Hrvoje Puskaric[1)]
Marija Zahar Djordjevic[1)]

1)Faculty of Engineering, University of Kragujevac, Serbia
xpboje@gmail.com, maja_199@yahoo.com

DETERMINATION OF A DEVELOPMENT PROCESS PERFORMANCE USING DEVELOPED FUZZY EXPERT SYSTEM

Abstract: *Determination of process performance is very important task for success of organization management. If the process performance is not measurable variable, its value could be evaluated by the members of management team. Various sources and types of uncertainty follow this estimate, and adequate tool for modeling these imprecision and ambiguities could be the theory of fuzzy sets. It is a powerful tool for determination of criteria weights, according to which alternatives can be evaluated and management problems can be solved. For that reason, this paper presents a mathematical model based on fuzzy sets theory, according to which is possible to assess the performance and characteristics of the development process in an organization. On the basis of this model a new fuzzy expert system was developed, by which it is possible to relatively easily determine the performance of the observed process.*
Keywords: *process performance, fuzzy logic, expert system*

1. INTRODUCTION

Setting business goals is one of the main objectives for management teams in a managing of an enterprise. In setting these goals, it is necessary to reach consensus and after that make some effort in order to achieve these goals. Also, having too many business goals is as worse as not having any. To solve this problem it's necessary to include process approach in managing enterprise in order to improve business efficiency and success.

Evaluation of business process performance shows quality of performance inside the enterprise. It can effect on better control of the processes, adjustment with business goals and allowing overview of achieved results. It is really hard to improve performances of all processes, so it is a must to focus on improving these processes which are in function of achieving the goals, and which in given time period have worse performances.

One of the ways for easier evaluation of performances can be in using computer programs that are based on certain models. In this paper evaluation of development process performance is supported with developed expert system that is based on theory of fuzzy sets. Using relative ratio of importance of criteria and using appropriate linguistic expressions it is possible to easier make a conclusion and apply appropriate measures for improving.

Criteria weights are in many papers determined using a procedure that is developed in the conventional AHP (*Analytic Hierarchy Process*) [1-5]). In this approach, the management team expresses their estimations by a numerical

scale, which is defined on the set of real numbers belonging to the interval (1-9). Also, relative importance of criteria is in many papers [6-9] given by a pair-wise comparison matrix, where the elements of the matrix are linguistic expressions. It is believed that this approach is closer to the human way of thinking because it's much easier for the management team to presents their estimates using linguistic expressions. On the other side, a number of papers are dealing with the evaluation of process performance, because this task is very important for the successful company management. For example, study in [10] proposes performance metrics for two-dimensional web-forming processes, while in [11] methodology was proposed for dynamic enterprise process performance evaluation with metric measurement models.

2. PROBLEM DEFINITION

To estimate process performance in a company it is necessary to have right kind of information about company. For the purpose of writing the paper, information are obtained from 20 small and medium sized companies (according to number of employees) which have in their description process of creating new products and are located in Kragujevac and surrounding area. Development process of these companies could be splited into five phases which can be presented as phases of PDCA cycle. Phases of these process are:

- Process of development planning - With the planning, company seeks to steer their future movements on avoiding incorrect actions and reducing possibility of failure from surroundings, also disorganized behavior inside the company itself. Development planning represents overview of possible future conditions as well as taking activities which will have as result securing best results for the company in the future.
- Process of designing - Goal of the designing process is to find efficient and suitable way from idea to product. To come up from quality idea to quality product it is required to take specific set of activities in designing process. Idea of developing new products or upgrading the existing one is coming up from demands which originates from industry, government, private sector, etc., all in goal of reducing investing costs and/or exploitation costs, increasing efficiency, comfort and similar.
- Process of technology design - Technology of the process is connecting several key elements as: material, equipment and tools, material transport, production systems, quality control, maintenance, etc.
- Process of verification and validation - Verification represents confirmation by providing objective proof that specifically provided requirements are fulfilled. This applies to analysis of projected and achieved. With validation, company gets confirmation by providing objective proof that required specifically provided requirements for use are fulfilled.
- Process of changing and improving - Depending on the level of process fulfillment, which can be read from measurement of activity, tracking and analyzing, there are two situations [12]: deviation from goal value is small and deviation from goal value is significant. In the first case we are accessing the continual upgrade of the process (Continuous Process Management) and in the second reengineering of the business process (Business Process Reengineering). Assumption for this is that goals are adjusted to best in class and quality policy of the organization [12].

Defined quality objectives for every mentioned phase apply only to an enterprise group which in their activity possesses processes of making new products. These objectives are the same for every development process phase, and they are shown on figure 1.

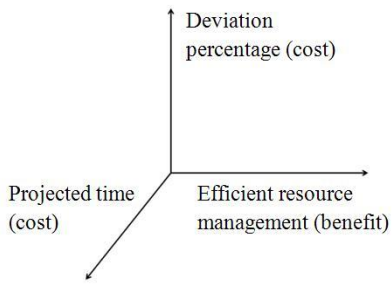

Figure 1. Quality objectives

Evaluations of these objectives in every observed time period are determined by management team, and total period of time for estimation in this paper is six months. Also, it is assumed that relative importance ratio of quality objectives is equal for each time period.

3. MATHEMATICAL MODEL

Mathematical model for evaluation of development process performance is based on the basic definitions of theory of fuzzy sets [13] which are relevant for understanding the model. In this paper, weights of the process phases are given through matrix of relative importance ratio (analog to Analytic Hierarchy Process – AHP). Modeling of linguistic expressions is based on theory of fuzzy sets and rules of fuzzy algebra [14-15].

It is assumed that importances of development process phases are not equal. Total number of phases is defined as *P*. Relative importance of process phases is given through pair-wise comparison matrix. Elements of this matrix are linguistic expressions which are modeled by triangular fuzzy numbers $\tilde{w}_{pp'}\ p', p, = 1,..,P; p' \neq p$. Upper, lower and modal value of these fuzzy numbers is marked as $l_{pp'}$, $u_{pp'}$ and $m_{pp'}$. Values in domain of these triangular fuzzy numbers belong to the set of real numbers in the interval (1-5). Value 1, or value 5, says that the first member compared to the second member of considered pair has equal or extreme importance, respectively. These linguistic expressions are:

- Very low importance - $\tilde{R}_1(x:1,1,2)$
- Low importance - $\tilde{R}_2(x:1,2,3)$
- Moderate importance - $\tilde{R}_3(x:2,3,4)$
- High importance - $\tilde{R}_4(x:3,4,5)$
- Very high importance - $\tilde{R}_5(x:4,5,5)$

Weight of the process p is calculated as mean value of all estimated values of relative importance of observed process in pair-wise comparison matrix.

$$\tilde{w}_p = \frac{1}{P} \cdot \sum_{1}^{P} \tilde{w}_{pp'}$$

This value is also a triangular fuzzy number, based upon the rules of fuzzy algebra. Value of this triangular number is defuzzed by using the method of maximal probability [14]. Representative scalar of fuzzy number $\tilde{w}_{pp'}$ is marked as w_p.

On the other side, as the values of quality objectives are not measurable, it can be imported real assumption that it is closer to human way of thinking to describe these values using linguistic expressions. Therefore, quality objective values in each period of time *t, t=1,..,T* and process phase *p, p=1,..,P* are evaluated by decision makers using seven linguistic expressions which are modeled using triangular fuzzy numbers. These values are marked as $\tilde{v}_{qt}^{p}$. Lower, upper and modal value of this fuzzy triangular number are defined as L_{qt}^{p}, U_{qt}^{p} and M_{qt}^{p}, respectively. Values of

these seven linguistic expressions are given as:

- Very low value - $\tilde{R}_1(y:1,1,2)$
- Low value - $\tilde{R}_2(y:1,2,3)$
- Medium low value - $\tilde{R}_3(y:1.5,3,4.5)$
- Medium value - $\tilde{R}_4(y:3.5,5,6.5)$
- Medium high value - $\tilde{R}_5(y:5.5,7,8.5)$
- High value - $\tilde{R}_6(y:7,8,9)$
- Very high value - $\tilde{R}_7(y:8,9,9)$

Fuzzy analysis of quality of development process in specific time period is based on aggregation of defined quality objectives on every phase of the process. Importance of quality objectives on a level of whole process is assumed to be equal.

In general case, quality objective nature can be benefit or cost. Applying process of linear normalization, domains of triangular fuzzy numbers, $\tilde{v}_{qt}^{p}$ are mapped into a set of real numbers, in the interval of [0-1] and then they become comparable. Normalized values of triangular fuzzy numbers are $\tilde{r}_{qt}^{p} = \left(z; L_{qt}^{p}, M_{qt}^{p}, U_{qt}^{p}\right)$.

Values of process phases respecting every quality objective in observed enterprise can be represented as a polyhedron. Assumption is that their values are calculated as polyhedron volume V_{pt}, $p = 1,..,P; t = 1,..,T$. Value V_{pt} belongs to the set of real numbers.

$$V_{pt} = \begin{vmatrix} b_{q1}^{pt} & b_{q2}^{pt} & 0 \\ b_{q1}^{pt} & 0 & b_{q3}^{pt} \\ 0 & b_{q2}^{pt} & b_{q3}^{pt} \end{vmatrix} = 2 \cdot b_{q1}^{pt} \cdot b_{q2}^{pt} \cdot b_{q3}^{pt}$$

Weighted normalized values of quality realization of development process in time period *t* is calculated as:

$$\tilde{w}_p = \frac{1}{P} \cdot \sum_{1}^{P} \tilde{w}_{pp'}$$

When these steps are done system is ranking process phases, while on the first place in rank is phase that has the lowest value. On the given results management team can take appropriate measures with aim to improve realization quality in those phases which have the lowest value.

Likewise, it is necessary to analyze managing during given time period to determine which time period is most critical. Based on the ranking of time periods, management team can take appropriate measures to improve efficiency of processes for that period. The ultimate goal is to increase the value of the quality of the implementation process in each period of time since it largely increases competitive advantage in the marketplace.

Based on the obtained results it is possible to calculate overall assessment for development process in the company and make it compares to other companies. This information is important for the management team of each company, and for potential investors, and even customers.

4. EXPERT SYSTEM FOR EVALUATION OF PROCESS PERFORMANCE

Expert system that is used for evaluation of development process performance is composed from few steps. Program is written as offline support for decision making and it is based on web technologies such as JavaScript and jQuery. System consists of two parts: user interface that is developed by using HTML and CSS markup language and a part that consider all necessary algorithms for calculating and decision making, and a base for its working is JavaScript and library jQuery.

In the first step it is necessary to enter dimensions of the pair wise comparison matrix of relative importance of

development process phases and after that values of fuzzy triangles need to be entered in the required fields. In the same way data about relative importance of time periods is entered in required fields in next step. After this, numbers, names and values of linguistic expressions for quality objectives are defined and entered in special part of user interface. Next step is setting types of quality objectives and their values in form of linguistic expressions for every phase of process and every time period. At the end, program calculates and makes conclusions about performance of development process phases and management over time. It shows information about which process phase is critical as well as in which time period management has low performance.

5. CASE STUDY & DISCUSSION

As it was mentioned in Chapter 2, data in this paper are obtained from the group of 20 small and medium companies. Development process of these companies is split into five phases. To solve the problem of evaluating process performances, management team sets the input matrix for relative ratio of importance of process phases which is for one company given as:

$$\begin{bmatrix} 1,1,1 & 1/\tilde{R}_2 & 1/\tilde{R}_3 & \tilde{R}_1 & 1/\tilde{R}_4 \\ \tilde{R}_2 & 1,1,1 & \tilde{R}_2 & \tilde{R}_3 & \tilde{R}_1 \\ \tilde{R}_3 & 1/\tilde{R}_2 & 1,1,1 & \tilde{R}_1 & \tilde{R}_2 \\ 1/\tilde{R}_1 & 1/\tilde{R}_3 & 1/\tilde{R}_1 & 1,1,1 & \tilde{R}_2 \\ \tilde{R}_4 & 1/\tilde{R}_1 & 1/\tilde{R}_2 & 1/\tilde{R}_2 & 1,1,1 \end{bmatrix}$$

Next figures are illustrating the work of fuzzy expert system which was made, based on data from this company.

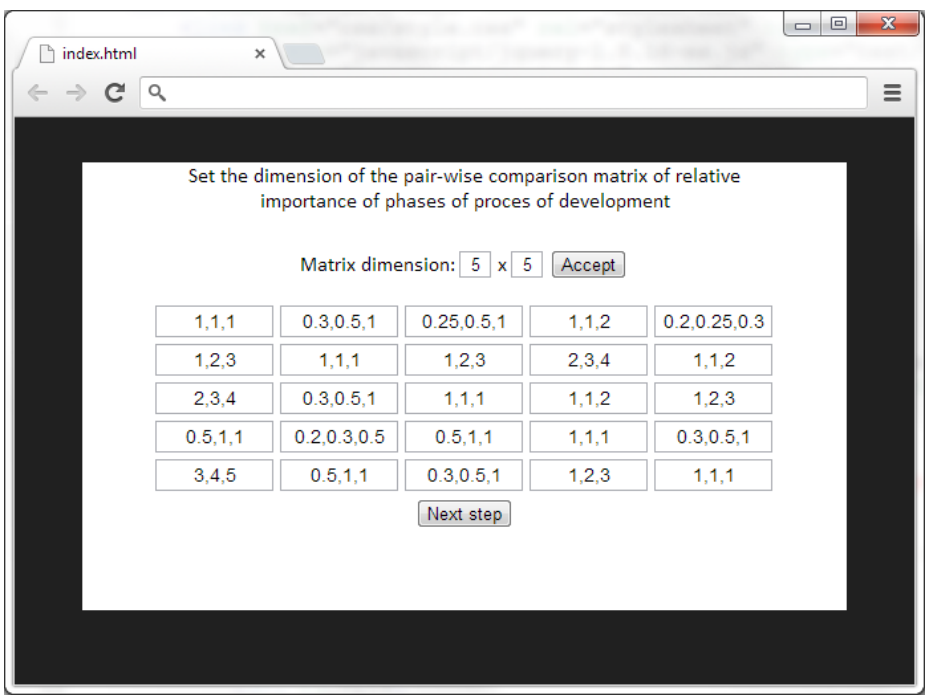

Figure 2. Pair-wise comparison matrix of relative importance of development process phases

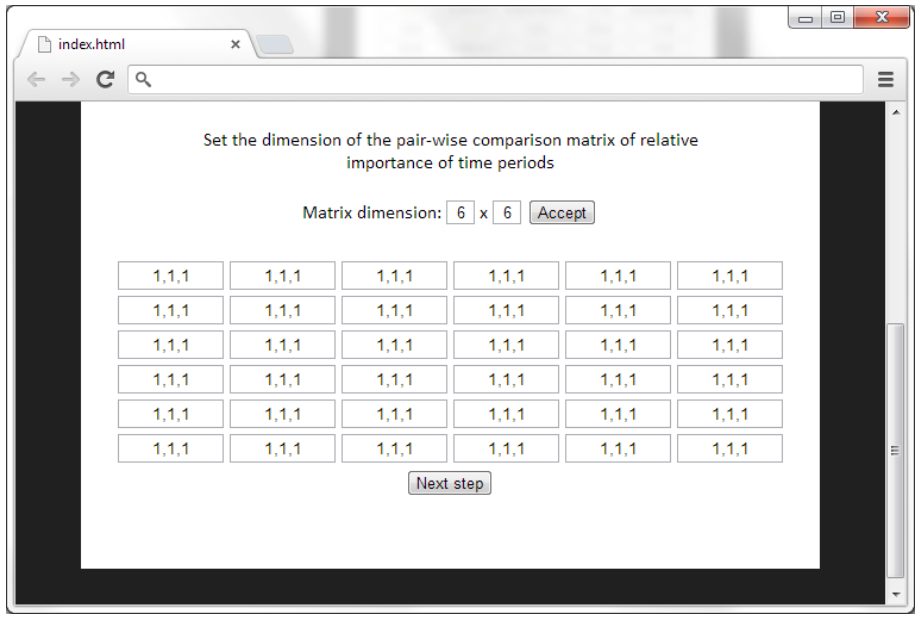

Figure 3. Pair-wise comparison matrix of relative importance of time periods

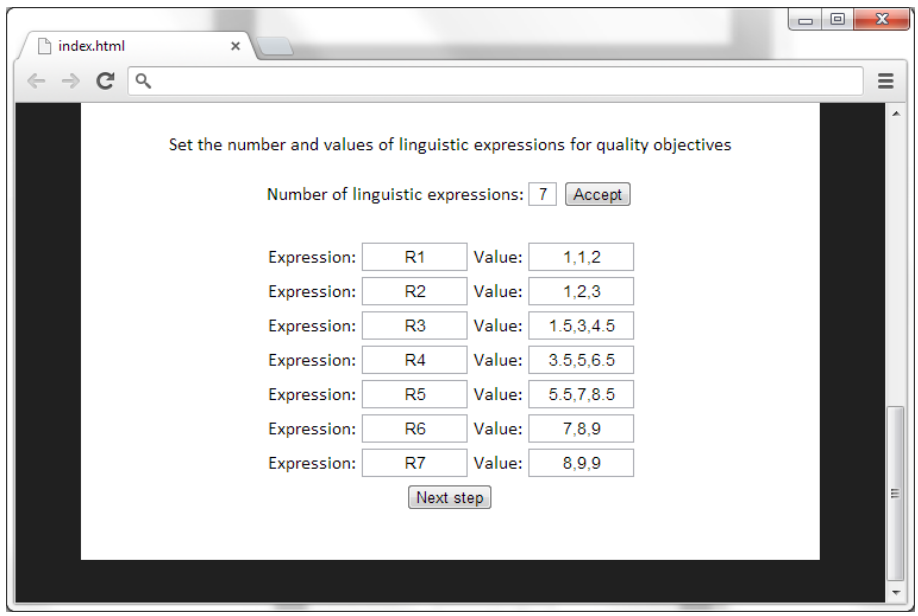

Figure 4. Setting the linguistic expressions

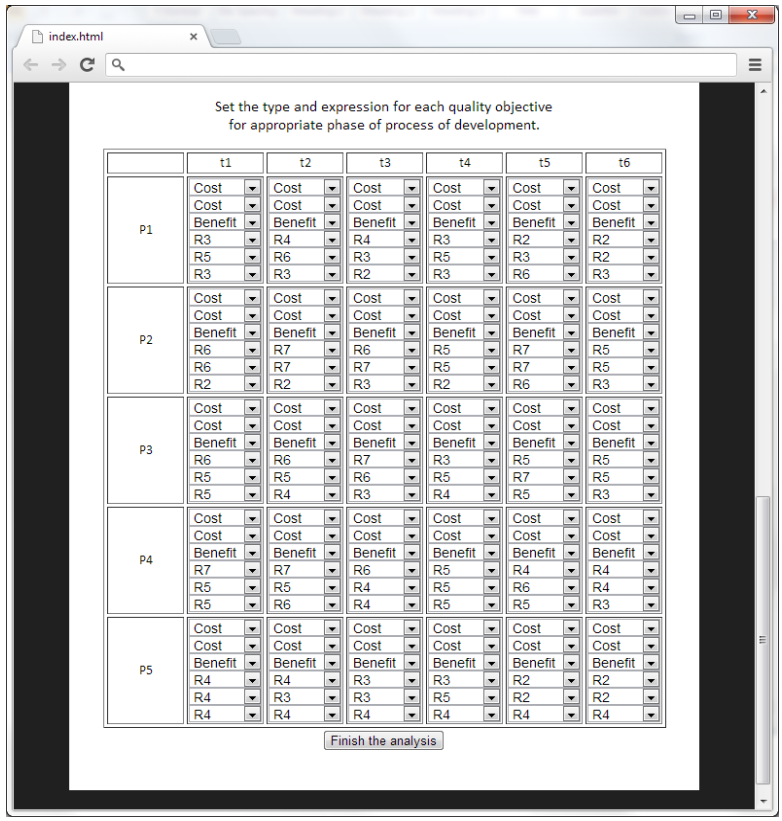

Figure 5. Setting the quality goals type and their linguistic values

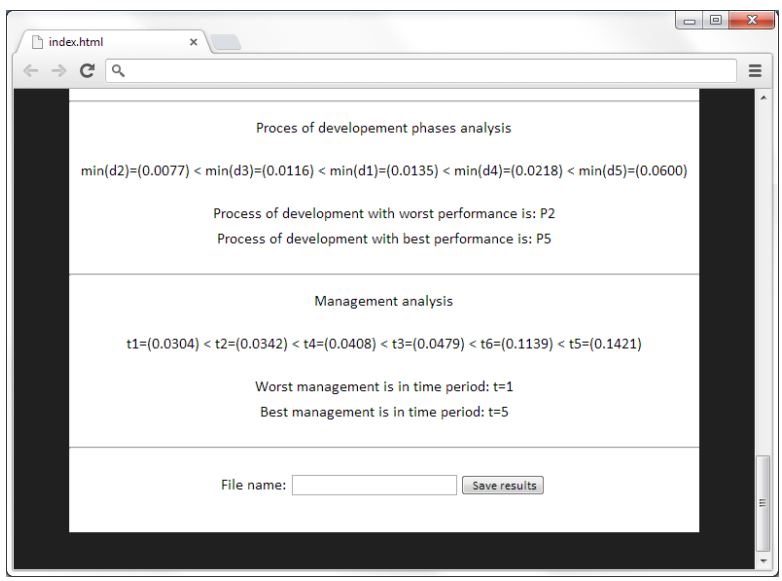

Figure 6. Displaying the results

The results for this company are shown in table 1.

Table 1. Performance analysis results for one company from the selected group

Organization 1			
Performance evaluation of phases	Rang	Performance evaluation of managing during time	Rang
Development planning = 0.0135	3	t_1=0.0304	1
Designing = 0.077	1	t_2=0.0342	2
Technology design = 0.0116	2	t_3=0.0479	4
Verification and validation = 0.0218	4	t_4=0.0408	3
Changing and improving = 0.0600	5	t_5=0.1421	6
		t_6=0.1139	5

In the given example, during observed time period, phase of development process that has the lowest performance is p_2 (*Process of designing*). On the other side, the best performance has Process of changing and improving. Likewise, time period in which managing is the worst is t_1, while period with the best managing is t_5.

Still, gotten results based upon the sample of 20 companies are quite different. By using the proposed fuzzy expert system development process performances for these companies are evaluated, and by sorting these data obtained results are presented in figure 7.

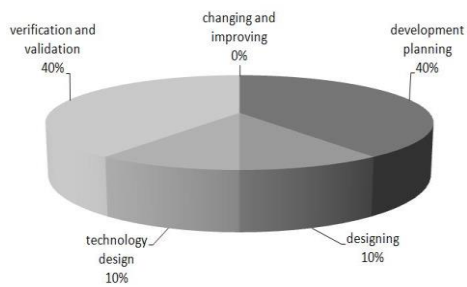

Figure 7. Phases of process with the lowest performance, for 20 companies

Phase of development planning and phase of verification and validation in 40% of enterprises are in the first place, which means they are the worst over time.

Low evaluation in phase of planning is expected because examples from practice show that small number of enterprises plan their processes. In most of the observed enterprises, process of planning is minimized and gives rough estimations upon quantity of resources. Also, risk analysis during process of development is often pushed back in second plan. Improvement of this phase assume to introduce a new or to improve existing activities depending upon observed enterprise. Examples from practice show that enterprises must improve planning of material and human resources. Beside these mentioned examples it is necessary to improve time planning.

On the other side, phase of verification and validation has low evaluation because in some enterprises it is skipped or neglected. Because of this, deviations from projected solution can be seen, which negatively impact on product quality and customer satisfaction. From the above mentioned, if there isn't a strong will to determine deviations from the real projected product, this phase represent a weak link in process of development. This is especially emphasized in companies whose business is based on private capital.

Phase of product designing and phase of technology designing in 10% of

enterprises are positioned first. Phase of changing and improving is not marked as worst in any of the mentioned enterprises.

By analyzing the managing over time, it can be concluded that in 50% of the cases the worst management is in period t_2 (Figure 8). Next in line is management in the first month with 32%, then follows third month with 18%. Management in 4th, 5th and 6th month is not marked as critical.

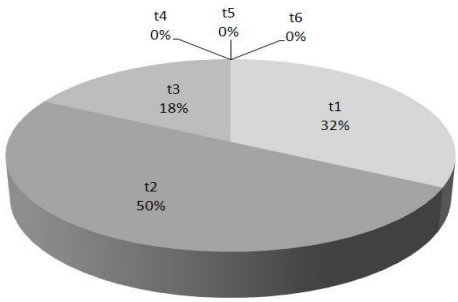

Figure 8. Time periods with the lowest performance, for 20 companies

Conclusion is that low evaluation of these phases in months 1 and 2 are determined by vacations and large number of holidays that really slow down operation of an enterprises in Serbia.

Based on the obtained results management team needs to set and make actions that are needed to be done to improve performance of critical phases of process, as well as managing in critical time periods.

6. CONCLUSION

Each organization needs to apply appropriate methods for monitoring and, where is possible to evaluate process performance. When planned results are not achieved, management team must take corrective action to ensure compliance of the products or services that the organization provides. Therefore, this paper proposes an expert system that can point to the critical processes within the company, and the management of critical periods and thus facilitate the task of the management team. Management team, thanks to developed system, can make certain conclusions and implement appropriate measures to repair the flaws inside organization and assure that same mistakes will not happen in the future.

REFERENCES:

[1] Galović, D., Petrović, R., & Zrnić, Đ. (1997). *Ranking suppliers and selection of supply strategy.* IFAC Conference of Industrial System, France.

[2] Galović, D. (2001). *Fazi pristup u ABC analizi u proizvodnom sistemu.* Simpozijum za operaciona istraživanja (SYMOPIS'01), Beograd.

[3] Tadić, D., & Stanojević, P. (2005). *Classification of items by new ABC method.* Eurofuse anniversary workshop, Beograd.

[4] Tadić, D., Tadić, B., Milanović, D., & Misita, M. Improvement of an adaption of a Hurwitz approach for the best production solution tribometer selection. *4th Int. Symposium of Industrial Engineering*, Belgrade, 2009.

[5] Tadić, B., Jeremić, B., Tadić, D., & Stančić, P. (2007). Naknadna korekcija vrednosti složenog tehničkog sistema. *Računovodstvo, 51*(3-4), 33-38.

[6] Gumus, T. A. (2009). Evaluation of hazardous waste transportation firms by using a two step fuzzy-AHP and TOPSIS methodology. *Expert System with Applications, 36,* 4067-4074.

[7] Tadić, D., Milanović, D., Misita, M., & Tadić, B. (2011). New integrated approach to the problem of ranking and supplier selection under uncertainties. *Proceedings of the Institution of Mechanical Engineers. Part B: Journal of Engineering manufacture*, *225*(b9), 1713-1724.

[8] Chan, S. T. F., & Kumar, N. (2007). Global supplier development considering risk factors using fuzzy extended AHP-based approach. *Int. Journal of Production Research, 46*, 417-431.

[9] Tadić, D., Arsovski, S., Stefanović, M., & Aleksić, A. (2010). *A Fuzzy AHP and TOPSIS for ELV Dismantling Selection.* 4th Int. Quality Conference, 377-384.

[10] Hölttä, V., & Koivo, H. (2011). Performance metrics for web-forming processes. *Journal of Process Control*, *21*(6), 885-892.

[11] Tan, W. A., Shen, W., & Zhao, J. (2006). A methodology for dynamic enterprise process performance evaluation. *Computers in Industry*, *58*(5), 474-485.

[12] Arsovski, S. (2006). *Process management.* Kragujevac: University of Kragujevac, (In Serbian).

[13] Tadić, D., Popović, P., Janković, S., & Matijević, M. (2007). *A fuzzy approach in evaluation therapeutic procedure-relevance for patient satisfaction.* 8th Balkan Conference on Operational Research, Zlatibor, Srbija.

[14] Zimmermann, H. J. (1996). *Fuzzy set Theory and its applications.* Boston: Kluwer Nijhoff Publising.

[15] Klir, G. J., & Folger, T. A. (1988). *Fuzzy sets, uncertainty and information*. Englewood, Cliffs, NJ: Pretence-Hall.