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SOFTWARE SOLUTION FOR THE EVALUATION OF THE BUSINESS PROCESS PERORMANCE IN MANUFACTURING SMEs BASED ON TIFNs

Abstract: *Business success of an enterprise largely depends on the success of business process management (BPM). Very important task for business managers in Small and Medium-sized Enterprises (SMEs) is to timely identify low performance of business processes and determine ways to improve it. In order to help managers in decision making, different software solutions for the evaluation and ranking of business processes, respecting their Key Performance Indicators (KPIs), have been created. The software solution presented in this paper is based on the fuzzy mathematical model which uses AHP with Triangular intuitionistic fuzzy numbers (TIFNs). It enables managers in SMEs to evaluate the performance of business processes and determine which process has the weakest performance and requires improvement.*
Key words: *Business Process Management; KPIs; Fuzzy Logic; TIFNs*

1. INTRODUCTION

Nowadays, in order to achieve success on the market, SMEs have to be focused on their business processes. It is widely recognized that good BPM is crucial for effectiveness of high level of business performance. It provides achievement of business objectives by the management and continuous improvement of business processes [1]. Performances of business processes need to be monitored and managed, which is possible to accomplish by monitoring and managing their KPIs [2].

During the management of business processes managers from SMEs are faced with multicriteria decision making problems, which can be very complex. Making decisions in these situations require analysis at a large amount of data at once, which is a difficult task. At the same time, it is necessary to monitor the values of KPIs, as well as their importance, which may be different within the process. If there is a large number of processes, the problem becomes even more complicated.

With the development of modern information science, modern expert systems and software solutions are increasingly emerging, helping the managers of these companies in decision making. Based on the entered data and built-in rules, they can effectively solve specific class of problems. This is especially important when it is necessary to perform complicated mathematical operations.

Software solutions discussed in this paper are based on the mathematical models which use the theory of fuzzy sets, where the uncertainties and imprecisions which occur are modelled by fuzzy numbers. These imprecisions are mostly related to the use of linguistic statements in description of the corresponding input data, and fuzzy numbers deal with these imprecisions in a very good manner.

Authors in [3] presented a fuzzy expert system which helps in the evaluation of development process performance. This system is based on triangular fuzzy numbers, and it can point to the critical phase of the development process and also time period with the weakest managing.

In the paper [4] an expert system, which determines the processes and products safety in the food chain during a given period of time was presented. It can help HACCP team to identify less secure processes and take appropriate management actions in order to improve management in the critical time periods.

Authors in [5] proposed the software solution to support supplier selection. This software is based on triangular fuzzy numbers and TOPSIS method and it can lead to savings in the purchase of medical implants by reducing the number of possible suppliers.

Gacic et al. [6] used MATLAB GA toolbox to develop a software solution which can solve the problem of Ranking and Optimization of Key Performance Indicators of the Strategy Process in manufacturing companies. It enables ranking of indicators, ranking of companies and comparing the strategy processes in different organizations.

Tadić et al. [7] presented a software solution which helps decision makers to make consensus in their opinions in order to evaluate weight vectors of business goals of internal processes. It is based on the model which uses the fuzzy delphi method with triangular fuzzy numbers.

All of these software solutions are based on the mathematical models in which the uncertainties and imprecisions are modelled by triangular fuzzy

numbers. For better dealing with these uncertainties, mentioned models could be improved by using different type of fuzzy numbers, for example triangular intuitionistic fuzzy numbers (TIFNs).

This paper provides the software solution based on the mathematical model partly developed in [8], and it is based on TIFNs. The program developed in [8] is based on the mathematical model where AHP method is used for the calculation of KPIs weights within each business process. This software solution ranks the manufacturing companies using the TOPSIS method, respecting both KPIs weights and values, and enables managers of these SMEs to benchmark KPIs of business processes with the best company in order to identify strengths and weaknesses in performance management.

Authors assumed that TIFNs present better way for the modelling of the human way of thinking than triangular fuzzy numbers. Unlike the program developed in [8], the software solution presented in this paper considers only one enterprise and the processes in it. It enables managers of the manufacturing enterprise to determine which process has the weakest performance and needs improvement.

2. THE PROBLEM STATEMENT

Developed software solution presented in this paper intend to assess and rank the business processes performance management success in a manufacturing SME, respecting the relative importance and values of KPIs.

Decision maker of an manufacturing SME estimates relative importance of KPIs*i*,*i'* in analogy to AHP method, using fuzzy pair-wise comparison matrix, at the level of each business process *p*:

$$\left[\tilde{w}_{ii'}^{p}\right]; i, i' = 1,..,I; p = 1,..,P \quad (1)$$

He makes judgments based on his/her knowledge and experience, so degree of uncertainty and imprecision exists. For that reason, he uses 5 predefined linguistic terms which means: slightly more important, a bit more important, more important, strongly more important and absolutely more important. These terms are modelled by TIFNs, while each TIFN is defined by six values, described in [8]:

$$\tilde{w}_{ii'}^{p} = \{\left(a_{ii'1}^{p}, a_{ii'2}^{p}, a_{ii'3}^{p}\right), \left(a_{ii'1}^{p}{}', a_{ii'2}^{p}, a_{ii'3}^{p}{}'\right)\} (2)$$

According to AHP, KPIs' weights are calculated, using the fuzzy geometrical mean method [9].

$$\tilde{w}_{i}^{p} = \frac{\tilde{m}_{i}^{p}}{\sum_{i=1}^{I} \tilde{m}_{i}^{p}} \quad (2)$$

$$\tilde{m}_{i}^{p} = \sqrt[I]{\tilde{w}_{i1}^{p} \cdot ... \cdot \tilde{w}_{iI}^{p}}; i = 1,..,I; p = 1,..,P \quad (3)$$

After that, decision maker estimates values of KPIs. He uses 7 terms, named: very low value, low value, almost low value, middle value, fairly high value, high value and very high value. They are also modelled by TIFNs, in accordance to [8]:

$$\tilde{v}_{i}^{p} = \{(b_{i1}^{p}, b_{i2}^{p}, b_{i3}^{p}), (b_{i1}^{p}{}', b_{i2}^{p}, b_{i3}^{p}{}')\} \quad (4)$$

Depending on the type of KPI, which can be benefit or cost, the linear normalization procedure is done:

for benefit-type of KPIs:

$$\tilde{r}_{i}^{p} = \{(\frac{b_{i1}^{p}}{b_{3}^{+}}, \frac{b_{i2}^{p}}{b_{3}^{+}}, \frac{b_{i3}^{p}}{b_{3}^{+}}), (\frac{b_{i1}^{p}{}'}{b_{3}^{+}}, \frac{b_{i2}^{p}}{b_{3}^{+}}, \frac{b_{i3}^{p}{}'}{b_{3}^{+}})\}$$

for cost-type of KPIs:

$$\tilde{r}_{i}^{p} = \{(\frac{b_{1}^{-}}{b_{i3}^{p}}, \frac{b_{1}^{-}}{b_{i2}^{p}}, \frac{b_{1}^{-}}{b_{i1}^{p}}), \left(\frac{b_{1}^{-}}{b_{i3}^{p}{}'}, \frac{b_{1}^{-}}{b_{i2}^{p}}, \frac{b_{1}^{-}}{b_{i1}^{p}{}'}\right)\} \quad (4)$$

After that, the weighted normalized KPIs values are calculated as:

$$\tilde{d}_{i}^{p} = \tilde{w}_{i}^{p} \cdot \tilde{r}_{i}^{p}; i = 1,..,I; p = 1,..,P \quad (5)$$

Then, the fuzzy ratings of performance management success at the level of each business process are calculated as:

$$\tilde{O}^{p} = \frac{\sum_{i=1}^{I} \tilde{d}_{i}^{p}}{I}; i=1,...,I; p=1,...,P \quad (6)$$

At the end, by using defuzzification procedure [10] representative scalars of these ratings are obtained and ranked:

$$O^{p} = defuzz\left(\tilde{O}^{p}\right) \quad (7)$$

3. THE SOFTWARE SOLUTION AND ILLUSTRATIVE EXAMPLE

Developed software solution uses HTML, CSS and JavaScript, for the front end, in order to display the interface and interact with the user, while the background data processing is performed using the PHP language for the backend.

Software was tested on data given from one manufacturing SME operating in the Republic of Serbia. Four business processes observed in this enterprise were: purchasing process (p=1), production process (p=2), marketing and sales process (p=3) and after sales service process (p=4), in accordance to [8]. It is assumed that the importance of this processes is equal. On the basis of the literature, for each of these processes appropriate KPIs were defined (see [8]).

When the program starts, it is necessary to choose dimension of the pair-wise comparison matrix for the observed process (Fig. 1).

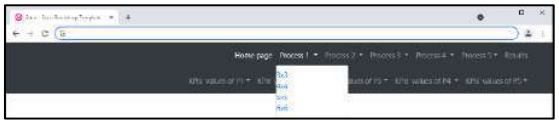

Fig. 1. Choosing of matrix dimension

Then, it necessary to fill in the data on the level of each of observed business process (Figures 2, 3, 4, 5). This is done in accordance to explanation given in Section 2.

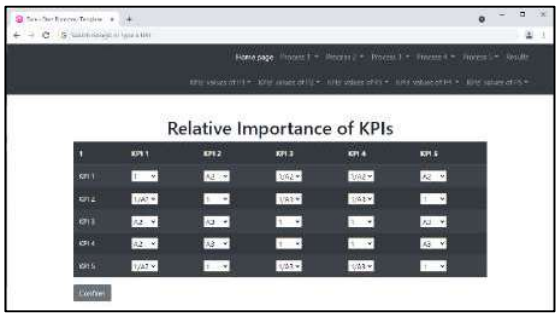

Fig. 2. Relative importance for process 1

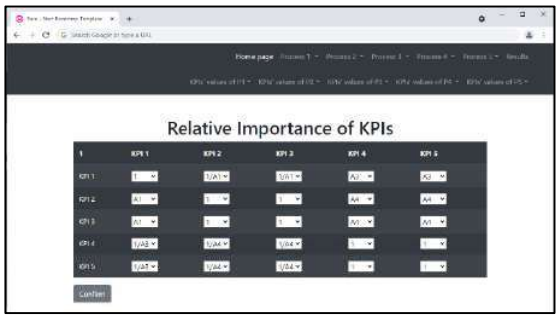

Fig. 3. Relative importance for process 2

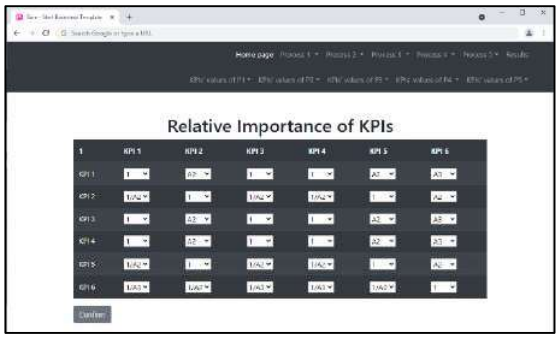

Fig. 4. Relative importance for process 3

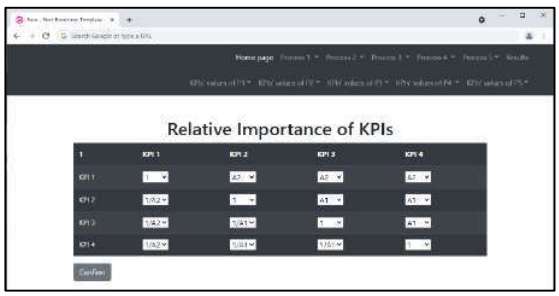

Fig. 5. Relative importance for process 4

This is followed by choosing the number of KPIs for each process and filling in the data about fuzzy assessments of the KPIs' values, at the level of each business process. These assessments are presented in Figures6-9.

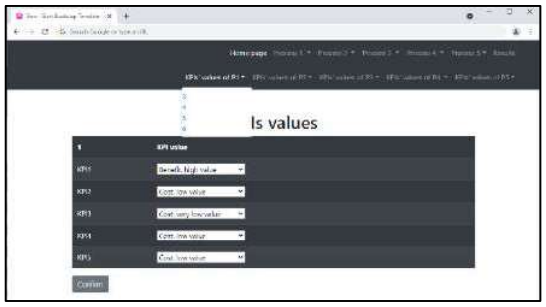

Fig. 6. KPIs values for process 1

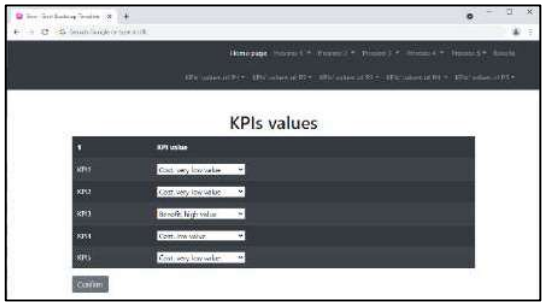

Fig. 7. KPIs values for process 2

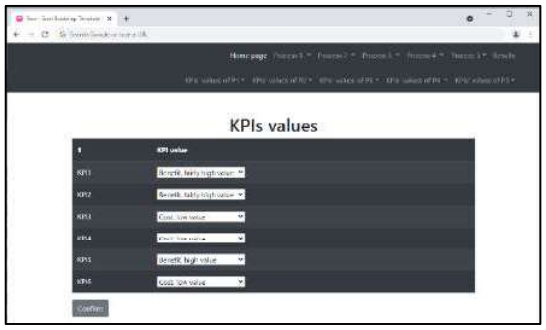

Fig. 8. KPIs values for process 3

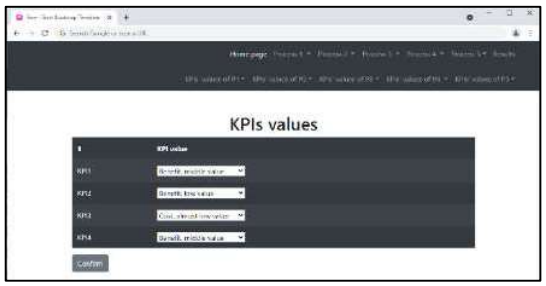

Fig. 9. KPIs values for process 4

When all input data has been entered, the program performs the calculation of the scalar ratings of performance management success at the level of each business process. Obtained results are shown on Figure 10.

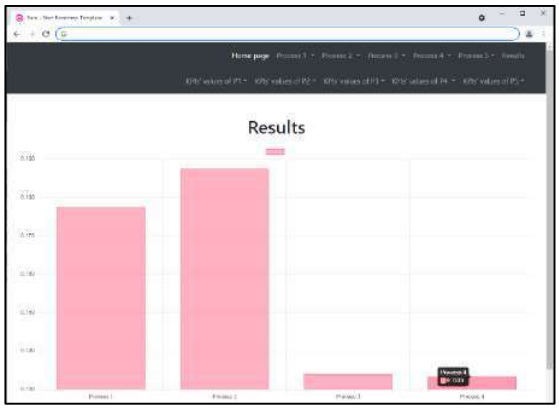

Fig. 10. Obtained results

It can be noticed that in observed manufacturing SME, process with the best performance management is process p=2, i.e. production process, and processes with the lowest performance management is process p=4, i.e. after sales service process. This means that manager of observed enterprise should focus his attention and resources on improving the after sales service. This can be done in different ways, depending on the manager's opinion and available resources.

4. CONCLUSION

Successful management of business processes performance is crucial for SMEs operating in today's competitive environment. In order to survive in the market, enterprises must constantly be focused on their business processes and their improvement.

In this paper, new software solution for the evaluation of performance management success in business processes was presented. This program is based on the intuitionistic fuzzy numbers which are more complex for the calculations than regular triangular fuzzy numbers. So, the developed program could be very useful because it greatly shortens the time required to obtain a solution. It is easy to use and very flexible. It allows the observation of five business processes at the same time, and up to six KPIs within each process.

By using the proposed program, manager of the enterprise can easily identify business process with the lowest value of performance management success. This enables him to take appropriate actions for improving of that business process, which will result in increasing of business effectiveness.

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