A Combined Process Mining for Improving Business Process

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Abstract—**Organizations use business process management to identify opportunities to reduce costs, increase service or product quality, etc. In this paper, a way to improve businesses processes using process mining techniques and standard methods of businesses process improvement is presented. Process mining has been used to fix the disadvantages of the existing standard methods. The presented approach is tested on a real process. After the process model is acquired using process mining analysis, business process improvement is proposed through a detailed analysis. Also, key performance indicators which are used to measure process performances, and a process model with a new resource allocation, which is improved from the aspect of the predefined key performance indications, is proposed. The experimental results have shown how the process can be improved with a better resource allocation.**

Keywords—*business process improvement; business process analysis; business process modeling; process discovery algorithms*

I. INTRODUCTION

Business process management (BPM) has become a new concept of management at the end of the previous century. Originally, BPM was accepted as a management discipline dealing with re-engineering and activity optimization in processes. The related economic methods were focused on documenting, modeling, and optimization was observed separately from IT. Today, BPM includes software products which are used by IT for modeling, implementation and execution of business processes. In [1] BPM is defined as: "supporting business processes using methods, techniques and software to design, enact, control and analyze operational processes involving humans, organizations, applications, documents and other sources of information". These days, business processes are obligated to be globally oriented, as well as being able to meet the needs of the group that uses them, whether it be employees, business partners, customers or management. Systems, as well as the requests, are becoming more complex, and the amount of data is getting increasingly bigger, in accordance with that it is necessary to use enhanced methods for improving business processes. Because of this, this paper presents a method which combines process mining techniques and the standard method for business process improvement.

The paper is organized as follows: section II presents a related work, which methods can be used to improve business processes combining similar approaches. Section III describes a method of using the presented approaches in business process improvement from the theoretical aspect. Business process improvement using the presented approach, is demonstrated on a particular process in Section IV. The conclusion of this paper is given in section V.

II. RELATED WORK

Using process mining techniques for improving business processes, as well as their combining with "traditional" methods of business process improvement is an already known topic. Z. Low and others in the paper [2] have presented how process improvement can be achieved by analyzing the execution history, i.e. by proposing process execution in the future, based on log files which contain detailed information about participants in the process, and about the duration of the steps in the process etc.

In her thesis [3], K. Gerke used process mining for managing and continuous process optimization. A procedure for continuous process improvement which detects deviations in process execution from the referenced model is presented. Deviation is detected by continuous monitoring of the execution and comparison to process specifications. Key performance indicators (KPI) indicators for the current (AS-IS) and enhanced (TO-BE) process model, are defined and compared. After that, processes, participants and resources are identified in the system, and the causes for the existing of differences in defined KPI indicators are analyzed. The presented method is tested on multiple processes in the ProM tool.

Paper [4] shows how waiting queues in the process can be analyzed using process mining. The authors have proposed the installation of predictors in the waiting queues and the results of the experiment have shown that predictors have a 30-40% higher accuracy in their results compared to the previous techniques.

It is possible to acquire hierarchical process models using a set of plug-ins [5]. The authors have implemented the presented approach in the ProM tool. The proposed method enables to reduce the complexity of the process model, to increase comprehensibility, to eliminate unnecessary details and it enables to achieve a better focus on the desired features of the process model. The simplification of the process model

using process mining techniques is presented in the paper [6], and the success of this approach is tested on real event log files.

In paper [7] a methodological approach for redesigning processes based on simulation techniques is presented, along with data and process mining tools. The presented methodology is comprised of: the problem description, determining the process set and identification of the participants, gap analysis, defining the project goal, extracting log files, discovering real process models, analyzing process performances, data mining analysis, analysis of key problems in the process, process simulations, improvement of the model, what-if analysis and implementation of the solution. This approach was experimentally tested in a process of acquisition in a private university in the USA. The combination of process mining techniques with simulation techniques is used in numerous papers [8-13].

III. COMBINING PROCESS MINING WITH CONVENTIONAL METHODS FOR BPM

Process mining can be used to discover, analyze and understand business processes based on the run-time behavior recorded in event logs [14]. Business processes can be analyzed from different perspectives using process mining techniques. Those perspectives are: data, organizational, workflow perspective and so on. The three main activities for which process mining is used are: discovery, conformance and enhancement. Using process mining it is possible to acquire a process model from the event log file. It is necessary that the event's log files are in MXML or XES format. More information about these formats can be found in [14].

Different algorithms such as the α algorithm, heuristic miner, genetic miner, are used for acquiring process models. Other than the acquirement of process models from the event's log files, the organizational structure included in the process can also be found. That way it is possible to analyze the exchange of tasks between the department and user, deploy of tasks, identify the participants that cooperate most in the process and so on.

The other way for implementing mining is conformance checking. In this case, an event log file is owned on one hand, and on the other, a process model. Using process mining, the concurrence of the real execution of the process model contained in the event's log files, and the process model, is tested. This way deviations, in case they exist, can be detected in real models and process models presented on "paper".

The third way of using the process mining is enhancing process models with additional data about the process such as probabilities of branching, duration of task execution, dependency between data and flow in the process and so on.

BPM methodologies have two main goals: presenting the execution of the current processes in organizations with activities and other corresponding elements, and presenting new process models in order to compare their performances [15].

Traditional methods of acquiring the current process model are realized through interviews, surveys, and workshops with participants in the process and business process owners.

Certain disadvantages of this approach exist. This approach is time consuming and expensive, especially in the case of complex processes in organizations. The biggest problem of this approach is that the process can be executed differently in reality than it is modeled, i.e. the disadvantages of this model are errors and incompleteness of the process. In order to avoid this problem, this paper will use process mining techniques for acquiring process models. The advantage of this approach is that it's accurate and it enables the acquirement of a process model like it is executed in reality, and it is possible to identify deviations. This approach is faster and cheaper than the traditional. The prerequisite for using this method is that there is information about the execution of the business process recorded in the log files.

IV. BUSINESS PROCESS ENHANCEMENT

A practical use of the presented approach is given in this section. The approach is tested on a process of managing business processes in a company in Bosnia and Herzegovina. This paper combines process mining techniques and standard methods of business process improvement presented in the previous section.

A. Analysis of AS-IS process model

As it is described in section III, business processes can be analyzed from different perspectives. In this paper, the process is analyzed from the workflow perspective. The genetic miner algorithm [16] was used for acquiring a process model from log files. Unlike the α algorithm, techniques for the heuristic and fuzzy mining approach, where the process model is acquired in one step and in a deterministic way, evolutionary approaches use the iterative method of finding solutions based on natural evolution. As with every genetic algorithm, there are 4 steps: initialization, selection, reproduction and stopping. Genetic process mining is flexible and robust. It can deal with problems of noise and incompleteness, as is the case with the heuristic approach. This approach can be easily adapted and expanded. Adaptaion to a particular problem can be done by setting the fitness function. The ProM tool [17] was used for acquiring the process model (Fig. 1). After applying the algorithm, a business process model like on ProM tool [17] was used for acquiring the process model (Fig. 2. is acquired.The acquired process model is converted to the value chain process model. More information about the value chain
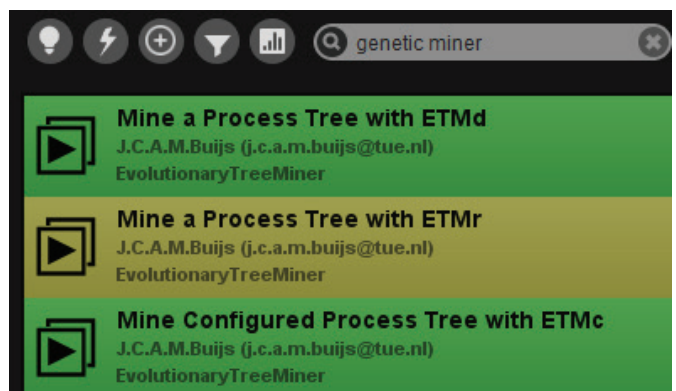

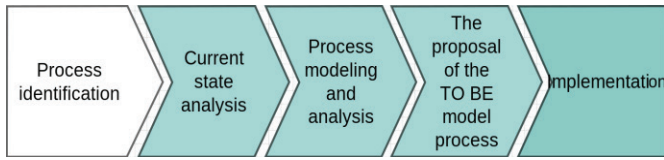Fig. 1. Application of the Genetic miner algorithm using the ProM tool.

Fig. 2. AS IS process model „Managing business processes".

process model can be found in [18]. The description of the business process steps is given below.

1) Process identification. The identification process of the business process starts with an internal initiative (from the company) or an external initiative (outside the company). After being accepted, the request is analyzed. Possibilities of realization with the help of their own resources and the eventual need for the engagement of external resources are considered among other things. Based on the analysis, the process for improvement is chosen and the project task is built. If the project task is not complex then the project task is built. If the issue is complex, an expert team is formed for the production of the project task, then the team develops the suggestion of the project task, which is then sent for revision. If the team's opinions for the revision are positive, then the suggestion for the project task is adopted. If the team's opinions for the revision are negative, then it is sent back for finishing, i.e., a re-production of the project task suggestion. When the Project task is adopted, then, if external collaborators are required, a service is arranged (ensured financial resources are required), and then the expert team's solution suggestion is produced.

2) Process modeling and analysis. Analysis and modeling of the business process starts with the verification of the AS-IS process model by the owner of the process. Deficiencies of the verified process model are determined with a simultaneous analysis of the cause of the deficiencies and comparison with the best practices, which results with a series of identified deficiencies of the process, which are then systemized in a document.

3) The proposal of the TO BE model process. Based on the document process shortcomings and improvement suggestions a suggestion of measures is produced for process improvement, then an activity operational plan for process improvement, which all together form the study of process improvement suggestion. If it is concluded that a revision is necessary, then the study revises the revision team, then after a positive opinion the study is adopted. If the revision is not necessary, the company's administration adopts the study.

4) Implementation. The end result of the process of improving the business process is an implemented, new, improved process which is implemented using the process of implementation. Based on the improvement proposal a way of implementation is chosen, which can be: change of organizational structure, change of the process, change of the documentation or technological change. After the change in the process, the change is documented, and the result is a new, enhanced business process, which is documented.

In order to measure the process performances it is necessary to define KPI. KPI present quantitative indicators of process execution. A KPIs are grouped into three units: *Cost KPI*, *Time KPI* i *Units KPI*.

Cost KPI

These indicators hold information about the cost of process execution, individual activities in the process, as well the cost of the resources engaged in the process. If c_i represents the cost of the *i*-th resource in the process in which *m* resources are engaged on *n* activities, then the total cost of all the resources engaged in the process in a time interval of (α, β) is (1):

$$C_{res} = \sum_{\substack{i=1,\dots,n \\ \alpha \leq t \leq \beta}} c_i \tag{1}$$

Also, a process can have work place costs as well as resource costs, such as: cost of workstation, cost of material, etc. If those costs are represented by $(c_a)_j$, then the total cost of the process under the assumption that activity *n* exists in the process is (2):

$$C = \sum_{\substack{i=1,\dots,n \\ \alpha \leq t \leq \beta}} c_i + \sum_{j=1,\dots,n} (c_a)_j \tag{2}$$

The total cost of activity *I* in the process is $c_i + (c_a)_i$, then the value of the relative cost of the activity is given in relation (3):

$$\frac{c_i + (c_a)_i}{\sum_{\substack{i=1,\dots,n \\ \alpha \leq t \leq \beta}} c_i + \sum_{j=1,\dots,n}(c_a)_j} \tag{3}$$

The goal in the business process improvement, i.e., development of the TO BE process model, is to minimize the value given with relation (2).

Time KPI

Time indicators refer to the time of the business process execution (*Cycle Time*), time of waiting (*Waiting Time*), a time of working (*Working Time*). Time of the business process execution t_c is equal to the sum of the waiting time w_i and working time t_i on all activities (4):

$$t_c = \sum_{i=1,\dots,n} w_i + \sum_{i=1,\dots,n} t_i \tag{4}$$

The waiting time w_i impacts the user's satisfaction. It is especially necessary to pay attention to this time in the process which serve end users, and it is necessary to be minimized. This time is related to the number of users that are assigned to the activity and it can be written $w_i = f(c_i)$. Also, this time is inversely proportional to the number of resources $w_i \sim 1/m_i$.

Units KPI

This indicator indicates process instances. The total number of executed process instances N, the number of process instances on activities M_i, the usage of resources u_i. All these parameters are connected to each other and it is impossible to

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observe them separately. The change of any of these parameters directly impacts the change of others parameters. These parameters can be measured using relations (5), (6), (7):

$$N = \sum_{i=1,\ldots,n} M_i \qquad (5)$$

$$M_i = \left\lceil \frac{t_i}{a_i} \right\rceil \qquad (6)$$

$$u_i = \frac{t_i}{\beta - \alpha} \qquad (7)$$

where a_i is the average duration time for activity i.

Cost KPI is related to time KPI through a number of human resources in the process. The larger the number of engaged human resources is, the larger the Cost KPI is. On the other hand, with a correct allocation of resources the time KPI can be decreased. When the number of resources in the process is smaller, the Cost KPI is smaller as well, but the time KPI is potentially larger.

The defined KPI indicators are used for measuring the performances of the AS-IS business process model.

B Proposal of the TO-BE process model

With the foundation of the process analysis „Managing business processes" the following weak spots of the process are identified:

1) The sub-process „Business Process Governance" is missing,

2) Adopted documents Framework for BPM and BPM politics don't exist,

3) Business processes are not mapped on strategic goals of the company,

4) There's no IT support for the process „Managing business processes" on the whole, with a special emphasis on modeling and quantitative business process analysis,

5) There is no standard form for a description of the business process,

6) There is no defined evaluation methodology for suggestions/initiatives for improvement,

7) There is no defined evaluation methodology for suggestions/initiatives for improvement,

8) A standard form for proposing improvement initiatives is not identified,

9) There is no continuous control and measurement of performances of the business process.

The following methods for business process improvement are established.

1) Improvement through process model change

The identified improvements which are classified as the business process improvements, refer to the proposal of business process flow or the establishment of a new process/sub-process, because the business process analysis identified redundancies in the process activities, process breaks or shortcomings of the clearly structured activity sequence.

2) Improvements through change of organizational structure or business rules

Business rules are definitions or restrictions of a certain business part. The rules are business politics excerpts and company practice. One of the applications of business rules is through defining business processes. The goal of the business rule is to controle or impact the performance of the business process, i.e. the business. The fact is that a organization's business changes over time, so it is necessary to change the business rules according to that. The business rule always needs to be set so it is possible to accurately determine its applicability, i.e. it is always clear what it means, what and who it refers to.

3) Improvements through digitalization of business processes

Process improvements which are directed to digitization of the business process, are focused on improvement through IT process support. The essence of the process doesn't change with this type of change, instead, it improves through increase in efficiency and automatization of certain activities.

4) Improvement of resource allocation in the business process

This method of improving the business process implies a better allocation of current resources in the business process, as well as the eventual engagement of new human resources in the process.

The proposed TO-BE process model is given in Fig. 3 [18].

The changes which are proposed in the TO BE process model are given below.

1) Establishing the subprocess „Business Process Governance". During identification of the AS-IS process it is established that the business process governance with which the mandate to the center of business process excellence is given, to follow and effectively manage business process, and identify and publish process owners. Governing business processes entails defining, making and implementing guidelines, rules, politics, which initiate responsibilities and activities during the entire life cycle of business processes.

2) Develop and adopt documents Framewrok for BPM and BPM politics. The main activities in the process 'business process governance' are production and adoption of documents framework for managing business processs, and politics of managing business processes, which, together with the methodology for managing business processes and conventions of modeling, present a mechanism for real business process management.

3) Business processes are not mapped on strategic company goals. The company's strategy is executed through the company's business processes, and therefore it is necessary within the 'process business process governance' to map which process impacts the execution of which strategic goal, in order for the execution of the strategy to be as effective as possible.
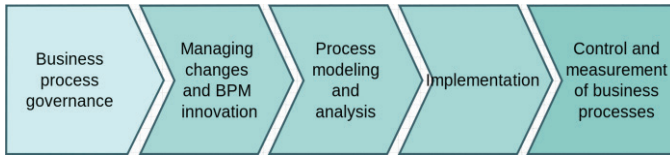
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Fig. 3. TO-BE process model „Managing business processes".

Other than that, mapping processes on strategic goals will give an insight to which processes are critical, i.e., key processes for execution of the strategy, and those processes will have a higher priority during the evaluation and selection of initiatives for improvement.

4) There's no IT support for the process „Managing business processes" on the whole. There's no IT support for the process „Business process governance" on the whole, with a special emphasis on modeling and quantitative business process analysis. This disadvantage is already acknowledged from the company, and it is entailed in the project „Implementation of the software platform for design and managing business processes", in which this document was made, software for managing business processes was acquired, which are mostly gonna be used in modeling activities, analysis and business process implementation.

5) Standardized form. It is necessary to adopt a standardized form for business process description within the methodology of managing business processes.

6) Standardization and adoption of the improvement suggestion/initiatives evaluation methodology. Identification, classification and improvement suggestion/initiative methodology adoption is proposed within the methodology for managing business processes.

7) Production and adoption of the form for the improvement initiative suggestion. Within the entire business process improvement „Managing business processes", production and adoption of a standardized form „Initiative for business process improvement" is proposed, with which a mechanism would be established where all owners can, according to the Sector for managing business processes,
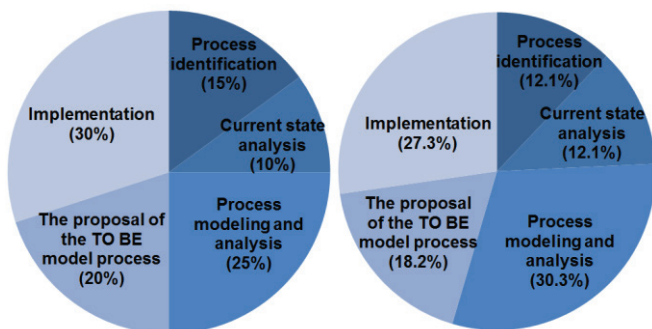
Subprocess	Current number of resources	Proposed number of resources
Process identification	3	2
Current state analysis	2	2
Process modeling and analysis	3	3
The proposal of the TO BE model process	4	3
Implementation	4	3

direct a suggestion for business process change/improvement.

Process controlling and business process measurement introduction. In order for the business process management to be executed based on the business process performances, i.e., real numbers, an integration of the BPM system with transaction systems is proposed, which support the execution of particular processes, in order to be able to follow the process execution in real time and to follow the previously defined KPI indicators.

8) Resource allocation in the process [10]. Analysis of the AS-IS process model established that the total number of allocated human resources in the process is 16. Three are allocated on the subprocess Process identification, two are allocated on the Current state analysis, as it is presented in table 1.

The proposed number of resources is also presented in table 1. For determining the proposed number of resources a simulation model was previously built [12]. For testing model SimEvents library was used from Matlab. The previously defined KPI indicators were measured: price of resources in the process C_{res} and the total resource utilization u_i. Fig. 4 shows the current share of the resource prices in the process, and it also shows that the largest expense is on sub-processes *Implementation* and *Process modeling and analysis*. The expenses are formed taking into account the number of resources, price of resources (work price) as well as the price of the work place. Fig. 4. also shows the share of the resource prices, according to the proposed resource allocation. Resource utilization is analyzed for the proposal of resource improvement in the business process (Fig. 5.) and the current expenses allocation (Fig. 4.). The black bars represent the
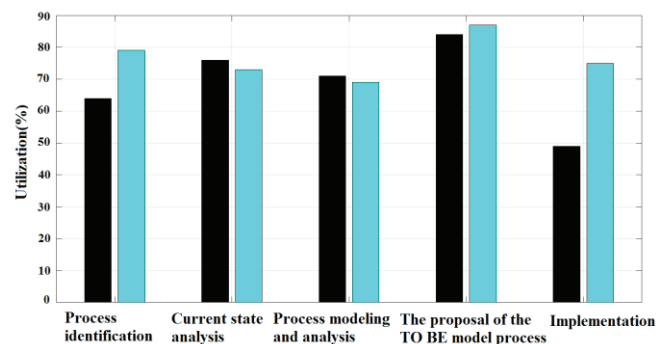

Fig. 4. The current and proposed allocation of expenses in the process „Managing business processes".

Fig. 5. Utilization of resources in the process „Managing business processes".

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current utilization of the resources in the business process, and the cyan bars represent the resourse utilization in the proposed resource allocation acquired with the simulation analysis. The figure shows that the proposed resource allocation enables *identification*, *The proposal of the TO BE model process* i *Implementation*. It is especially expressed in the subprocess *Implementation*. Also, the proposed solution releases three resources which can be used in some other processes in the organization. The results were presented to a company that will further decide about the business process improvement, but the procedure of process changing is slow and long.

V. CONCLUSION

This paper presents an approach for business process improvement using process mining and standard methods for business process improvement. First, the AS-IS process model is acquired. In order to get the current process model the way it is executed in reality, the genetic miner algorithm from the class of process discovery algorithms is used. KPI indicators, which are used for measuring the current process being executed, are defined. The TO-BE process model which is susceptible to a process flow change, is proposed. Other than the change of the process flow, a way of working on some activities in the process is proposed. Performances of the process are measured from the aspect of resource usage and their cost in the process. A new resource allocation is proposed on the current process in order to ensure better resource usage. For KPI measurement, the simulation model was previously built.

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