Discovery and Evaluation of Fixed Capital Facility Processes Based on Process Mining Approach: A Case Study of the Bank Loan Acceptance Process in Iran

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***Abstract*-- Fixed capital facility processes have many steps, control points, and approvals with long durations. In this regard, banks with more awareness and knowledge by analyzing and evaluating their processes can do better than their competitors in improving them and providing customer service. To tackle this challenge, process mining is one of the effective and efficient methods for analyzing processes, i.e., discovering and evaluating their quality. This paper aims to find and evaluate the model of the fixed capital facilities acceptance process based on the mentioned method. The proposed six-step method includes event logs preparation, process model discovery, evaluation and compliance checking, results analysis, analysis based on the fuzzy method, and comparison of results. The discovered process model is evaluated based on the quality dimensions of the process model, namely precision, fitness, simplicity, and generalization. Also, the results obtained from different methods are compared with each other. In addition to the discovery of the process model, one of the results was the heuristic algorithm having the best performance in terms of the mentioned criteria, with a value of 0.833. Particularly, it excelled in precision with a value of 0.656. The genetic algorithm, with a value of 0.946, exhibited the best fitness performance. Another result is the superior performance of the fuzzy technique compared to other methods. Furthermore, bottlenecks, activities with the highest repetition in a case, and branches and users with the most significant role in the process were identified.**

***Index Terms*-- Fixed capital facilities, discovery, process mining, fuzzy method, process model quality**

I. INTRODUCTION

The core of today's organizations is business processes, and each organization uses several processes to provide services according to its nature and field of work[1]. Financial and banking organizations have long-term facility processes, which are complex and involve many steps, control points, and approvals. Fixed capital and working capital are among the most common types of facilities offered to businesses in Iranian banks to maintain the status quo or develop. The processes of providing fixed capital or working capital facilities have several sub-processes or macro-stages. Among others, we can refer to the processes of acceptance, evaluation, monitoring, contract, or payment. One of the crucial operational steps in fixed capital processes is the process of loan acceptance, which includes activities related to the facility application [2].

Today, banks and financial institutions that have more awareness and knowledge about their operational and daily processes can perform more successfully than others and competitors. Therefore, the evaluation of the running processes is of great importance. However, the analysis and investigations related to the improvement, efficiency, productivity, and promotion of such processes using old and traditional methods have various challenges[3]. Nowadays, such assessments and analyses are performed using a process model; in fact, process models play a fundamental role in organizations for redesigning, conformance checking, and process evaluation[4]. Traditionally, the criteria of connectivity, coherence, complexity, modularity, and size were used to evaluate business processes, which were based on the formal process model[5-7]. The results based on these criteria can be far from the reality and the results after the implementation of the processes. According to the investigations carried out for the analysis and evaluation of business processes, two points of view, based on the official process model and event log, are of great importance[8]. Considering that the type based on the event log is based on the results of implementation, this point of view has been used in the present research. Process mining is one of the effective and efficient techniques based on event logs that are used today to analyze and evaluate organizational processes. This technique can identify and discover the process model, problems, inefficiencies, defects, and bottlenecks. Its important features are: the discovery and evaluation of process models, performance analysis, conformance checking, organizational analysis, and process continuous improvement [9].

Considering that for the analysis and evaluation of processes, the used process model is of great importance, the

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choice of the desired algorithm and technique in discovering the model and the quality of the discovered model are also of great importance [10].

Common techniques such as alpha, alpha++, genetics, and discovery, along with the fuzzy method, are among the process model miners [11]. Also, the criteria of precision, fitness, generalization, and simplicity are used to evaluate the quality of the discovered process model [12].

Considering the importance of analyzing banking processes, especially the processes of fixed capital facilities for financial institutions, and the efficiency of the process mining method for analyzing such processes, the main contributions of the present research can be described as follows:

1) Discovering the model of the fixed capital facilities acceptance process based on the results of the process implementation, i.e. the event logs extracted from the studied bank facility system based on the common methods of model discovery, i.e. alpha, alpha++, genetic, and heuristic algorithms.

2) Evaluating the discovered models based on process model quality criteria, i.e. fitness, precision, generalization, and simplicity, and comparing the results with each other.

3) Discovering the process model based on the fuzzy method and comparing it with the results of common methods of discovering the process model.

Additionally, in this research, the event log of the fixed capital loan acceptance process of one of the active banks in Iran is used. Also, the required analyses are performed based on ProM 5.2 and Fluxicon Disco tools.

The research questions are as follows:

1. What model do the processes of accepting fixed capital facilities have in practice and reality?
2. What is the quality of the discovered processes model according to the evaluation criteria?
3. What knowledge and information can be extracted as a result of the process mining of facility acceptance processes?
4. Overall, which technique has better performance for analyzing and evaluating loan acceptance processes?

The rest of the present paper is organized as follows: Section II reviews related works. The research method is explained in Section III. In the following, the findings and discussion are presented in sections IV and V, respectively. Finally, conclusions and future work are presented in Section VI.

II. RESEARCH LITERATURE

In this section, concepts related to the research literature are briefly discussed: fixed capital, process mining, process model quality metrics, and research background.

A. Fixed investment

In accounting or economics, fixed investment refers to physical assets held for a certain period. In other words, it is not used for current expenses[13].

B. Process mining

Process mining methods provide the insights necessary to control, manage, and enhance processes[14]. There are different types of process mining. The three main types are discovery, conformance checking, and enhancement. The purpose of discovery is to extract a model based on event logs without using previous and official information. The type of conformance checking determines whether the event logs conform to the discovered model and vice versa. Enhancement refers to the improvement of a process model using event logs[15].

C. Process model quality metrics

The purpose of discovering the process model is to automatically generate the process model based on the recorded event data resulting from operational processes. In the last decade, many process discovery methods have been developed. Each of these techniques uses a different method to obtain the process model. Various quality dimensions or metrics are used to measure how well a process model describes the cases. The evaluation of the Petri net-based process model is based on the mentioned metrics[16]. These criteria are: fitness, precision, generalization, and simplicity[17]. Fig. 1 depicts these criteria.

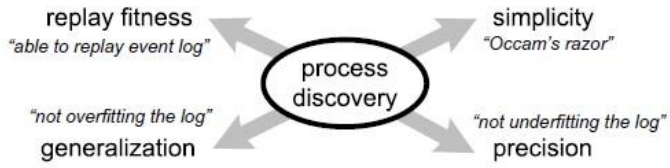

Fig. 1. Quality metrics for process model discovery[17]

C.a. Fitness

The fitness metric refers to the ability of a model to replay the behaviors recorded in the event log, that is, the more the process model can play a larger number of behaviors (cases) without problems, the better the fitness [18].

C.b. Simplicity

The metric of simplicity in the model refers to the comprehensibility of the model, in other words, how easily the discovery model can show the observed behaviors in the event log[18].

C.c. Precision

The precision metric refers to not allowing the process model to play behaviors that are very different from the behaviors in the event log[18].

C.d Generalization

The metric of generalization refers to the fact that the process model should not be exclusive to the behaviors mentioned in the event log but should be able to be generalized to other behaviors[18].

D. Research background

Dila et al. used the V-model to verify and validate business processes to detect errors. Verification and validation are techniques used to detect errors, inconsistencies, and incompleteness in samples. Verification involves a set of

activities to ensure the correctness of the model, while validation ensures that the model is meaningful to users[19]. Delias et al. used the techniques of doubly robust estimation, propensity score weighting, and regression adjustment to evaluate the impact of interventions aimed at improving the business process model based on event logs, to reduce errors. This research presented a step-by-step method[20].

Kady et al. investigated deviations from the model of beekeeping processes during implementation through the evaluation of pattern-based models. This research uses a common library of random patterns about making deviations during execution and simple techniques based on mathematics to prevent the use of inconsistent patterns[21]. Victor Gallego Fontanella et al. used conformance checking metrics to automatically detect Gradual Drift Detection on a synthetic event log with different distributions of changes. Compared to the main state-of-the-art algorithms, it had better classification accuracy[22]. Urrea-Contreras et al. used process mining to improve the software development process in SME organizations. The method used had the steps of pre-processing Jira system event data, model discovery and compliance check, and other process analysis perspectives[23]. EL KODSSI & Sbai, applied process mining in a smart environment based on unstructured data generated by sensors. The method used includes the steps of selecting, converting, and generating event logs, applying process mining, and generating a process model[24]. Rashed et al. applied process mining techniques in the healthcare context to discover typical pathways followed by specific patients. The proposed method consists of three stages: pre-processing, model discovery, and performance analysis[25]. Erdogan & Tarhan used multi-perspective process mining techniques to analyze the goal-based performance of the emergency process to understand and recognize the timeliness of emergency services[26]. Daniel Reibner, Abel Armas-Cervantes, and Marcello La Rosa presented a six-step process mining framework, which includes find, build, derive, extract, and aggregate, to calculate pattern-based generalization criteria. Additionally, the mentioned framework was instantiated into a measure based on repetitive and concurrent patterns with nine steps[27]. To understand the quality of real models in organizations, Burke et al. studied the quality metric and relationships of the stochastic process model based on two experiments. Six real event logs were used. The models were based on random generation and stochastic discovery. By analyzing a variety of calculation metrics among the available models, three quality dimensions of adhesion, relevance, and simplicity were proposed[28]. Sungkono et al. presented the Graph Advanced Invisible Task in Non-free choice technique in a study for the management of large event logs, that is, partitioning event logs and generating rules to join these chunks. Compared to similar methods, this technique had better performance in the evaluation of extractive models, based on fitness, precision, generalization, and simplicity metrics[29].

Gorji et al presented a methodology based on process mining by developing a questionnaire. It includes the preparation of an event log of education processes in Mazandaran province, using model discovery techniques such as alpha, alpha++, heuristics, and genetics. The discovered models are then evaluated and matched with the drawn processes. Genetic and heuristic algorithms performed better in fitness and simplicity metrics[30]. Blum gave a survey study to group metrics such as fitness, precision, generalization, and simplicity regarding the process model evaluation discovered from various process mining techniques[18]. Adriansyah et al presented a precision metric based on alignment to evaluate the quality of the process model and evaluated it on synthetic and real event logs[31]. In a study, Buijs et al showed that process discovery algorithms usually cover two metrics out of the four main indicators[17].

Van Dongen et al presented the criteria of fitness, precision, and generalization based on alignment and anti-alignment to evaluate the quality of process models[32].

Dharmawan and Amelia presented a system for evaluation to improve the quality of Micro, Small, and Medium Enterprises processes. In this research, seven quality control tools were used: cause and effect diagrams, Pareto charts, histograms, control charts, scatter charts, quality control charts, and check sheets[33]. Kahloun et al used the metrics of coherence, coupling, complexity, modularity, and size to evaluate processes with a case study of the tracking of curriculum offers process[5].

Vim Khalif et al adopted the criteria related to the concepts of the business process model with the object-oriented software metrics. They obtained new criteria that provide more information about the complexity of the business processes, the coherence between the tasks of the process, and the coupling between the processes themselves. Processes that have less connection and more coherence are higher quality process models[6].

Although each of the studies listed in Table I has reached its goals, some of them were limited to providing models or frameworks, while others were based on formal model methods. Additionally, other research that was based on process mining only focused on Petri net-based model quality criteria. Therefore, there is a research gap in examining the real data obtained from the information system by considering and comparing the discovery and evaluation methods based on Petri net and fuzzy models. It is also necessary to consider the introduction of a combination method that can be used by experts in the field of work.

III. RESEARCH METHOD

The method used in the present research is based on the techniques and concepts of the mining process in its manifest[34]. The event log used in this research is related to the process of accepting fixed capital facilities of an active bank in Iran. The mentioned method includes six stages: extracting and preparing the event log, discovering the process model based on common algorithms, conformance checking and evaluating the process model based on the quality metrics of the model, analyzing the results of the third stage, analyzing based on the fuzzy techniques, and comparing the results and summing up with experts in the field of work. The mentioned method is depicted in Fig. 2.

TABLE I
Comparison of Studies

point of view	goals	study
Presentation of the model and framework	Verification and validation of business processes to detect errors	[19]
Combination of business process management and process mining	Using doubly robust estimation techniques, combining propensity score weighting and regression adjustment, to evaluate the impact of interventions to improve the business process model based on event log to reduce errors	[20]
Pattern-based model with the assistance of domain experts and mathematical techniques	Evaluation, improvement, and modification of the process	[21]
Process mining	Detect Gradual Drift Detection	[22]
Process mining	Process model discovery, and other analyses	[23]
Process mining	Process model discovery	[24]
Process mining	For model discovery, and performance analysis	[25]
Process mining	Multi-perspective analyses	[26]
Process mining	to calculate pattern-based generalization criteria	[27]
Process mining	To propose three quality dimensions of adhesion, relevance, and simplicity	[27]
Process mining	To evaluate extractive models	[29]
Process mining	Re-engineering the organizational structure and evaluating the process model	[30]
Based on quality control tools	Improving the quality of micro, small, and medium enterprise processes.	[33]
Official model metrics	Evaluating the process model with a case study of tracking the curriculum offers process.	[5]
Process mining	Evaluation of the quality of the process model	[32]
Process mining	Categorizing the metrics that have been proposed to measure the results of different techniques about process .discovery techniques	[18]
Process mining	Evaluating the quality of the process model on synthetic and real event log	[31]
Process mining	Examining the effect of model quality metrics	[17]
Business process management by the concepts of object orientation	Examining the complexity of business processes, coherence between process tasks, and interconnection between processes	[6]

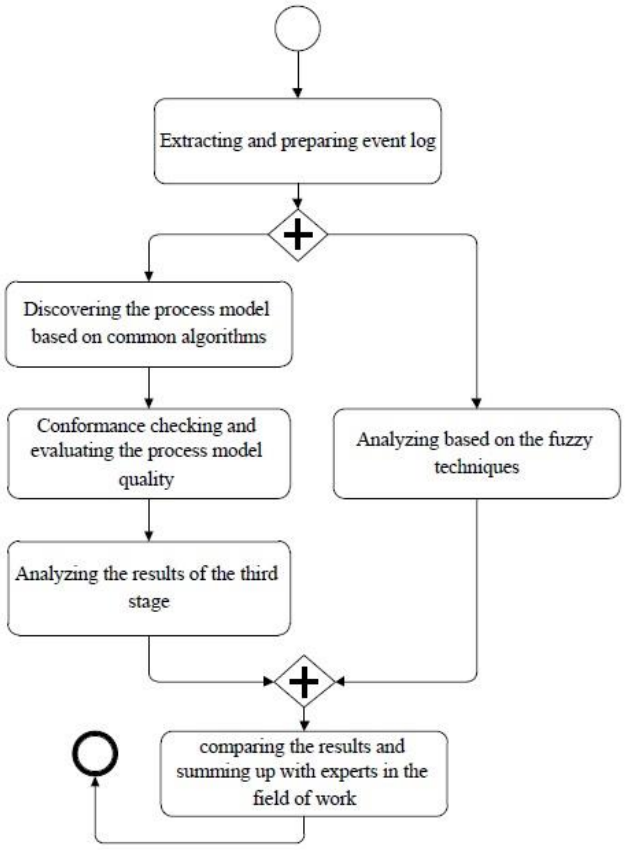

Fig. 2. The proposed method

A. *Extracting and preparing event log*

In this stage, the event log is extracted from the information system related to loan acceptance. The event log includes the loan acceptance number, activity name, start timestamp, end timestamp, branch ID, and actor. The data is then cleaned to address missing values, incomplete data, loans added from intermediate stages, and records without dates and activity. To maintain data confidentiality, the branch and actor values are coded. Additionally, event log traces and Latin naming related to stages are simplified, and traces with less than two repetitions are excluded from the research. Finally, an XML file is prepared for entering into ProM 5.2 tools.

B. *Process discovery based on common algorithms*

In this step, by entering the event log prepared in the previous step into ProM 5.2, the process model is discovered based on alpha, alpha++, heuristic, and genetic algorithms. To evaluate the quality of the discovered process, the heuristic and genetic process models are converted into a Petri net [35-37].

Considering that the studied process is unstructured, in other words, it has a large number of traces with a small number of behaviors, and the superiority of the heuristic method is in the face of noise and low-repetition behaviors[37]. Therefore, this method is also used to discover the process model.

C. *Conformance checking and evaluation of the process*

At this stage, the compatibility between the event log and the discovered models is checked, and the values related to the metrics of precision, fitness, and simplicity are calculated using the ProM 5.2 tools. The generalization metric is calculated using (1) [17].

$$Q_g = 1 - \frac{\sum_{nodes}\left(\sqrt{\#executions}\right)^{-1}}{T} \quad (1)$$

In the above formula, T refers to the total count of process model transitions and #execution refers to the count of executions of each transition according to the different traces in the event log.

D. Analyzing the results of the third stage

In this step, the values of fitness, precision, simplicity, and generalization metrics, along with the average value of these indicators related to different algorithms, are calculated and compared with each other.

E. Analyzing based on the fuzzy method

The prerequisite for examining process models based on common algorithms used in this research is Petri net-based. These networks are not suitable for complex processes with too many connections and for real event logs. They face problems and challenges such as representational bias and internal inconsistency. Internal inconsistency means that when the event log is replayed by the model, there is a possibility of a deadlock or remaining token, meaning the model is not sound[10]. Additionally, the discovered model based on methods such as alpha, alpha++, heuristics, and genetics cannot be analyzed and understood when the process is unstructured and has many connections between activities. The model resulting from the mentioned techniques does not have features such as aggregation, abstraction, emphasis, and customization [38]. In contrast, the fuzzy algorithm can balance the process model in terms of the four mentioned metrics and can zoom in and out of the process model, filter activities, and connections between activities based on their importance[34]. A fuzzy algorithm based on three basic indicators of unary significance, binary significance and binary correlation, and other criteria i.e. relative significance, utility, and utility ratio between activities A and B can ignore the unimportant edges entered into the activities[38].

Unary Significance: refers to the frequency of each activity.

Binary Significance: deals with the frequency of connections between two activities.

Binary Correlation:: This metric refers to the correlation between two activities and calculates its value.

Relative significance is calculated based on equation (2)[38].

$$rel(A,B) = \frac{1}{2} * \frac{sig(A,B)}{\sum_{x \in N} sig(A,X)} + \frac{1}{2} * \frac{sig(A,B)}{\sum_{x \in N} sig(X,B)} \quad (2)$$

rel(A, B): relative significance between two activities

N: count of activities

sig(A, B): the frequency of connections between two activities

A and B: two examples of activities

For each edge A → B, its utility, util (A, B), which considers the weighted sum of significance and correlation, the edge filter approach is implemented.

Utility is calculated based on equation (3)[38].

$$ratio\ ur \in [0,1]\ util(A,B) = ur*sig(A,B)+(1-ur)*cor(A,B) \quad (3)$$

cor(A, B): measures the distance between events in a precedence relation, that is, how closely related two events are to each other.

The utility ratio is denoted by "ur" and can have a value from 0 to 1. It is used to calculate the utility between activities. In this research, the variable used to analyze the process performance analysis is the average time of the activity.

F. Comparing the results and summarizing with experts in the field of work.

In this step, all the results obtained from steps 3 and 5 are examined and scrutinized, and the models, results, and achievements obtained are reviewed by experts in the field. Finally, the consolidated knowledge obtained from the research results and field specialists is provided to the organization.

IV. Results and findings

In this section, the findings and results related to the research are presented according to the steps mentioned in the research method.

A. Extracting and preparing event log

The dataset used in this research includes 546 cases of acceptance of fixed capital facilities with 13 stages, including 6052 event log records related to one of the active banks in Iran.

The dataset used in this research includes the following fields, which are recorded and stored by the facility system of the studied bank as an event log:

Case ID:

The unique number of each facility is generated by the facility system during the registration of the facility request.

Activity:

It refers to the stages of the facility process. In other words, several steps are taken until the facility is paid to the applicant to complete the process.

Start Time Stamp:

Refers to the start date and time of each stage.

End Time Stamp:

Refers to the date and time of completion of each stage.

Resource:

Refers to the branch performing the activity.

Actor User:

Refers to the user performing the activity.

Simplified Activity:

The simplified title of the steps to create the input XML file of the ProM5.2 tool.

Table II lists the Latin names associated with the process steps for preparing the XML file and entering it into the ProM 5.2 tools.

TABLE II
Simplifying Process Steps

Activity	Simplified	Activity	Simplified
Completing/editing project specifications	E	Examining the second stage of fixed capital	M
Management and technical departments of fixed capital	G	Trusteeship Committee	N
Financial sector of fixed capital	F	Investigating the first financial and technical stage of fixed capital	L
Registration of design and product specifications	D	Referral of fixed capital request to the user 3 financial-managerial and technical .departments	B
Fixed capital market sector	I	Investigating the first stage of the fixed capital market	K
Referring to the fixed capital request to user 2	A	Registration of project specifications - location and permits	C
Referral of fixed capital request to the user 3 - sections of the market			H

After filtering the traces with fewer than 2 cases, the remaining 301 cases were analyzed. Table III displays the simplified event logs, which include traces and the frequency of cases for each trace. Disco, Excel, and SQL Server tools were used to calculate the frequency of cases for each trace.

TABLE III
Some of the Traces, Along With the Count of Cases For Each Trace

Trace	Count	Trace	Count
ABCDEFGLM	22	ABEGLMN	11
ABCDEGFLM	21	ABEHGFLIKM	11
ABCDEGLM	19	ABCDEGHFLIKM	10
ABEGLM	19	ABCDEGLMN	9
ABEFGLM	13	ABCDEFHGLIKM	9

Table III shows some of the traces along with the count of cases for each trace.

Subsequently, the XML file generated from the traces was prepared. Table IV shows a portion of the event logs.

TABLE IV
A Part of the Event Logs

Case ID	Activity	Start Timestamp	Complete Timestamp
2085	Referring to the fixed capital request to the user2	6/11/2017 11:48	6/11/2017 11:53
2085	Referral of fixed capital request to the user 3 financial-managerial and technical departments.	6/11/2017 11:53	6/11/2017 13:28
2085	Registration of project specifications - location and permits	6/11/2017 13:28	6/12/2017 17:15
2085	Registration of design and product specifications	6/12/2017 17:15	6/12/2017 17:21
2085	Completing/editing project specifications	6/12/2017 17:21	6/12/2017 17:26

The part of the prepared XML file:

```
<Process id="1" description="Dr_Log_ProM5.2">
<ProcessInstance id="1" description="ABCDEFGLM">
<Data>
<Attribute name="numSimilarInstances">22</Attribute>
</Data>
<AuditTrailEntry>
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</AuditTrailEntry>
<AuditTrailEntry>
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<AuditTrailEntry>
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<AuditTrailEntry>
<WorkflowModelElement>M</WorkflowModelElement>
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</AuditTrailEntry>
</ProcessInstance>
```

B. Process discovery based on common algorithms

At this stage, the process model was discovered based on alpha, alpha++, heuristic, and genetic algorithms. Considering that a Petri net is needed to perform conformance checking on the discovered models of genetic and heuristic algorithms, the mentioned models were converted into a Petri net.

The discovered models are depicted in Fig. 3.

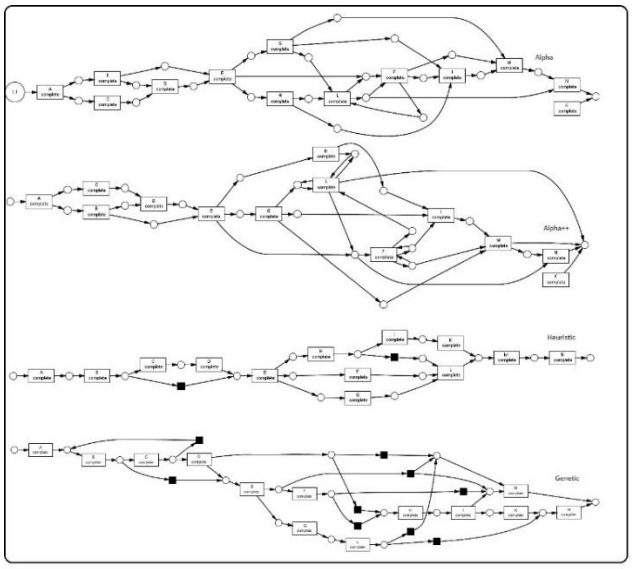

Fig. 3. Discovered models based on the methods used

C. *Conformance checking and evaluation of the process*

At this stage, based on the discovered model of the used algorithms, conformance with the event report was checked. The values of fitness, precision, simplicity, and generalization metric related to each algorithm, along with their average, are listed in Table V.

TABLE V
Comparing the Results of Algorithms

Algorithm	generalization	precision	fitness	Simplicity	average
Alpha	0.852	0.363	0.776	1	**0.747**
Alpha++	0.859	0.363	0.731	1	**0.738**
Heuristic	0.836	0.656	0.843	1	**0.833**
Genetics	0.836	0.541	0.946	1	**0.830**

Fitness refers to the ability of a model to replay the behaviors recorded in the event log. That is, the better the process model can play a larger number of behaviors (cases) without problems, the better the fitness. The simplicity in the model refers to the comprehensibility of the model, in other words, how easily the discovery model can show the observed behaviors in the event log. The precision refers to not allowing the process model to play behaviors that are very different from the behaviors in the event log. The generalization refers to the fact that the process model should not be exclusive to the behaviors mentioned in the event log, but should be able to be generalized to other behaviors[18].

D. Analyzing the results of the third stage

Examining and evaluating the discovered process model resulting from different techniques shows that the Alpha and Alpha++ algorithms do not cover traces with K activity. Contrary to this, genetic and heuristic techniques can cover traces with K activity. The research showed that the Alpha and Alpha++ algorithms are not fully efficient regarding the real event log related to the information system of providing fixed capital facilities. According to Table III and the comparison of different algorithms based on the mentioned metrics, the simplicity value for all four techniques is equal to 1, which shows the comprehensibility of the process model. The genetic and heuristic algorithms respectively had the highest fitness value, and the alpha generation algorithms had lower fitness. The heuristic method was superior to other methods in terms of precision.

The Alpha algorithm had the lowest precision. In terms of generalization, the Alpha++ algorithm has the best performance. One of the challenges of the mentioned methods is the act of simplifying and preparing the XML file and relying on Petri net for analysis. On the other hand, usually real event logs are unstructured, have wide connections, and have a large number of steps. Simplifying them is very difficult and faces human error. According to the mentioned cases, if other phases related to the process of providing fixed capital facilities and a comprehensive review of the process are added, the models discovered by the mentioned methods will not be very understandable and analyzed. Therefore, there is a need to use fuzzy methods that have the appropriate characteristics of this issue for real running processes.

E. Analyzing based on the fuzzy method

At this stage, without applying filters and simplifications, all 6052 event logs, including 546 facility cases, were entered into ProM5.2 tools. By considering ur = 0.7 and including all activities, the process model was discovered. The important point was the high flexibility of this method for the analyst's initiative. This method provided a lot of information and knowledge by applying multiple filters on concurrent, looping, and other activities. Next, the event logs were entered into the Disco tools for the desired analysis. In the extracted model, the frequency of each activity was calculated about the total cases. Activities A, E, and G had the most repetitions in a case. Fig. 4

shows a part of the discovered process model with ProM 5.2 and Disco tools and a count of frequent activities. For the mentioned activities, the repetition values in a case were obtained as 19, 10, and 8, respectively, and this can indicate a deficiency in the implementation of the process.

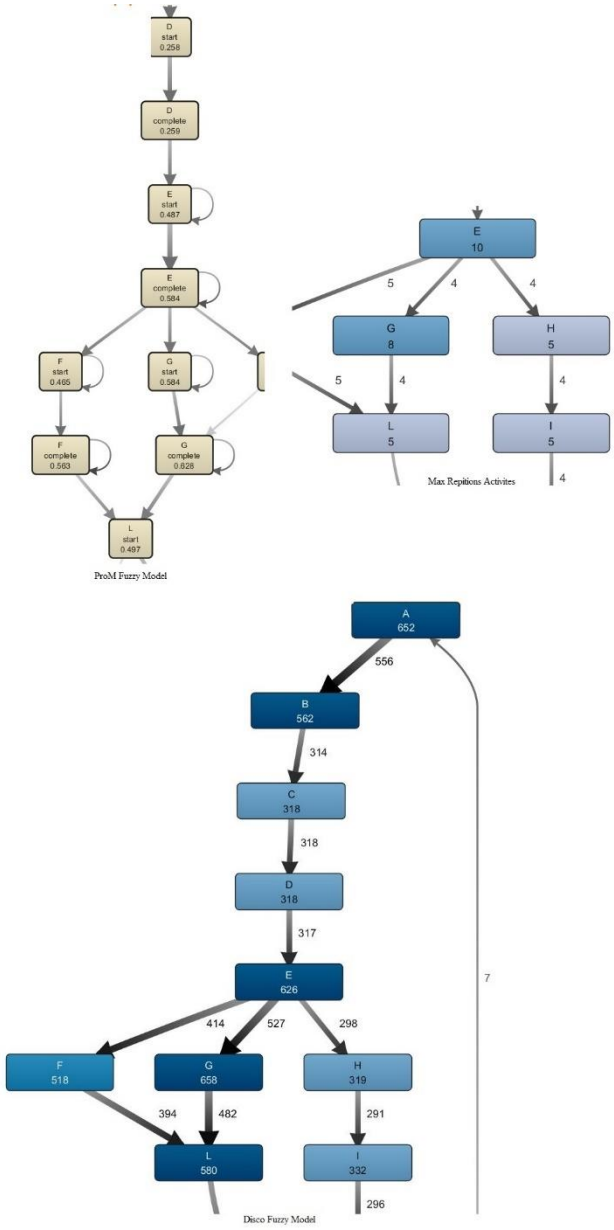

Fig. 4. Discovered models based on the fuzzy method

By using the performance analysis feature of the Disco tools with a filter of cases less than 7 days, activities C, F, N, and I, which refer to steps Registration of project specifications - location and permits, financial sector of fixed capital, Trusteeship Committee, and fixed capital market sector respectively, were identified as bottlenecks in the process of accepting fixed capital facilities. Fig. 5 shows a part of the performance analysis. Also, cases with high average waiting times, process variants were identified and the statistical information of activities and users were extracted.

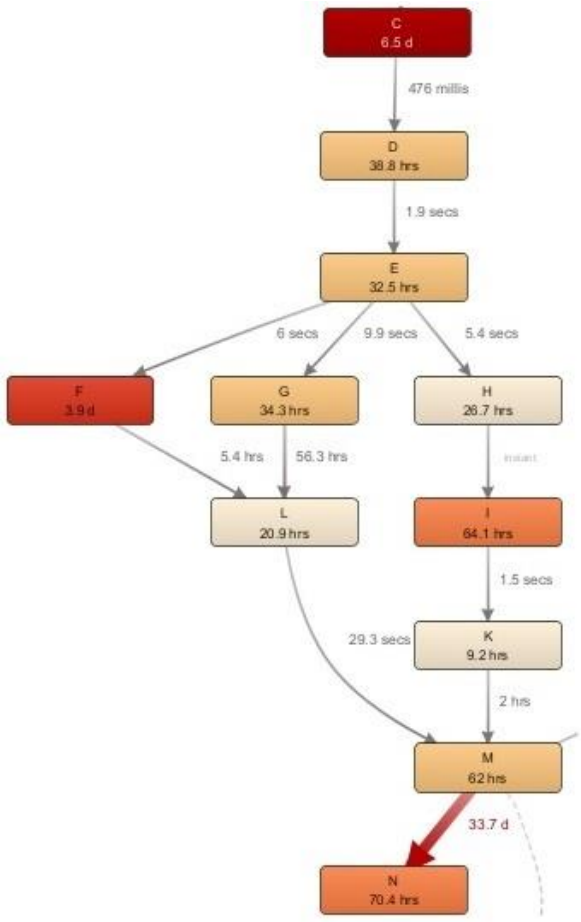

Fig. 5. Identified bottlenecks

Another output that could be extracted based on the fuzzy method is the handover works in different bank branches. Branch No. 50 was recognized as having the greatest role among the branches in carrying out the payment processes of fixed capital facilities. Also, the users who played the most important role in the process were identified. Fig. 6 shows parts of them, the names of them have been coded to maintain confidentiality.

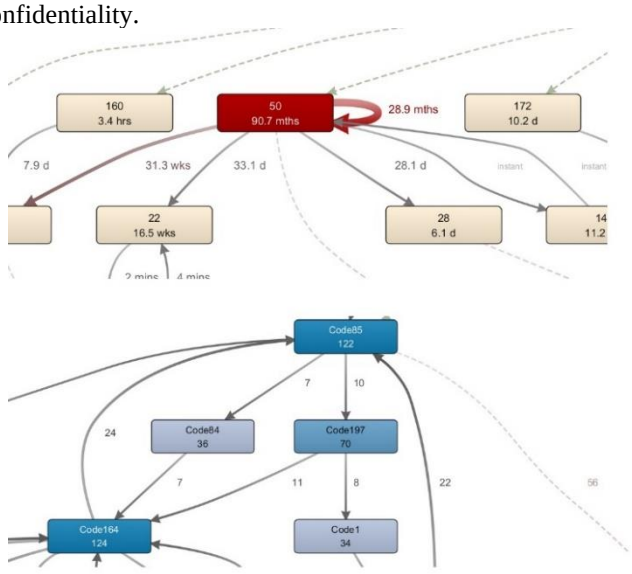

Fig. 6. Users and branches play the most significant role in the process.

A lot of knowledge and statistical information was obtained from the fuzzy method, which is omitted in this research due to its practicality.

F. Comparing the results and summarizing with experts in the field of work

According to the findings regarding the quality metrics of the process model, the heuristic algorithm demonstrated the best performance among the process models based on Petri net. This was determined based on the average value of metrics such as fitness, simplicity, generalization, and precision. However, a drawback of this method was the lack of flexibility in its discovery model, which made it difficult for experts in the field to analyze and understand the process. In other words, it was not possible to filter and personalize the process model based on features such as binary correlation and binary significance of activities. The discovered process models based on alpha and alpha++ did not perform well due to their low average value in the mentioned dimensions.

In addition, the current research showed that the fuzzy method, in addition to having no restrictions for repeating activities in a case, does not need to simplify the event logs. It also provides a lot of knowledge about the real process model, frequent activities, process performance based on the average time of activities, and other statistical outputs. According to the review and presentation of the mentioned achievements to the field experts, the discovered process model obtained from the methods used in the research, especially the fuzzy technique, was approved. In addition, the bottleneck activities identified by the fuzzy method were introduced to the field experts to modify and improve the process, and the field experts confirmed the results of the research.

After discussing and exchanging opinions and reviewing the mentioned results, correction suggestions were presented. These suggestions include merging and removing some activities, solving the problem of the information system regarding the repetition of certain activities, and modifying the process model.

Additionally, based on the findings of the current research, the branches and users who played the most significant role in the process were introduced to the bank. With the investigation carried out by the experts, problems such as the excessive repetition of some steps and the sheer compliance of the information system used with the existing situation without structural and process redesigning were identified. In this regard, according to the knowledge and information discovered, necessary suggestions for improving the process, dividing appropriate work, delegating authority to the branches, solving bottlenecks in activities, and changing the information system were presented as a scientific report that can be relied upon and trusted by the trustees for decision making.

V. Discussion

This study showed that one of the best methods for evaluating business processes is the use of process mining techniques, concepts, and tools. In comparison with other methods, i.e. evaluating the process model based on the official model, the mentioned method is more reliable and is very close to the reality of the process implementation because it is based on the results after the implementation of the processes.

The strength of the current research is the evaluation of the process model using event logs. The reason for this is the evaluation of the real process model instead of the official model. Based on the present research, the model of the acceptance process of fixed capital facilities was discovered. The extracted model was confirmed according to the experimental findings of experts in the field. Therefore, the first research question was fully answered.

In line with the answer to the second question and based on the discovered models using alpha, alpha++, heuristic and genetic algorithms, the value of the simplicity dimension was obtained as 1 for all of them. In terms of fitness and precision metrics, the heuristic technique obtained values of 0.843 and 0.656, respectively, and showed that this algorithm has better performance than other methods in terms of precision. Also, the performance of the genetic algorithm was the best with a fitness value of 0.941. The obvious point in the results is the low precision of Alpha and Alpha++ algorithms with a value of 0.363, which was somehow predictable due to the limitations of these methods[36]. In terms of generalization, the values obtained for all methods were close to each other. Finally, the ranking of the algorithms in terms of the average value associated with all the dimensions was heuristic, genetics, alpha, and alpha++ respectively. The average values of the heuristic and genetic algorithms were very close to each other, which is a sign of the superiority of these techniques. These results are consistent with the studies of other researchers who have examined different methods of process model discovery[10]. The average values of the metrics were around 0.8. However, the techniques mentioned for analyzing and evaluating the fixed capital process had some defects and challenges. These techniques lacked the features of abstraction, emphasis, aggregation, and customization in the process model. Additionally, the weakness of the Petri net in using these techniques on the event logs of fixed capital processes was confirmed. In contrast to this, the effectiveness of the fuzzy method was validated due to its possession of the mentioned characteristics. This study was able to discover the real model of the process with its innovation in using a real event log along with the use of the fuzzy technique to identify the bottleneck stages of the process and activities with the most repetitions in a case.

According to the knowledge acquired from research and discussions with experts in the field, suggestions were made to improve the process model. These suggestions included merging activities referral of the fixed capital request to user 3 and referral of the fixed capital request to user 2, as well as stages Registration of design and product specifications, financial sector of fixed capital, and fixed capital market sector. The present study confirmed the presence of errors and defects in the current information system. Based on the research findings, a proposal was made to prioritize the modification or replacement of the current information system for senior managers of the bank.

In response to the fourth question, one of the findings of the

current research is to prove the effectiveness of the fuzzy method in the analysis of the processes of providing fixed capital facilities.

VI. CONCLUSION

In this article, the model of the fixed capital facilities acceptance process was discovered using the concepts and methods of process mining based on real event logs. Additionally, the model discovery methods were evaluated in terms of process model quality criteria, based on the proposed method. The results indicated that the heuristic and fuzzy methods demonstrated high performance. Furthermore, the fuzzy method outperformed other techniques for real and unstructured event logs associated with facility processes.

Among the limitations of the current research, we can mention the small sample used for event logs and the lack of coverage of other major phases of the process of providing fixed capital facilities. In addition, the impossibility of calculating the generalization by ProM 5.2 is another limitation of the present research. It is suggested to use other process model discovery methods and techniques, especially the inductive method, and other process analysis techniques, especially organizational analysis, in future research. In addition, for a better evaluation, the whole process should be examined comprehensively, including all major phases. It is also suggested to use multidimensional process-centric analysis in future studies. In other words, dimensions such as provincial comparison, the type of industry used, or the type of payment currency should be analyzed.

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