**Martin Januska**[1], **Radim Spicar**[2]

## RISK MANAGEMENT SYSTEM DEVELOPMENT: THE CASE OF THE UNIVERSITY OF WEST BOHEMIA IN PILSEN

***This article deals with the historical development of risk factors at the University of West Bohemia and describes the development of a risk management system currently being used by the University. A risk management system has been established at the University of West Bohemia at the beginning of 2007. The methodology used to create risk registers and risk maps is described and critically evaluated in the first part of the article. The second part of the article deals with a comparison of the key risks development observed specifically in the years 2007–2012. During these 6 years, there has been a fundamental shift in the perception of risk and the entire monitored risk portfolio has transformed significantly as well. Bad practices in risk management are also addressed.***

***Keywords:*** *risk management system; higher education; university management; risk evolution.*

**Мартін Янушка, Радім Шпіцар**

## РОЗВИТОК СИСТЕМИ УПРАВЛІННЯ РИЗИКАМИ: ЗА ДАНИМИ УНІВЕРСИТЕТУ ЗАХІДНОЇ БОГЕМІЇ В ПІЛЬЗЕНІ

***У статті показано історію розвитку чинників ризику на прикладі Університету Західної Богемії та описано розвиток університетської системи управління ризиками. Дана система була впроваджена університетом у 2007 році. Її методологія включає в себе формування регістрів ризиків та складання мапи ризиків. Проведено критичний аналіз змін у мапах ризиків протягом 2007–2012 років. За ці 6 років відбулися суттєві зміни в сприйнятті ризиків та весь портфель ризиків суттєво змінився. Окремо описано випадки провалів в управлінні ризиками університету.***

***Ключові слова:*** *система управління ризиками; вища освіта; менеджмент університету; еволюція ризику.*

***Форм. 6. Табл. 6. Літ. 27.***

**Мартин Янушка, Радим Шпицар**

## РАЗВИТИЕ СИСТЕМЫ УПРАВЛЕНИЯ РИСКАМИ: ПО ДАННЫМ УНИВЕРСИТЕТА ЗАПАДНОЙ БОГЕМИИ В ПИЛЬЗЕНЕ

***В статье показана история развития факторов риска на примере Университета Западной Богемии и описано развитие университетской системы управления рисками. Данная система была внедрена университетом в 2007 году. Её методология включала в себя формирование регистров рисков и составление карты рисков. Проведен критический анализ изменений в картах рисков в течение 2007–2012 годов. В течение этих 6 лет произошли значительные изменения в восприятии рисков и весь портфель рисков существенно изменился. Отдельно описаны случаи провалов в управлении рисками университета.***

***Ключевые слова:*** *система управления рисками; высшее образование; менеджмент университета; эволюция риска.*

**Introduction.** The object of this article is the risk management system at the University of West Bohemia in Pilsen (hereafter referred to as UWB). The first part of the article deals with the methodology used in the risk management system at UWB and the way in which risk maps are created and key or significant risks determined. In the second part of the article, risks and their development over the last 5 years are discussed.

[1] University of West Bohemia, Pilsen, Czech Republic.
[2] University of West Bohemia, Pilsen, Czech Republic.

The first risk map was established in 2007 and has been modified twice since then. The last modification took place in 2012 and one of the authors of this article was directly involved in the creation of a new risk map as a member of the expert team delegated by the Faculty of Economics. An interesting fact leading to the emergence of this article is a huge shift in the risk perception in this relatively short period of time and also, in the authors' opinion, certain bad practices used during the creation of the new risk map.

**History of Risk Management System at University of West Bohemia in Pilsen.** Due the fact that the authors did not participate in the implementation of the risk management system at the UWB in 2007, but came as the delegated experts in 2012, the following chapter is based on (Podola, 2007). J. Podola was at that time the risk manager of the UWB.

The risk management system of the UWB was created in 2006 as a part of the development project "Implementation of a risk management system". This project was finished in the second half of 2006. It was conducted in cooperation with Technical University in Brno and with participation of an external consultancy company, Ernst & Young. The outcome of this project was a set of control documents (implementation materials), through which it became possible to implement a risk management system in the UWB conditions.

The risk management system was implemented in early 2007. First, the organizational structure of the system was created, consisting of the Risk Management Committee, the Risk Manager and the owners of specific risks. The scope of individual components of the risk management system was established in the controlling documentation, formally expressed by Rector Directive No. 12R/2007 – Risk management system. The supreme authority of this system is the Risk Management Committee composed of the representatives of UWB management (Vice-Rectors, Quaestor), the Risk Manager and the Head of Internal Audit. The Risk Management Committee mainly discusses key factors which affect the functioning of the risk management system. The Risk Manager then coordinates the risk owners and supplies them with information from the Committee meetings. The Risk Manager also prepares materials for these meetings. Risk owners are responsible for monitoring their assigned key risks. The owners then create a risk card and update it according to the information gained by monitoring the risk. Changes are then collected in a risk report, created at regular periods and passed to the Risk Manager. The Risk Manager then compiles a comprehensive risk report on the basis of individual risk reports and this is later discussed by the Risk Management Committee.

The first comprehensive report was prepared as per the current state of key risks on March 31, 2007.

**The methodology for the identification and assessment of risks.** One of the basic risk assessment methodologies was used for risk assessment in case of the UWB. The methodology was prepared by Ernst & Young in 2006. It is a modified and simplified version of the FMEA methodology, which has been implemented in a number of standards and documents (standards: MIL-STD-1629 A; EN 60812:2006; QS-9000; VDA 4.2; Tichy, 2006: 184; Veber, 2007; Mcdermott et al., 1996; Stamatis, 2003).

The FMEA methodology calculates the number of the so-called PIR (priority indicators of risk) which is the probability of risk, multiplied by its impact and pro-

bability of its detection. In the methodology used at the UWB, this number is called the degree of risk significance.

The methodology used here is more simple because it only provides an assessment using the *level of importance of risk* (*S*), which is obtained by multiplying the *probability of risk* (*P*) and the *impact of risk* (*D*) and ignores the probability of detection. Similar allocation of risks is described by a number of authors such as (Korecky and Trnkovsky, 2011: 292; Tichy, 2006: 194; Dolezal et al., 2012: 82; Kafka, 2009: 82; Fotr and Hnilica, 2009). Easy and quick risk management system increases competitiveness (Tausl Prochazkova et al., 2013).

$$\textit{level of importance of the risk (S)} = \textit{probability of the risk (P)} \times \textit{impact of the risk (D)}$$

Based on the level of their importance, risks are divided into 3 groups:

***Key risks*** with the level of importance greater than 7 in 2007 and greater than13.53 in 2012.

***Serious risks*** with the level of importance in the range 2.5 to 7 in 2007 and 9.87 to 13.53 in 2012.

***Common risks*** with the level of importance less than 2.5 in 2007 and less than 9.87 in 2012.

The use of traffic light colors is recommended for example by (Fotr et al., 2012; Korecky and Trnkovsky, 2011).

Risks can be displayed in a so-called risk map based on their probability (*P*) and impact (*D*) (Korecky and Trnkovsky, 2011: 292; Tichy, 2006: 194).

A "risk map" is a graph where horizontal axis represents probability values (*P*) and vertical axis represents the value of impact (*D*). Each risk is represented in the map by a single point. This view can be used to determine their theoretical limits.

To obtain data to compile a risk map, each part of the University (faculties and external departments) have nominated one expert to the expert team. Each expert first suggested up to 3 risks from each of the following areas:

- Finance.
- Human Resources.
- Study area (education).
- Research, Development and Innovation.
- Management.
- Information Technology (ICT).
- Legislation.

The Risk Manager of the UWB thereafter processed all the proposed risks and sent the selected set of risks back to the expert group for evaluation. Risks were judged on two scales, their probability and their impact. The following scales were used.

The evaluation scale for impact of the risk:

1) very small (impact on several individuals);
2) small (impact on the workplace);
3) significant (impact on a single department);
4) highly significant (impact on multiple departments);
5) catastrophic (impact on the whole university).

The evaluation scale for probability of the risk:

1) almost impossible;

2) unlikely;
3) normally possible;
4) likely;
5) very likely.

Answers were processed and displayed on the risk map.

This approach of subjective weighting is called "Direct assessment by experts", described in (Liu et al., 2011; Liu et al., 2012; Wang et al., 2009; Zhang and Chu, 2011; Gargama and Chaturvedi, 2011; Braglia et al., 2003). It is also possible to use the directly given weighting method or the objective weighting method (Liu et al., 2013) but in the case of a university, direct assessment by experts is the most suitable.

In the evaluation of 2012, a different methodology for determining risk limits is used than in the final report by Ernst & Young (2006). Ernst & Young (2006) sets these limits arbitrarily.

Risks with the level of significance > 7 are key risks and risks with the level of significance of < 2.5 are common risks.

In the evaluation methodology as of 2012 (Marek and Toupal; 2012), a different method of limits calculation was used. In the theoretical limits calculation procedure, the area of the map is divided into 3 areas, whose size corresponds to the percentage of individual risk groups. Thus, 15% are key risks and 50% are severe risks. This corresponds to the limit of 13.53 for key risks and 9.87 for common risks. Marek and Toupal (2012) noted in their report the following procedure to calculate limits:

Whole surface of the map is 5 x 5 = 25 units.

Point $X_m$ is determined by solving the equation:

$$5 = \frac{S}{x_m} \Rightarrow x_m = \frac{S}{5}. \quad (1)$$

The area of rectangle $P_1$ is:

$$P_1 = 5x_m = S. \quad (2)$$

Area $P_2$ is:

$$P_2 = \int_{x_m}^{5} \frac{S}{5} dx = S \times (2\ln 5 - \ln S). \quad (3)$$

Whole area "under" the border limit in the risk map is:

$$P_1 + P_2 = S \times (1 + 2\ln 5 - \ln S). \quad (4)$$

To obtain the area of size 100α (%) it is necessary to apply equation:

$$25\alpha = S \times (1 + 2\ln 5 - \ln S). \quad (5)$$

Value $S$ is obtained numerically from:

$$\alpha = \frac{S \times (1 + 2\ln 5 - \ln S)}{25}. \quad (6)$$

According to the authors, this method of limits calculation is unnecessarily complicated. There is an easier way to determine numerical limits – to calculate them by a simple algorithm. Risks are sorted according to the level of their importance and the exact risk percentages of individual groups are separated. So, for example, if 15% of the most important risks were to be considered key risks and the total number of all risks was 100, the limit for key risks would be equal to the level of importance ($S$) of

the 16th most important risk. The authors point out that in practice limits are most commonly determined by agreement, on the basis of risk analysis or in advance, not by calculation (Sankar and Prabhu, 2001; Abdelgawad and Fayek, 2010; Bowles and Pelaez, 1995).

According to the authors, the risk limit for key and serious risks should be set arbitrarily, not based on the percentage of both, as it is now, so that the level of risk importance would be less than 11 for key risks and less than 6 for serious risks.

**Risk catalogue of the University of West Bohemia in 2007.** 93 risks were identified during the first risk analysis, out of which 33 were selected for further classification. The risks were evaluated basing on the methodology developed by Ernst & Young in 2006. 12 key risks were selected for further monitoring. The following tables specify key risks (Table 1), serious risks (Table 2) and common risks (Table 3). 60 risks were determined to be insignificant and were disregarded by the expert group.

*Table 1.* **Key risks 2007,** UWB information

| Number | Area | Risk |
|---|---|---|
| K1 | Management | Lack of communication between the components of the university and its employees |
| K2 | Management | Inadequate staff capacity to deal with the EU projects |
| K3 | R&D | Inability to raise funds to support R&D |
| K4 | Management | Poor preparation of investments documentation and its processing |
| K5 | HR | Lack of qualified personnel |
| K6 | PR | The concept of external communication and promotion strategy is missing |
| K7 | HR | Conflicts of interest arising from business and private activities of employees, absence of an ethical code |
| K8 | Management | Irresponsibly prepared projects transferring resources to other entities and leaving the substantive responsibility on UWB as a whole |
| K9 | Management | Non-functional management of the UWB |
| K10 | Finance | Breaking the rules of drawing subsidies |
| K11 | Legislation | Ignorance and disrespect for the law |
| K12 | ICT | Lack of data protection |

The risk owner was determined for each risk. The task of a risk owner was to describe the risk and to propose steps on reducing the level of its importance. Another task of the risk owner was to monitor the development of the risk and deliver a report twice a year.

**Risk catalogue of the University of West Bohemia in 2012.** In the second half of 2012, the units of the UWB were challenged to nominate their representatives to a team whose aim was to draft a new risk map. This was a part of the institutional development plan of the UWB, specifically the Risks-12 project. The participants had to suggest what they perceive as risks from the perspective of the component they represent, especially in relation to strategic objectives of the University.

Experts participating in the evaluation received neither the results of previous analyses, nor previous risk maps to prevent influence on their own judgment.

After the first round, there were 25 risks identified by more than one expert. These risks were sent to the same group for further evaluation.

Subsequent evaluation is based on the historical aspects of the methodology created by Ernst & Young, 2006.

*Table 2.* **Serious risks 2007,** UWB information

| Number | Area | Risk |
|---|---|---|
| S1 | ICT | Development of IT systems is not implemented conceptually |
| S2 | Study area /strategy | Demographic decline |
| S3 | Management | Inadequate internal control, non-compliance with internal control requirements of the EU |
| S4 | Management | Insufficiencies in the essential requirements for internal control systems, non-functional risk management system |
| S5 | Study area | Unemployment of graduates |
| S6 | HR | Low employee motivation |
| S7 | PR | Negative media and political campaign against the UWB (damages to reputation, outflow of students, investors and contracts) |
| S8 | Study area | Loss of competitiveness due to loss of accreditation, conflict of interest between university policies and the policies of individual faculties |
| S9 | Management /strategy | Inconvenient, expensive and oversized UWB infrastructure |
| S10 | Management | Process control is completely missing – risk of tax and accounting errors |
| S11 | Legislation | Poor contractual relations, incomplete documents, fraudulent conduct, exceeding powers |

*Table 3.* **Common risks 2007,** UWB information

| Number | Area | Risk |
|---|---|---|
| C1 | Management /strategy | Increasing competition |
| C2 | Finance | Liquidity - Cash flow |
| C3 | Management | Non-functional cooperation between faculties, disagreement and harming each other's interests |
| C4 | Management | Incorrect public contracts, incomplete documentation, late submission of papers, administrative errors |
| C5 | ICT | Out of date and inaccurate input data |
| C6 | Finance | Poor financial statements – incomeplete, inaccurate or submitted late - which leads to fines and other penalties |
| C7 | Legislation | Poor and disadvantageous contracts |
| C8 | Management | Poor property protection |
| C9 | Finance | Incorrect budget based on subsidies, with no own income, grants, projects and complementary activities |
| C10 | Management | Poor schedule, which is not centrally coordinated and organized |

Due to the fact that that only 4 risks in total were considered critical by the experts and all of them were financial risks or their main impact was on finance, it was decided that the most significant risk in each area (HR, PR, R&D etc.) is to be transferred to critical risks. The authors of this article think this solution is unfortunate because it contradicts the use of an evaluation system based on the significance. For example, the risk "IS support of UWB activities is not fully functional and is not up to European standards" was transferred to the key risk group, even when there are 11 more significant risks with a higher *level of importance*. On the other hand, the effort of UWB management to eliminate the most important risk in each group is under-

standable. The reason for this is that the response to each key risk must be incorporated into the university's strategic documents, namely its development plan.

The last column in Tables 4–6 shows whether a risk was already identified or mentioned in the risk map from 2007 and at what position.

*Table 4.* **Key risks 2012,** UWB information

| Number | Area | Risk | 2007 number |
|---|---|---|---|
| K1 | Study area | Demographic decline | S2 |
| K2 | Finance | Inability to respond to the new funding model (currently monitored: Inability to raise funds to support research and development) | K3 |
| K3 | Finance | Incorrect structure of financial resources | |
| K4 | Finance | Full-cost model does not work | |
| K5/S2 | Management | Strategic indicators are not achieved and controlled (currently monitored: Non-functional UWB management) | K9 |
| K6/S7 | R&D | Projects are not addressed in accordance with valid documentation (including performance indicators) | |
| K7/S8 | HR | Inadequate qualification and age structure of employees (currently monitored: Lack of qualified personnel) | K5 |
| K8/C2 | ICT | IS support of UWB activities is not fully functional and is not compatible with European standards | |

*Table 5.* **Serious risks 2012,** UWB information

| Number | Area | Risk | 2007 number |
|---|---|---|---|
| S1 | Finance | The issue of internal financing | |
| S2 | | Transferred to K5 | |
| S3 | ICT | The absence of an IS with relevant data (currently monitored: Out of date and inaccurate input data) | C5 |
| S4 | Management | Non-functional cooperation of the UWB parts (corporate identity, responsibility, communication, monitoring the completion of tasks) | C3 |
| S5 | Study area | Inability to respond to current needs of the labor market (currently monitored: Unemployment of graduates) | S5 |
| S6 | Study area | Insufficient incoming and outcoming mobility | |
| S7 | | Transferred to K6 | |
| S8 | | Transferred to K7 | |
| S9 | Management | Non-functional system of quality assurance | |
| S10 | Legislation | Legislation is not respected (currently monitored: Ignorance and disrespect for the law) | K11 |
| S11 | Management | The disintegration of UWB to multiple components | |
| S12 | HR | Non-functional career system (including non-functional system of evaluation and rewarding employees), (currently monitored: Low employee motivation) | S6 |
| S13 | Study area | Loss of accreditation of study subjects/courses (currently monitored: loss of competitiveness due to loss of accreditation, conflict of interests between university policies and the policies of individual faculties) | S8 |

*Table 6.* **Common risks 2012,** UWB information

| Number | Area | Risk | 2007 number |
|---|---|---|---|
| C1 | Legislation | Increase in regulation and lack of clarity | |
| C2 | | Transferred to K8 | |
| C3 | R&D | Inadequate implementation of results | |
| C4 | ICT | Inability to provide information resources | |
| C5 | ICT | Filing service is not fully functional | |
| C6 | HR | Non-functional system of employees education | |
| C7 | HR | Low loyalty of employees (currently monitored: Conflicts of interest arising from business and private activities of employees, absence of an ethical code) | K7 |
| C8 | Legislation | Inconsistency between internal regulation of each unit of the UWB | |

Tables 4–6 demonstrate the shift in risk perception over the 5 years of risk management system operation.

**Reasons for shift in risks perception.** As evident from the differences in Tables 1–3 and 4–6, there has been a significant shift in risk perception. Only 11 risks preserved from the original 33 from 2007. The reason is that not all of the monitored risks were eliminated. University environment in the Czech Republic has changed significantly as well.

***Key risks:*** There were 12 key risks in 2007 but just 3 are still perceived as the key ones in 2012. One is perceived as a serious risk and one as a common risk. The rest are not mentioned in the 2012 risk analysis at all. Some of them have been eliminated over time, some of them are still perceived by the authors. But these risks are no longer perceived as a threat of such a level that it would be necessary to monitor them.

As seen from Table 4, all key risks are related to finances and funding of the university. In the authors' opinion, the main reason is the decrease of student normative (tuition paid by the government). The average normative amount fell by 12.1% between 2010 and 2012 and the basic normative decreased by 17.3%, while the number of allowed new recruited students has decreased as well (see the norms of the Ministry of Education). The duration of grants has been reduced and their funding has been cut.

Universities, especially humanities faculties, whose main source of income was their subsidy per student and which mostly use the basic normative suddenly have found themselves in financial distress and are forced to significantly increase their efforts to obtain additional funding from other sources. In the authors' opinion, this is the main reason behind high ratings of financial risks.

Key risks that are retained from 2007:

1. K2: Inability to respond to the new funding model (simultaneously monitored: Inability to raise funds to support R&D).

2. K5/S2: Strategic indicators are not achieved and controlled (simultaneously monitored: Non-functional UWB management).

3. K7/S8: Inadequate qualification and age structure of employees (simultaneously monitored: Lack of qualified personnel).

4. S11: The disintegration of UWB to multiple components.

5. C7: Low loyalty of employees (simultaneously monitored: Conflicts of interest arising from business and private activities of employees, absence of an ethical code).

Risks 2 and 3 are key risks just because they are the most important representatives of their group.

Serious risks: 3 of 11 serious risks remain from 2007. Demographic decline is now seen as the most serious key risk.

Serious risks that are retained from 2007:

1. K1: Demographic decline.

2. S12: Non-functional career system (including non-functional system of rewarding employees and of their evaluation), (simultaneously monitored: Low employee motivation).

3. S13: Loss of accreditation of study subjects/courses (simultaneously monitored: The loss of competitiveness due to loss of accreditation, conflict of interest between university policies and policies of faculties).

Risk S13 appeared in serious risks mainly because of the case related to the Law Faculty of UWB. (Law faculty has only two specializations and in 2011, the accreditation committee proposed removing accreditation for the specialization Law and Legal Science, which concerned 80% of the faculty students at that point.)

Common risks: Only 3 common risks remain from 2007, but it is important to mention that the perception of those risks has shifted and now they are perceived as serious ones.

Common risks that are retained from 2007:

1. S3: The absence of an IS with relevant data (simultaneously monitored: Out of date and inaccurate input data).

2. S4: Non-functional cooperation of the UWB parts (corporate identity, responsibility, communication, monitoring the tasks completion).

3. S5: Inability to respond to current needs of the labor market (simultaneously monitored: Unemployment of graduates).

**Conclusion.** When comparing the risks defined and evaluated by the expert group in 2007 and 2012 it is important to note that most risks perceived as the key ones in 2007 are no longer mentioned in the new risk map of 2012. There is a clearly visible shift in perception of the most important risks – mainly from the area of management and quality to the financial area. Risks identified as key risks in 2012 are financial risks. The most significant risk identified is "Demographic decline", which is located in the Study area group, but is in direct relation to finance. In the authors' opinion, the main reason for this shift in risks perception towards financial ones is the decrease of student normative and the consequent funding problems. Separate faculties are forced to deal with them, and naturally this has a detrimental impact on their functioning.

An interesting fact in the 2012 map is that risks which the authors view as very substantial are not evaluated as the key risks. Namely VaVpI projects (operational programs of research and development for innovation) and the bankruptcy of certain units of the UWB are significantly underestimated. The explanation of this can lie in poor wording of the risk name or in the lack of verbal descriptions in the previous ver-

sion as of 2007. Considering that VaVpI projects in their volume are currently larger than the entire annual operating budget of the University, they should definitely be seen as crucial (key risks). As for the risk of bankruptcy of a university unit, it is understandable that before the scandal with the Law Faculty nobody had anticipated such a risk.

The analysis results regarding the trends in risk development at UWB is that huge emphasis has to be placed on funding and effective management in the upcoming years, as the university or some of its units already find themselves on the edge of financial sustainability of their normal operations.

It is important to realize however, that although financial risks are immediate, they are only the symptoms or effects of other problems. The university management should primarily be focused on long-term development plans to deal with finding and removing the root causes for internal risks, which can be effectively addressed. A risk which may be directly affected by university management remains on the risk map for several years should be considered as a warning sign.

The authors suggest that the risk management system should be simple and agile. The risk map should be reevaluated every year by partially different groups to bring new perspective to the analysis) and different results (key risks) should be addressed in strategic development documents of the university. And if some risk persists in the risk map longer than 1–2 years, university management should explain the reasons for it to the Academic Senate in its annual report.

**References:**

*Abdelgawad, M., Fayek, A.R.* (2010). Risk Management in the Construction Industry Using Combined Fuzzy FMEA and Fuzzy AHP. Journal of Construction and Management, Vol. 136, No. 9.

American standard: Department of Defense (1980). MIL-STD-1629 A, Procedures for Performing a Failure Mode, Effects and Critically Analysis. Washington DC.

*Bowles, J.B., Pelaez, C.E.* (1995). Fuzzy logic prioritization of failures in a system failure mode, effects and criticality analysis. Reliability Engineering and System Safety, 50: 203–213.

*Braglia, M., Frosolini, M., Montanari, R.* (2003). Fuzzy TOPSIS approach for failure mode, effects and criticality analysis. Quality and Reliability Engineering International, 19: 425–443.

*Dolezal, J., Machal, P., Lacko, B.* (2012). Projektovy management podle IPMA. Vol. 2. Praha: Grada. 526 p.

Ernst & Young (2006). Rychle zavedeni integrovaneho systemu rizeni rizik na ZCU ZAVERECNA ZPRAVA. ICZ a.s., Hvezdova 2a, 140 00 Praha 4 Ernst & Young 2006. Plzen.

*Fotr, J., Vacik, E., Soucek, I., Spacek, M., Hajek, S.* (2012). Tvorba strategie a strategicke planovani: teorie a praxe. Praha: Grada. 381 p.

*Gargama, H., Chaturvedi, S.K.* (2011). Criticality assessment models for failure mode effects and criticality analysis using fuzzy logic. IEEE Transactions on Reliability, 60: 102–110.

German standard: Verband der Automobilindustrie (1996). VDA 4.2 Sicherung der Qualitдt vor Serieneinsatz System FMEA. VDA, Frankfurt.

*Hnilica, J., Fotr, J.* (2009). Aplikovana analyza rizika ve financnim managementu a investicnim rozhodovani. 1. vyd. Praha: Grada. 262 p.

International standard: EN 60812:2006. Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA), 2006.

International standard: QS-9000, Quality System Requirements QS-9000, 1998.

*Kafka, T.* (2009). Pruvodce pro interni audit a risk management. 1. vyd. Praha: C.H. Beck, 2009. 167 p.

*Korecky, M., Trkovsky, V.* (2010). Management rizik projektu: se zamerenim na projekty v prumyslovych podnicich. Praha: Grada. 583 p.

*Liu, H.C., Liu, L., Bian, Q.H., Lin, Q.L., Dong, N., Xu, P.C.* (2011). Failure mode and effects analysis using fuzzy evidential reasoning approach and grey theory. Expert Systems with Applications, 38: 4403–4415.

*Liu, H.C., Liu, L., Liu, N.* (2013). Risk evaluation approaches in failure mode and effects analysis: A literature review. Expert Systems with Applications, 40(2): 828–838.

*Liu, H.C., Liu, L., Liu, N., Mao, L.X.* (2012). Risk evaluation in failure mode and effects analysis with extended VIKOR method under fuzzy environment. Expert Systems with Applications, 39: 12926–12934.

*Marek P., Toupal, T.* (2012). Vyhodnoceni expertnich dotazniku k hodnoceni potencialnich rizikovych jevu na ZCU: interni zprava. ZCU.

*Mcdermott, R.E., Mikulak, R.J., Beauregard, M.R.* (1996). The basics of FMEA. New York: Quality Resources. 76 p.

*Podola, J.* (2007). System rizeni rizik implementovan. Interni informacni zprava ZCU. UWB.

*Sankar, N.R., Prabhu, B.S.* (2001). Modified approach for prioritization of failures in a system failure mode and effects analysis. International Journal of Quality & Reliability Management, 18: 324–336.

*Stamatis, D.* (2003). Failure mode and effect analysis: FMEA from theory to execution. 2nd ed., rev. and expanded. Milwaukee, Wisc.: ASQ Quality Press. 455 p.

*Tausl Prochazkova, P., Jelinkova, E., Krechovska, M.* (2013). Evolving innovation perspectives on higher education and its role to competitiveness. Proceedings of the 11th International Conference Liberec Economic Forum 2013 (pp. 575–584). Liberec: Technical University.

*Tichy, M.* (2006). Ovladani rizika: analyza a management. Vyd. 1. Praha: C.H. Beck. 396 p.

*Veber, J.* (2007). Rizeni jakosti a ochrana spotrebitele. Vol 2. Praha: Grada. 201 p.

*Wang, Y.M., Chin, K.S., Poon, G.K.K., Yang, J.B.* (2009). Risk evaluation in failure mode and effects analysis using fuzzy weighted geometric mean. Expert Systems with Applications, 36: 1195–1207.

*Zhang, Z.F., Chu, X.N.* (2011). Risk prioritization in failure mode and effects analysis under uncertainty. Expert Systems with Applications, 38: 206–214.

Стаття надійшла до редакції 3.02.2015.