowledge, which uses evaluation charts according to different methods, plays an important role several times.

The first micro experiment:

Results of the experiment thus show that due to formerly set boundary conditions we had expected similar, not significantly different RPN numbers from each expert group, yet a different result occurred. There are significant differences between the RPN numbers of the groups. How can it be explained? In our opinion it is caused by the phenomena that risk preference of the groups are different group by group. It can happen if there is a group risk level deriving from individual risk preference of groups, namely subjectivity influenced by different factors. (Because of short extent of the article we would not go in details on these factors). It is defined by group risk preference level, namely group intersubjictivity. Our opinion seems to be justified that in technological life in interdisciplinary areas such as safety science and other engineering areas, quality issues, and analysis methods, like risk analysis where human subject cannot be excluded despite all our efforts to achieve objectivity (introducing scales), notion of intersubjictivity should be used. As a result in evaluating RPN numbers of FMEA analysis the dangerous situation when an intersubjective group result considered less risky, was accepted as objective, in other words it was accepted without hesitation by another engineer or engineer group, and there was no further need to intervene reducing risk level. That could emerge another question: should FMEA analysis be quitted from analysis methods? We think that this would not be the solution. According to us an evaluation method should be worked out that can eliminate distortion effect of intersubjectivity. This could be achieved by applying Fuzzy mathematics but this may be the topic of our next article.

REFERENCES

[1] E. Farkasova, *Lehet (csak) objektív a megismerés?* Kalligram. Pesti Kalligram Könyvkiadó és Könyvterjesztő Kft., Budapest, 1995.

[2] T. Hankovszky, *Az interszubjektivitás reménye, Apokaliptika és posztmodernitás*, Szent Vince Szakkollégium, Piliscsaba, 2009.

[3] IEC (1985), *Analysis techniques for system reliability Procedure for failure modes and effects analysis (FMEA)*, IEC Publication 812.

[4] **Rob Kantner**: *QS 9000 Answer book*, Panem Kft, Budapest, 1999

[5] *Lehetséges hibamód és hatáselemzés (FMEA)* Referencia kézikönyv 4. kiadás (2008)

[6] G. Szilágyi, K. Lukács, B. Szamosi, L. Pokorádi, *"A QS 9000 és a VDA szerinti hibamód és -hatáselemzések összehasonlítása"* Repüléstudományi Közlemények, Szolnok, Vol 2014(2) pp. 413-425.