24th national & 10th international conference
QUALITY SYSTEM CONDITION FOR SUCCESFULL BUSINESS AND COMPETITIVENESS
Kopaonik, Kraljevi čardaci SPA
18.-20. May 2022

SOFTWARE SOLUTION IN THE FUNCTION OF VULNERABILITY ASSESSMENT OF PROJECTS IN UNCERTAIN ENVIRONMENTS

Hrvoje Puškarić[1]

Marija Zahar Đorđević[2]

Aleksandar Đorđević[3]

Miladin Stefanović[4]

Aleksandar Mišković[5]

Abstract: *In this paper, following the recommendations from the literature, a project management software was developed which is based on a model of project vulnerability assessment methodology that integrates exposure, sensitivity and static adaptive capacity in conditions of uncertainty. Based on the calculated value of vulnerability, project managers can take appropriate actions that can lead to a reduction of vulnerabilities, which at the same time increases the effectiveness of project management as a whole. By applying the proposed fuzzy method, vulnerability of each phase of technical and technological projects at the consortium level due to the action of each group of risk factors can be calculated, respecting multi criterias and their values. The proposed model and software solution was tested and verified on a group of six small and medium enterprises that make up a consortium in which one joint technical-technological project has been implemented.*

Keywords: *Project management, Software solution, Information system, Database applications, Risk quantification and uncertainty*

JEL Classification*:* *D81, L86*

[1] Hrvoje Puškarić, Academy of Professional Studies Sumadija, Kragujevac, Serbia, Center for Quality, Faculty of Engineering, Kragujevac, Serbia, hpuskaric@asss.edu.rs
[2] Marija Zahar Đorđević, Center for Quality, University of Kragujevac, Faculty of Engineering, Kragujevac, Serbia, maja_199@yahoo.com
[3] Aleksandar Đorđević, Center for Quality, University of Kragujevac, Faculty of Engineering, Kragujevac, Serbia, adjordjevic@kg.ac.rs
[4] Miladin Stefanović, Center for Quality, University of Kragujevac, Faculty of Engineering, Kragujevac, Serbia, miladin@kg.ac.rs
[5] Aleksandar Mišković, Academy of Professional Studies Sumadija, Kragujevac, Serbia, amiskovic@asss.edu.rs

1. INTRODUCTION

Project management can be considered as a complex task consisted of identifying input performance, identifying output performance and defining adequate performance optimization strategies in order to achieve positive results.

It is known that the effectiveness of project implementation and the effectiveness of the company are positively correlated. Assessing projects from the aspect of vulnerability, as well as taking appropriate measures that can lead to a reduction in the vulnerability of projects, also leads to an increase in the effectiveness of the company.

However, developed mathematical models for project management, as well as software solutions based on sensitivity assessments that include aspects of exposure, sensitivity, and adaptive capacity cannot be found in the literature.

In addition, there is no generally accepted definition of quantification of vulnerabilities in the field of organizations and management. Given the fact that vulnerability is closely related to risk assessment, this project vulnerability assessment is even more complex.

Respecting all the above facts, the problem of assessing the vulnerability of projects implemented in small and medium enterprises has become very interesting in recent decades for both researchers and the domain of practice.

2. LITERATURE REVIEW

In the literature, project management is one of the fields of industrial engineering that has become a very interesting field of research in recent decades[6][7][8][9][10][11][12][13][14]. With the realization of the project, it is possible to increase the effectiveness of business, business processes and the whole company.

The importance of vulnerability assessment to identify priority project activities has been discussed in detail in the scientific literature [15][16][17][18].

According to them, vulnerability assessments can take different forms depending on the field for which the vulnerability is observed. Following these recommendations, a project vulnerability assessment methodology is presented and integrates exposure, sensitivity and static adaptive capacity

[6] Borgonovo, E., Gatti, S. and Peccati, L., 2010. What drives value creation in investment projects? An application of sensitivity analysis to project finance transactions. *European Journal of Operational Research*, 205(1), pp.227-236.
[7] Castellano, J., & Roehm, H. (2001). The Problems with Managing by Objectives and Results. Quality Progress, 1, 39-46.
[8] Deslandres, V. and Pierreval, H., 1997. Knowledge acquisition issues in the design of decision support systems in quality control. *European Journal of Operational Research*, 103(2), pp.296-311.
[9] Yescombe, E.R. (2014). Chapter 3 - Project Development and Management, Principles of Project Finance (Second edition), 29-60.
[10] Frame, J., 2010. Managing projects in organizations. San Francisco, Ca.: Jossey Bass.
[11] Besner, C. and Hobbs, B., 2006. The Perceived Value and Potential Contribution of Project Management Practices to Project Success. Project Management Journal, 37(3), pp.37-48.
[12] Thomas, J. and Mullaly, M., 2007. Understanding the Value of Project Management: First Steps on an International Investigation in Search of Value. *Project Management Journal*, 38(3), pp.74-89.
[13] Dimova, L., Sevastianov, P. and Sevastianov, D., 2006. MCDM in a fuzzy setting: Investment projects assessment application. *International Journal of Production Economics*, 100(1), pp.10-29.
[14] Golany, B. and Rothblum, U., 2008. Optimal investment in development projects. *Operations Research Letters*, 36(6), pp.657-661.
[15] Moss, R.H., Malone, E.L., & Brenkert, A.L. (2001). Vulnerability to climate change: a quantitative approach. Joint Global Change Research Institute. PNNL-SA-33642. Pacific Northwest National Laboratory, Washington
[16] Cutter, SL., Emrich, CT., Webb, JJ., Morath, D. (2009). Social vulnerability to climate variability hazards: a review of the literature. Report to Oxfam America, Final
[17] Aleksic, A., Puskaric, H., Tadic, D. and Stefanovic, M., 2017. Project management issues: vulnerability management assessment. *Kybernetes*, 46(7), pp.1171-1188.
[18] Wongbusarakum, S., & Loper, C. (2011). Indicators to assess community-level social vulnerability to climate change: an addendum to SocMon and SEM-Pasifika regional socioeconomic monitoring guidelines.

into the spatial decision-making framework by applying a multicriteria decision-making dimension 192021

Although there are different tools, software and procedures for determining vulnerability that take into account different factors, their numerous shortcomings are noted, so a new software model has been proposed and a solution based on the above aspects of vulnerability.

3. PROJECT VULNERABILITY MODEL

A model that assesses the vulnerability of projects arising from possible risk factors in the planning phase of projects before their implementation [22] is considered in this paper. The vulnerability[23], or vulnerability of the project itself can be analyzed through all phases of the project taking into account the analysis of risk factors. Risk factors are assessed from different angles, covering different areas defined by the BS 6079 series of standards.

Sensitivity evaluation is a quantitative risk analysis and a set of modeling techniques used to determine which risks have the greatest possible impact on a project [24]. The degree to which the uncertainty of each element of the project affects the objective under examination is studied, when all other uncertain elements are kept at the level of their basic values. Sensitivity analysis [25] assesses the effect of achieving project objectives if certain assumptions are not met, or only partially.

Therefore, the main goal of sensitivity assessment lies in analyzing and predicting the impact of project input parameters that may affect the resulting performance of the project itself by observing the relative change of any input parameter and analyzing changes in relation to outputs.

Risk exposure is the quantified potential for business loss. The company's exposure to risk due to the realization of each risk factor and within each phase of the project can be calculated as the product of the probability of occurrence of the factor and the severity of the consequences arising from its action incident. The company's exposure to risk factors respecting each phase of the project can be determined by applying mathematical expressions[26].

The values of the variables that exist in the expressions for determining the exposure of companies to risk factors cannot always be determined precisely, but these values can be described qualitatively. The development of mathematical theories, such as fuzzy set theory, allows these qualitative variables to be described in an exact way. This approach to modeling the exposure of companies to risk factors was used in the development of this software solution.

---

[19] Patel, S., Graham, J. and Ralston, P., 2008. Quantitatively assessing the vulnerability of critical information systems: A new method for evaluating security enhancements. *International Journal of Information Management*, 28(6), pp.483-491.

[20] Pingue, F., Petrazzuoli, S., Obrizzo, F., Tammaro, U., De Martino, P. and Zuccaro, G., 2011. Monitoring system of buildings with high vulnerability in presence of slow ground deformations (The Campi Flegrei, Italy, case). *Measurement*, 44(9), pp.1628-1644.

[21] Tran, L., Knight, C., O'Neill, R., Smith, E., Riitters, K. and Wickham, J., 2002. Fuzzy Decision Analysis for Integrated Environmental Vulnerability Assessment of the Mid-Atlantic Region 1. *Environmental Management*, 29(6), pp.845-859.

[22] Aleksic, A., Puskaric, H., Tadic, D. and Stefanovic, M., 2017. Project management issues: vulnerability management assessment. *Kybernetes*, 46(7), pp.1171-1188.

[23] Aleksić, A., Stefanović, M., Tadić, D. and Arsovski, S., 2014. A fuzzy model for assessment of organization vulnerability. *Measurement*, 51, pp.214-223.

[24] Borgonovo, E., Gatti, S. and Peccati, L., 2010. What drives value creation in investment projects? An application of sensitivity analysis to project finance transactions. *European Journal of Operational Research*, 205(1), pp.227-236.

[25] Aleksić, A., Stefanović, M., Arsovski, S. and Tadić, D., 2013. An assessment of organizational resilience potential in SMEs of the process industry, a fuzzy approach. *Journal of Loss Prevention in the Process Industries*, 26(6), pp.1238-1245.

[26] Aleksić, A., Stefanović, M., Arsovski, S. and Tadić, D., 2013. An assessment of organizational resilience potential in SMEs of the process industry, a fuzzy approach. *Journal of Loss Prevention in the Process Industries*, 26(6), pp.1238-1245.

Static adaptive capacity can be viewed as a process in which the management team of the organization defines procedures for the implementation of common business activities that may be disrupted due to the action of various factors.

Taking into account the definitions of adaptive capacity [27][28] it can be said that it is the organization's ability to anticipate, prepare, respond and to adapt to gradual changes and sudden disturbances in order to survive and benefit from the situations that have arisen.

3.1. Mathematical model of vulnerability

The software solution is based on the mentioned model which assesses the vulnerability of projects arising from possible risk factors in the project planning phase before their implementation. The vulnerability, or vulnerability of the project itself can be analyzed through all phases of the project taking into account the analysis of risk factors. Risk factors are assessed from different angles, covering different areas defined by the BS 6079 [29][30] series of standards.

The sensitivity and exposure of each project phase is generally different for different risk factors. However, the value of these parameters may differ at different stages of the project, although the manifested risk is the same, so the assessment of sensitivity and exposure should be performed at the level of each phase of the project and each risk. The value of sensitivity and exposure of each project phase f, f = 1,…, F derived from the manifested risk factor r, r = 1,…, R is assessed by the expert team managing the project, respectively. They use predefined linguistic expressions that are modeled using triangular phase numbers.

As mentioned, the reduction of vulnerability of each project phase f, f = 1,…, F can be achieved through appropriate procedure, instruction or application of good practices on how to react if the risk factor r, r = 1,…, R is manifested and lead to an undesirable outcome. Possession of this type of document and willingness to implement it can be treated as static adaptive capacity. The value of static adaptive capacity should be determined at the level of SMEs. Its value can be accurately assessed according to the opinion of the management team whose decisions are formed by consensus.

Data for the assessment of project vulnerability were obtained by applying survey methods for which the management team of each company provided estimates of each group of risk factors that affect the implementation. Risk groups are presented by a series of standards [31][32] and depending on the aspect of project vulnerability, the assessment team has changed as well as the criteria for assessing.

Depending on the enterprise sensitivity, exposure or static adaptive capacity, three different data sets are obtained that feed the multi-criteria fuzzy mathematical model and analyze the overall vulnerability of the project at the level of the overall consortium. Exit from this model provides information on the basis of which experts in management positions can predict the future situation in the early stages of project initiation. This is important in order to determine in a timely manner the setting of appropriate strategies to improve the capacity and ability of project activities to recover very quickly due to potential uncertainties during project implementation.

---

[27] S Everly, G., 2015. Building an organizational culture of resilience through resilient leadership. *International Journal of Emergency Mental Health and Human Resilience*, 17(02).

[28] Kolay, M., 2017. Measurement of Organizational Resilience - An Approach. *SSRN Electronic Journal*,.

[29] BSI Standards Publication Project management –Part 2: Vocabulary (BS 6079-2:2000), (March 2000), available at: http://shop.bsigroup.com/en/ProductDetail/?pid=000000000030029005, (accessed April 2015)

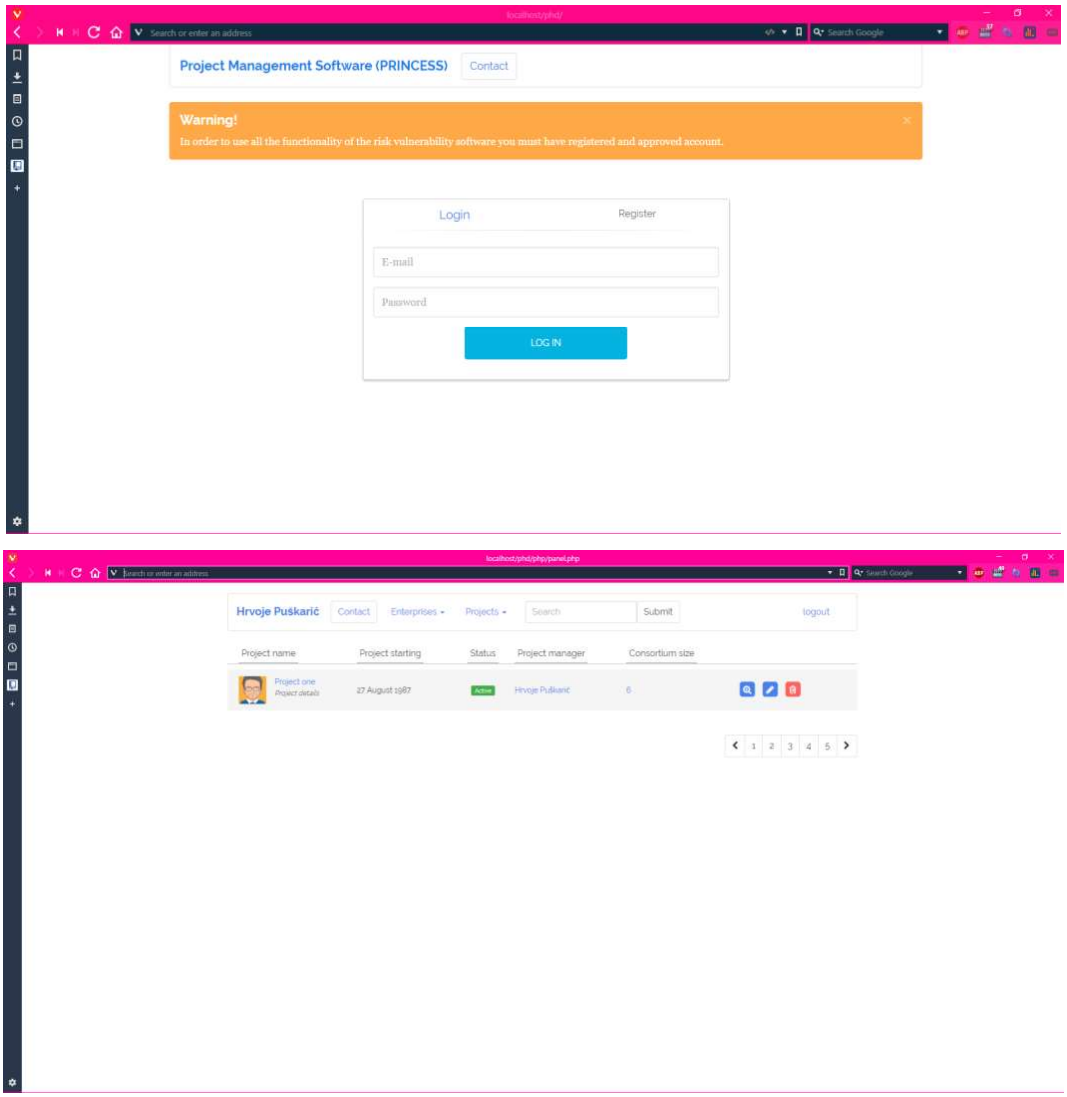
[30] BSI Standards Publication, Project management – Part 3: Guide to the management of business related project risk (BS 6079-3:2000) (January 2000), available at: http://shop.bsigroup.com/en/ProductDetail/?pid=000000000019994545 (accessed April 2015)

[31] BSI Standards Publication Project management –Part 2: Vocabulary (BS 6079-2:2000), (March 2000), available at: http://shop.bsigroup.com/en/ProductDetail/?pid=000000000030029005, (accessed April 2015)

[32] BSI Standards Publication, Project management – Part 3: Guide to the management of business related project risk (BS 6079-3:2000) (January 2000), available at: http://shop.bsigroup.com/en/ProductDetail/?pid=000000000019994545 (accessed April 2015)

4. SOFTWARE MODEL

During the development of the software solution which is based on a proposed model (Picture 1), authors of this paper made a comparative analysis of the software solutions that are most common in the management of organizations. This was done to create a complete package that would provide users with a simple and efficient solution for rapid analysis of project vulnerability results and complete reporting on critical factors.



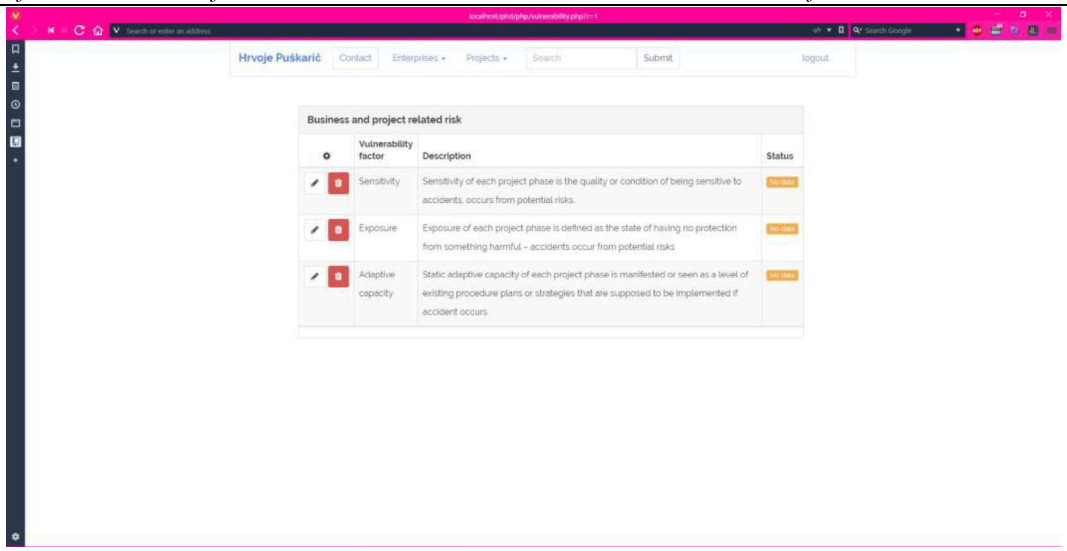
Picture 1. Software home page and control panel

To manage risks, the software uses risk groups prescribed by the standard [33][34], which includes seven risk factors and the elements that make it up.

The data is entered in a certain format and for each entry the user receives information on whether all the data has been entered. In this way there is feedback that there is no data on the current risk factor, that the data is not completely entered or a message that the data is entered in the appropriate format. These data are entered for each vulnerability axis separately (Figure 2).

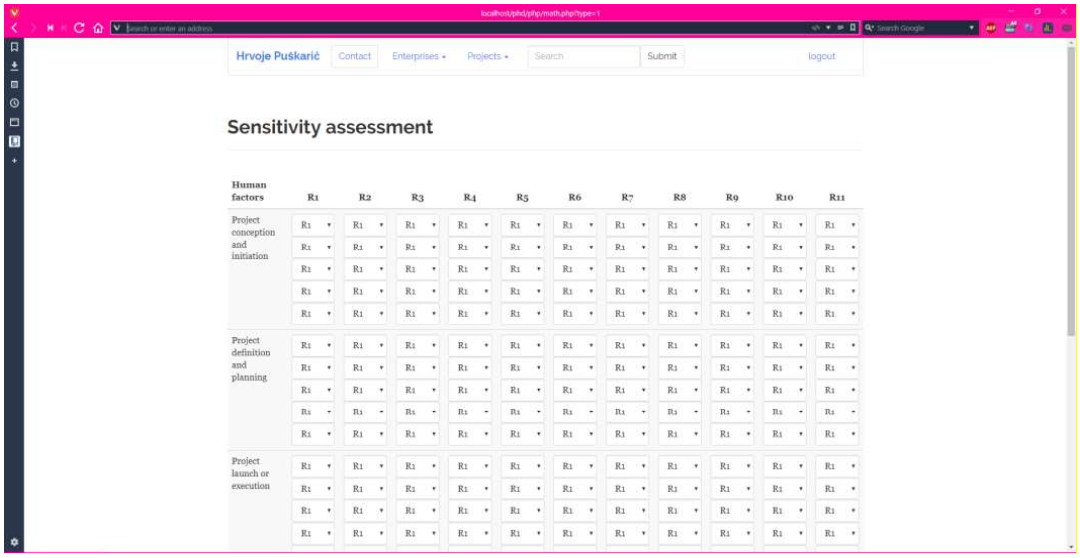
[33] BSI Standards Publication Project management –Part 2: Vocabulary (BS 6079-2:2000), (March 2000), available at: http://shop.bsigroup.com/en/ProductDetail/?pid=000000000030029005, (accessed April 2015)

[34] BSI Standards Publication, Project management – Part 3: Guide to the management of business related project risk (BS 6079-3:2000) (January 2000), available at: http://shop.bsigroup.com/en/ProductDetail/?pid=000000000019994545 (accessed April 2015)



Picture 2. Three axes of vulnerability

Each of the elements of vulnerability is assessed differently and this is defined by a mathematical model using data which is collected by a survey. Grades are assigned to the software linguistically (Picture 3) from the drop-down menu, in accordance with the prescribed model.



Picture 3. Linguistic model of sensitivity assessment

By changing any of these parameters, it is possible to correct the mathematical model in order to obtain the desired accuracy or speed in obtaining data.

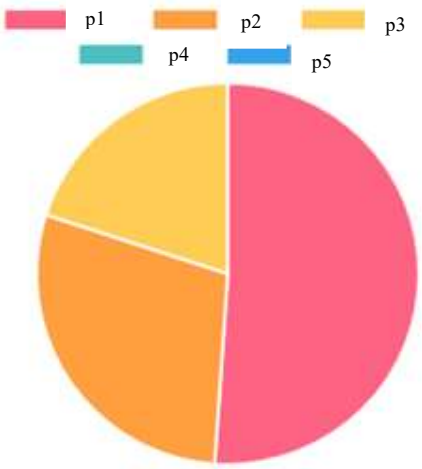
The installation of the software itself requires an internet domain with access to the database after which the installation script automatically configures the files and the user has very little interaction in this step. When this step is completed, the user receives performance information and can continue to use the software tool as described.

5. MODEL RESULTS

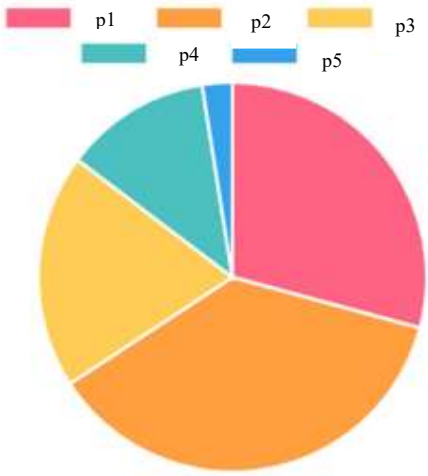
Software focuses on how data is analyzed based on the obtained surveys and how the results are presented to decision makers. Model-based software can significantly improve the quality of information made available to decision makers by applying a variety of statistical methods to analyze

and report results. Each risk group is presented in the standard [35][36] and analyzed respecting all three axes of project vulnerability at the consortium level.

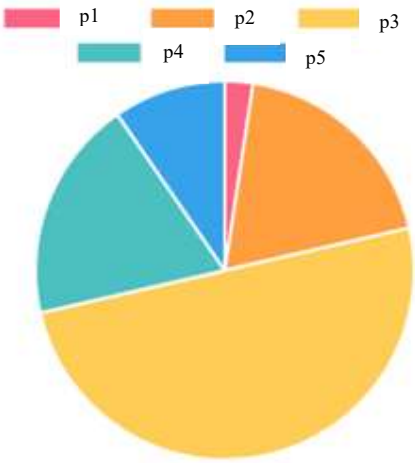
Based on the results obtained from the mathematical model of the software, it is possible to go deeper into the analysis of phase criticality by determining statistically which phase is in the first, second and third place in terms of criticality. The software at the end of analysis shows the user the the most vulnerable phases taking in the account project consortium Picture 3, Picture 4 and Picture 5.



Picture 3. Ranking of phases that are in the first place of vulnerability



Picture 4. Ranking phases that are in the second place of vulnerability



Picture 5. Ranking of phases that are in the third place of vulnerability

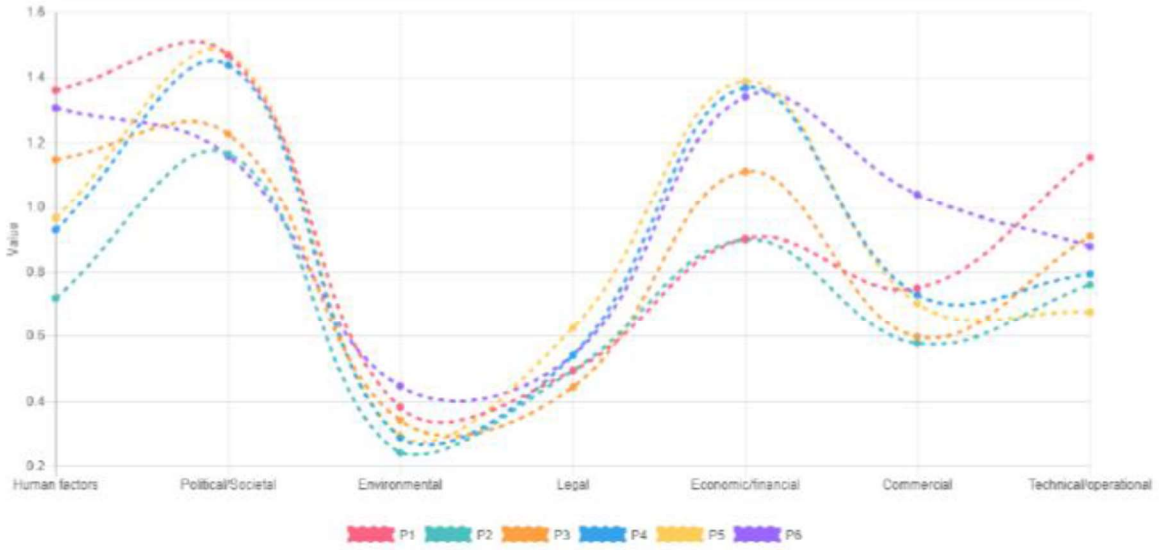
In addition to analyzing the criticality of project phases, project vulnerability management software provides a complete analysis of the impact of each individual risk group.

[35] BSI Standards Publication Project management –Part 2: Vocabulary (BS 6079-2:2000), (March 2000), available at: http://shop.bsigroup.com/en/ProductDetail/?pid=000000000030029005, (accessed April 2015)

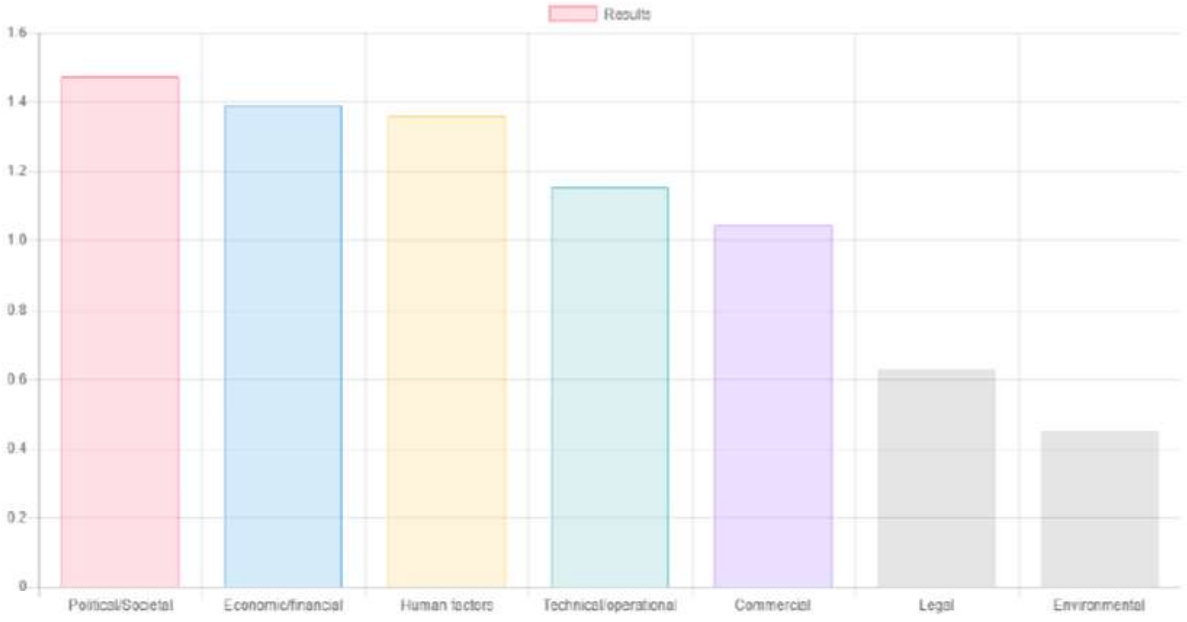
[36] BSI Standards Publication, Project management – Part 3: Guide to the management of business related project risk (BS 6079-3:2000) (January 2000), available at: http://shop.bsigroup.com/en/ProductDetail/?pid=000000000019994545 (accessed April 2015)

Critical diagrams of risk groups are also presented at the level of each company individually, as well as a joint combined diagram of criticality analysis for the entire consortium participating in the project.

The combined diagram for showing the criticality of risk groups is shown in Picture 6, while the ranked risk groups are shown in Picture 7.



Picture 6. Vulnerability of the project at the level of each risk group and each company of the project consortium



Picture 7. Ranking groups of risk factors by criticality

6. CONCLUSION

It is noticeable that software can be the key to providing new products and launching continuous product and service innovations or some other aspect of the business as it can play a strategic role in achieving customer satisfaction, controlling costs and creating a competitive advantage.

However, despite the benefits of such solutions, SMEs are still reluctant to purchase and use such products. Disagreements are due to the complexity of the solutions themselves, because a large number of employees who would use the solution are not professional enough and require the mandatory use of computers, both to use the software solution and to collect and store large amounts of data and information. Another disadvantage comes from the cost of these products. Procurement costs are accompanied by other costs that may relate to the installation of the solution, staff training, upgrade of the solution, etc.

Practice has shown that the use of appropriate software solutions can be the key to providing new products and initiating continuous innovation of products, services or other aspects of business, because it can play a strategic role in achieving customer satisfaction, cost control and competitive advantage.

Future research needs to define more deeply the models of companies for which this approach to vulnerability analysis is applicable in a wider range of activities. From the point of view of the mathematical model, it is necessary to consider different methods for estimating the elements of project vulnerability, such as sensitivity, exposure and static adaptive capacity, so that the model is understandable to both theorists and practitioners. Regarding the software solution, it is necessary to analyze other risk factors that may arise during implementation because the presented groups proposed by the standard are not final. Therefore, it is necessary to develop systems for adding and modifying existing factors within the existing model as well as archiving systems.

LITERATURE:

[1] Borgonovo, E., Gatti, S. and Peccati, L., 2010. What drives value creation in investment projects? An application of sensitivity analysis to project finance transactions. *European Journal of Operational Research*, 205(1), pp.227-236.

[2] Castellano, J., & Roehm, H. (2001). The Problems with Managing by Objectives and Results. Quality Progress, 1, 39-46.

[3] Deslandres, V. and Pierreval, H., 1997. Knowledge acquisition issues in the design of decision support systems in quality control. *European Journal of Operational Research*, 103(2), pp.296-311.

[4] Yescombe, E.R. (2014). Chapter 3 - Project Development and Management, Principles of Project Finance (Second edition), 29-60.

[5] Frame, J., 2010. Managing projects in organizations. San Francisco, Ca.: Jossey Bass.

[6] Besner, C. and Hobbs, B., 2006. The Perceived Value and Potential Contribution of Project Management Practices to Project Success. Project Management Journal, 37(3), pp.37-48.

[7] Thomas, J. and Mullaly, M., 2007. Understanding the Value of Project Management: First Steps on an International Investigation in Search of Value. *Project Management Journal*, 38(3), pp.74-89.

[8] Dimova, L., Sevastianov, P. and Sevastianov, D., 2006. MCDM in a fuzzy setting: Investment projects assessment application. *International Journal of Production Economics*, 100(1), pp.10-29.

[9] Golany, B. and Rothblum, U., 2008. Optimal investment in development projects. *Operations Research Letters*, 36(6), pp.657-661.

[10] Moss, R.H., Malone, E.L., & Brenkert, A.L. (2001). Vulnerability to climate change: a quantitative approach. Joint Global Change Research Institute. PNNL-SA-33642. Pacific Northwest National Laboratory, Washington

[11] Cutter, SL., Emrich, CT., Webb, JJ., Morath, D. (2009). Social vulnerability to climate variability hazards: a review of the literature. Report to Oxfam America, Final

[12] Aleksic, A., Puskaric, H., Tadic, D. and Stefanovic, M., 2017. Project management issues: vulnerability management assessment. *Kybernetes*, 46(7), pp.1171-1188.

[13] Wongbusarakum, S., & Loper, C. (2011). Indicators to assess community-level social vulnerability to climate change: an addendum to SocMon and SEM-Pasifika regional socioeconomic monitoring guidelines.

[14] Patel, S., Graham, J. and Ralston, P., 2008. Quantitatively assessing the vulnerability of critical information systems: A new method for evaluating security enhancements. *International Journal of Information Management*, 28(6), pp.483-491.

[15] Pingue, F., Petrazzuoli, S., Obrizzo, F., Tammaro, U., De Martino, P. and Zuccaro, G., 2011. Monitoring system of buildings with high vulnerability in presence of slow ground deformations (The Campi Flegrei, Italy, case). *Measurement*, 44(9), pp.1628-1644.

[16] Tran, L., Knight, C., O'Neill, R., Smith, E., Riitters, K. and Wickham, J., 2002. Fuzzy Decision Analysis for Integrated Environmental Vulnerability Assessment of the Mid-Atlantic Region 1. *Environmental Management*, 29(6), pp.845-859.

[17] Aleksić, A., Stefanović, M., Tadić, D. and Arsovski, S., 2014. A fuzzy model for assessment of organization vulnerability. *Measurement*, 51, pp.214-223.

[18] Aleksić, A., Stefanović, M., Arsovski, S. and Tadić, D., 2013. An assessment of organizational resilience potential in SMEs of the process industry, a fuzzy approach. *Journal of Loss Prevention in the Process Industries*, 26(6), pp.1238-1245.

[19] S Everly, G., 2015. Building an organizational culture of resilience through resilient leadership. *International Journal of Emergency Mental Health and Human Resilience*, 17(02).

[20] Kolay, M., 2017. Measurement of Organizational Resilience - An Approach. *SSRN Electronic Journal*,.

[21] BSI Standards Publication Project management –Part 2: Vocabulary (BS 6079-2:2000), (March 2000), available at: http://shop.bsigroup.com/en/ProductDetail/?pid=000000000030029005, (accessed April 2015)

[22] BSI Standards Publication, Project management – Part 3: Guide to the management of business related project risk (BS 6079-3:2000) (January 2000), available at: http://shop.bsigroup.com/en/ProductDetail/?pid=000000000019994545 (accessed April 2015)

[23] BSI Standards Publication Project management –Part 2: Vocabulary (BS 6079-2:2000), (March 2000), available at: http://shop.bsigroup.com/en/ProductDetail/?pid=000000000030029005, (accessed April 2015)

[24] Хрвоје Пушкарић, „Развој фази више-критеријумског модела и софтвера за оцењивање и управљање техничко-технолошким пројектима“, Докторска теза, Факултет инжењерских наука Универзитета у Крагујевцу, Крагујевац, 5.4.2019., бр. страна 209,