Abstract— Software maintenance is recognized as the most costly part of software life cycle. Evaluation of maintenance processes in order to improve planning activities is essential for increasing the efficiency of services provided to clients and the quality of software products. This paper presents a study on evaluating five typical maintenance processes in small software company. Evaluation is based on fuzzy screening procedure and includes four experts, three from the company and one from the university. Data for processes description are extracted from the internal repository of maintenance requests in the company and discretized by experts. Results of data analysis indicate that fuzzy screening is suitable technique for evaluating maintenance process, which is necessary for improving maintenance planning and management activities.

I. INTRODUCTION

Maintenance has become critical and profitable business in most types of organizations and systems. This is especially true for software organizations since software is an artifact that can be easily changed. Software maintenance is generally defined as any work on a software system after its initial delivery. According to Parikh [1], software maintenance includes understanding and documenting existing systems, extending existing functions, adding new functions, finding and correcting bugs, answering questions for users and operations staff, training new systems staff, rewriting, restructuring, converting and purging software.

Software companies do not devote sufficient attention to software maintenance management. In the article [2], the authors reported that majority of software organizations do not have any defined process for their software maintenance activities. As a consequence, there is an evident crisis of management and lack of planning in software maintenance [3]. Sousa [4] presented the research on the maintenance process conducted with people involved in the process, where 2.7% thought that the maintenance process is effective, while 70.2% of them believe that the maintenance process has a very low efficiency level. Improvement of software maintenance processes will lead to enhancement of the software products quality, which requires understanding the scope of maintenance activities and the context of work on a daily basis. This is even more important for small software companies because of their constraints in resources, and problems identified in everyday maintenance practice [5][6].

Maintenance process, according to ISO/IEC 12207 Software Life Cycle Processes Standard is defined as a primary process in software life cycle [7]. Software maintenance process is a set of various activities, usually initiated by clients. The diversity of maintenance processes and activities depends on the domain where software is used, software size, frequency of changes, and limitations in the work schedule, resources and budget [8]. Evaluation of various parameters of maintenance process is important because of their influence on product and service quality [9]. However, according to Pino et al. [10] many software organizations do not have defined and established procedures for maintenance activities because of the lack of maintenance process management models.

Systems based on fuzzy logic have been used in different fields for making decisions, controlling systems or forecasting. For example, in [11] the authors proposed a new method based on linguistic model inversion and fuzzy rule reduction for controlling plant. Further, Precup et al. [12] proposed two fuzzy controllers for tire slip control in anti-lock braking systems and the conducted simulation showed advantages of fuzzy controllers comparing to traditional ones. In [13] the authors proposed hierarchical multi agent control system based on rule based fuzzy system that enables improving the rule base under uncertain conditions and processing of a priori inserted expert knowledge, while Aisjah and Arfifin [14] described the strategy in maritime weather forecasting by using fuzzy logic.

Decision making techniques have recently gained attention in many areas of software engineering, such as choosing among a finite set of architectural alternatives during system design [15], requirements prioritization [16], role assignment for personnel in software development teams [17], or improving the configuration items selection process for software development [18]. Efficient maintenance requires that managers (and maintainers) are able to forecast future maintenance activities based on predictable patterns of maintenance work. Faghihini and Mollaverdi [19] recommended a broader view of the maintenance managers by considering more than one criterion in making an appropriate decision. Decision makers should study identified maintenance problem in such a way that considers variety of factors that affect planning and solving activities in maintenance. Despite that fact, decision-making studies are rare in

Evaluating Software Maintenance Processes in Small Software Company based on Fuzzy Screening

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software maintenance. For example, Bauer and Heinemann [20] presented the approach for the automated analysis and visualization of the API dependences for software projects that allows decisions in software maintenance scenarios, or Stojanov et al. [21] presented fuzzy screening based approach for evaluating software maintenance tasks.

This paper presents an approach for evaluating and selecting maintenance processes for planning maintenance activities in a small software company based on fuzzy screening. This study is a part of a large project (from 2011 to 2014) with the goal to assess and improve maintenance practice in the selected software company. The rest of the paper is structured as follows. The second section provides background on fuzzy screening technique. The third section presents the case study with the data based on real data from company internal repository of maintenance requests. The last section contains conclusions and some remarks for further research.

II. FUZZY SCREENING

The decision making process is certainly very important and it is not the same for each domain. For example, the process of making the decision (diagnose) in the field of medicine is different compared to evaluation of optimization of certain technical system. Common features of the decision making process in different domains are:

- The existence of multiple attributes to be observed or measured and
- The existence of several experts who will evaluate attributes.

The values of the observed attributes can be categorical, defined by real numbers or even defined by words of spoken language (linguistic terms).

Let attribute \( A \) takes value from the set \( \{ a_1, a_2, a_3 \} \). For decision-making process, it is very important that attribute’s values satisfy some relation, e.g. \( a_2 \leq a_3 \leq a_1 \). These kinds of attributes are called criteria attributes or simply criteria. Each expert involved in decision process evaluates the importance of each criterion, so we have Multi-Expert Multi-Criteria Decision Making (ME-MCDM) process. ME-MCDM is particularly suitable when there are many alternatives, each described by the same criteria. The process of ranking alternatives based on ME-MCDM can be based on Fuzzy Screening Procedure (FSP) [21][22][23][24][25] that are useful for the selection of a small subset of alternatives from much larger set of alternatives. Each alternative is described by minimal information. As mentioned before, the process involves criteria attributes used for alternative description, as well as experts whose opinion must be considered. The FSP consists of three components:

1. Set \( X \) of \( p \) alternatives \( X = \{ x_1, ..., x_p \} \).
2. Set \( E \) of \( r \) experts \( E = \{ e_1, ..., e_r \} \).
3. Set \( C \) of \( n \) criteria attributes \( C = \{ c_1, ..., c_n \} \).

Each expert for each alternative gives his/her opinion (score) how well that alternative satisfies each of the criteria. For this process, the scale \( S \) of \( n \) elements is used, where \( m \) is usually 5 or 7. For \( m=5 \) scale \( S \) is defined by: Very High (VH)-S5, High (H)-S4, Medium (M)-S3, Low (L)-S2, Very Low (VL)-S1. For \( m=7 \) scale \( S \) is defined by: Outstanding (OU)-S7, Very High (VH)-S6, High (H)-S5, Medium (M)-S4, Low (L)-S3, Very Low (VL)-S2, None (N)-S1. Natural ordering applies to scale \( S \): \( S_7 > S_6 > S_5 > S_4 > S_3 > S_2 > S_1 \)

The definition of the negation for the scale \( S \):

\[
\text{neg}(S_i) = S_{m-i+1}
\]

The FSP is particularly suitable when there are multiple experts who do not agree on criterion importance. For example, the opinion of expert \( E_1 \) is that criterion \( C \) should not be considered at all, while expert \( E_2 \) believes that the criterion \( C \) is not essential but it should be taken into account while considering an outcome of the decision making process. Therefore, expert \( E_1 \) will assign importance value N (None) to criterion \( C \), while expert \( E_2 \) will assign importance value VL (Very Low) or L (Low) to the same criterion \( C \). The FSP steps are:

1. The definition of a scale (usually five-point or seven-point scale)
2. The definition of table where rows presents entities while columns are criteria. Every cell of the table is the criterion value for certain row (entity)
3. Every expert gives his/her opinion of how important is each criterion by applying the scale defined in step 1.
4. Every expert gives score for each cell in the table by applying the same scale defined in step 1.
5. Overall score \( U \) for each entity for certain expert is calculated by (2):

\[
U = \min (\text{neg}(I_j) \lor s_j)
\]

In (2) \( I_j \) is importance of \( j \)-th criterion while \( s_j \) is score of \( j \)-th criterion given by certain expert.

6. Step 5 is repeated for every expert

Resulting cumulative score for each entity is calculated by some aggregation function. Often, Ordered Weighted Averaging (OWA) operator, defined by Ronald R. Yager [23] is utilized. Screening procedure is done by reordering entities (rows) by its cumulative scores.

The applications of FSP are numerous and cover various domains. There are many variations of FSP. In [25] a fuzzy decision rules are applied and combined with FSP. This method implies the usage of fuzzy variables, fuzzy sets defined by membership functions and fuzzy decision rules. Linguistic terms such as: high, low, medium are defined by fuzzy sets (membership functions are applied) and fuzzy decision rules are obtained by experts. The final outcome is calculated by applying similarity measure and threshold value in the process of screening international distribution centres.

In [26] fuzzy decision rules defined by fuzzy variables whose values are defined by fuzzy sets via membership functions are used in order to develop fuzzy expert system. If part of fuzzy rule is formed by aggregation of multiple fuzzy propositions while Then part is formed by single fuzzy proposition. Expertise is done by definition of fuzzy values; every expert must give his/her opinion about
fuzzy values via membership function. The final decision is done by Mamdani-type fuzzy logic controller (fuzzy logic implication is defined by min operator). Similar approach is presented in [27], but this approach uses two seven-point scales $S_i$ and $S_j$ given in Table I.

In Table I membership functions are Gaussian where $a$ and $b$ are function parameters. This approach also uses fuzzy decision rules and FSP for fashion retailer’s decision making.

A. Aggregation Function Based on OWA Operator

After overall score is calculated by (2) for each entity (alternative) and for each expert, the next step in the process is calculation of entity’s total score taking into account the opinions of all experts. In other words, it is necessary to aggregate scores of all experts to compute the total score by some aggregation function. As in [24] “This function can be seen as a generalization of the idea of how many experts it feels need to agree on an alternative for it to be acceptable to pass the screening process”. Besides some trivial, as well as more complex definitions of the aggregation function $Q$, the function that emulates the average is denoted as $Q(k) = S_{(k)}$, where

$$b(k) = \text{Int} \left[ 1 + \left( \frac{k - 1}{r} \right) \right].$$

In (3) Int[$a$] returns a value that is the closest to $a$, $q$ is number of points on the scale and $r$ is the number of experts. OWA operator is usually applied in this stage. An OWA [23] operator of dimension $n$ is a mapping $F: R^n \rightarrow R$ that has associated vector: $w = (w_1, ..., w_n)^T$, where $w_i \in [0,1], 1 \leq i \leq n$. Furthermore:

$$\sum_{j=1}^{n} w_j = 1,$$

and $F(a_1, ..., a_n) = \sum_{j=1}^{n} w_j b_j$,

where $b_j$ is the $j$-th largest element of the bag $<a_1, ..., a_n>$.

After appropriately selected $Q$, it is possible to use the OWA method for aggregating experts’ opinions. The total score $T$ for an entity is calculated by (4):

$$T = \max_{j} (Q_j \land B_j).$$

In (4) $B_j$ is the worst of the $j$-th top scores.

III. CASE STUDY

This study was conducted in a very small software company that maintains over 30 business software applications used by local clients in Serbia. Maintenance activities consume 84% of total activities in the company [28]. Data analysis is based on the real data extracted from records available in the company internal repository of maintenance requests (MR) for the period from May 2010 to November 2011. For each MR, a programmer is assigned in order to ensure its processing.

All MRs are recorded in the internal repository in the company. Although, MR process is usually tailored for the current request (and user), a general maintenance process with typical phases exists in the company. The following times (see Figure 1) exist in the MR process:

- **Scheduling time (ST)**. This is a time interval from the date of recording a MR in the repository to the date when a request is assigned to a programmer. A programmer can reject a request and forward it to another programmer. In the repository, only the last successful assignment for a particular request is saved.

- **Acceptance time (AT)**. This is a time interval from the date of recording a MR in the repository to the date when a programmer accepts a request for realization.

- **Completion time (CT)**. This is a time interval from the date of recording a MR in the repository to the date when a programmer completes all technical activities related to the MR realization.

Charging maintenance services to clients is based on recorded working hours spent on each request. The analysis includes the following types of working hours (see Figure 1):

- **Working hours spent in the company (Company Working Hours, CWH)**. Recorded working hours that a programmer spends on activities in the company.

- **Working hours spent on Internet (Internet Working Hours, IWH)**. Recorded working hours that a programmer spends on activities that require Internet access to clients’ information system.
Working hours spent at client side (Client Side Working Hours, CSWH). Recorded working hours that a programmer spends at client side (in client’s company).

Few types of maintenance processes can be distinguished in the company. All these types of maintenance processes are recorded in the repository with the same attributes, some of which are time intervals and working hours that are presented in Figure 1. These types of maintenance processes are:

- modification – the most common process with modified software as the output,
- installation – installation of software modules or new software products in client’s business environment,
- training – training of end users in a client company,
- administration – setting and configuring parameters of software application installed at client side, and
- support – assistance to customers in the operation of their software and/or integrated software and hardware products [29].

A. Initial Data Set

Data analysis is based on real data extracted for typical maintenance processes recorded in the internal repository in the company [28]. Data were discretized for five typical maintenance processes by using the scale with five values: Very High (VH), High (H), Medium (M), Low (L), and Very Low (VL). The analysis is based on the decisions of four experts: three software experts (E1, E2 and E3) from the company, and one researcher (E4) with more than ten years of experience with small software companies.

Timeline of typical maintenance processes is described with the following attributes: Scheduling Time (ST), Acceptance Time (AT), Completion Time (CT), Company Working Hours (CWH), Internet Working Hours (IWH), and Client Side Working Hours (CSWH). These attributes are selected as criteria for evaluating maintenance processes. In Table II are presented values that describe the importance of each attribute according to experts. Values from Table II indicate that for expert E1 the highest importance have scheduling and completion time, and work in the company. For Expert E2 the highest importance has scheduling and completion time and work at client side. For expert E3 the highest importance has completion time and work in the company. For expert E4 the highest importance have completion time, work at Internet and in the company.

Experts also provided the evaluation of five typical maintenance processes by using the same scale with five values. Table III presents the discrete values assigned to the selected criteria for typical maintenance processes by expert E1. The similar tables for evaluation of maintenance processes were created with the values obtained from experts E2, E3 and E4 (Tables IV, V and VI respectively).

B. Data Analysis

The overall scores for all five processes are calculated by (2) based on evaluation of selected criteria and processes by each expert separately. For example, the score $U_{11}$ for the first alternative (modification process) according to the first expert is calculated as:

$$U_{11} = \min \{\max (\text{Neg}(H), M), \max (\text{Neg}(M), M), \max (\text{Neg}(H), VH), \max (\text{Neg}(H), VH), \max (\text{Neg}(L), M), \max (\text{Neg}(L), VH)\}$$

$$U_{11} = \min \{\max (L, M), \max (M, M), \max (L, VH), \max (L, VH), \max (H, H), \max (H, L)\}$$

$$U_{11} = \min \{M, VH, VH, VH, H\}$$

$$U_{11} = M.$$
C. Discussion of Results

According to all experts, modification and administration processes are more important than installation, training and support. This conclusion is based on total scores for all processes. However, more detailed insight into scores obtained by each expert revealed that the worst ranked process is training. Modification process is usually implemented through the work in the company, while administration is based on the work at Internet and at client side. These results are very important for planning maintenance activities in terms of available programmers in the company and available access to information system at the client side, and increasing the performances such as productivity and profitability [30][31].

IV. CONCLUSIONS

Evaluation of maintenance processes based on criteria attributes that reflect timeline of processes is important for improving planning of maintenance activities. The criteria attributes refer to timing of MR processing (scheduling, acceptance and completion) and consumption of working hours that provide basis for managing workload of programmers in the company and charging the services to clients. According to the results of data analysis, fuzzy screening provides easy to use and reliable approach for evaluating typical maintenance processes and distinguishing processes (alternatives) that deserve more attention in planning maintenance activities.

Several research directions appear. The first one is related to development of a method and appropriate tool for quantifying real data available in maintenance repositories (in companies or available on Internet). This direction will include pre-processing of data available in various formats in order to be easily quantified and prepared as input data for fuzzy screening procedure. The next possible research direction will be comparison of this approach with other commonly used ME-MCDM approaches on the same data sets. The most promising direction will be modification of the presented approach through introduction of moderating parameters and comparison of results with this approach.

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REFERENCES


### TABLE VII. ALTERNATIVE EVALUATION

<table>
<thead>
<tr>
<th>Alternative (Processes)</th>
<th>E1</th>
<th>E2</th>
<th>E3</th>
<th>E4</th>
<th>Total score (OWA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modification</td>
<td>M</td>
<td>L</td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Installation</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Training</td>
<td>L</td>
<td>L</td>
<td>VL</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Administration</td>
<td>L</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Support</td>
<td>L</td>
<td>VL</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
</tbody>
</table>

\[ U_1 = \max\{\min(L,M),\min(M,M),\min(H,M),\min(VH,L)\} \]
\[ U_1 = \max\{L,M,M,L\} \]

\[ U_1 = M \]


