Improving the Effectiveness of Enterprise Resource Planning (ERP) System Implementation using a Hybrid Process Mining and FMEA Framework

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Abstract

Recent research on critical failure factors (CFFs) in ERP projects shows that the discovery and implementation of organizational processes are among the top seven main groups of CFFs. In this paper, a hybrid process mining and FMEA framework is presented to quantify the risk factors associated with process non-conformance. This approach is designed to increase the effectiveness of implementing ERP solutions in organizations, based on the identification and assessment of business process risks using the FMEA methodology. This study contributes by enhancing the BPM life cycle using process mining algorithms. To validate the proposed approach, a case study is conducted on the warehousing and logistics management process in one of the largest grain trading companies in Iran. The results of the research show that the use of the proposed approach can reduce the RPN of this process from 336 to 16 thus increasing the effectiveness of the ERP solution deployed.

Keywords:
BPM, Process Mining, FMEA, ERP Systems, Risk management

1. Introduction and Literature Review

The complexity of business process models during the past decades has become one of the reasons for the creation of Enterprise resource planning (ERP) information systems to respond to these complexities. Simple information systems with limited capabilities were transformed into complex information systems, integrated with architecture. Today, the business processes that were turned into information systems or automated business process management software by experts in this field have become key assets in organizations.

ERP approaches are described as computer-based information systems designed to process an organization's transactions and facilitate integrated, real-time planning. Although ERP approaches can bring a competitive advantage to organizations, the high failure rates are a major concern. One of the goals of implementing ERP solutions is to improve the processes of organizations to gain a competitive advantage in the market. Recent studies have concluded that the failure rate of ERP implementation projects is between 67% to 90%. It is said that 70% of ERP implementation projects do not achieve their estimated benefits, and three-quarters of these projects fail. (Amid 2012) Recent research on critical failure factors (CFFs) in ERP projects shows that problems related to the identification and implementation of organizational processes are one of the seven main groups of critical failure factors. (Ahmad 2013)Also, results show that the good practices of knowledge management favor a suitable use of ERP, and consequently lead to an undeniable improvement in the decision-making process.(Chaabouni et al. 2014).

Although Enterprise Resource Planning (ERP) systems are being used widely all around the world, they bring along many problems as well as benefits. Most of these implementations are failures and inadequate adoption is just one of the failure factors. Best practices of ERP systems may be designed with a software company working in a partnering relationship with a key industry customer to develop a package to meet the unique requirements of a particular industry. Unfortunately, lots of companies are using ERP systems, but rather than adopting their processes to the system, companies are trying to adopt ERP systems to the way they do business and this negativity in turn reflects on users, too. They do not use the system efficiently. (Basoglu et al. 2007)

In 2020, Eseryel et al., in a study of large US-based companies, stated that information systems implementations fail more than 70% of the time and that the implementation of ERPs is so risky and expensive that this failure may lead to the destruction of many small and medium enterprises. (Eseryel et al. 2020)

Amin amid et al., in 2011 classified the critical failure factors (CFFs) in ERP projects into seven groups such as vendor and consultant, human resources, managerial, project management, processes, organizational and technical. In this study, lack of process-oriented vision, weak business process re-engineering, and lack of skilled people in the organization's processes was introduced as part of the critical failure factors of the process group. (Amid 2012)
In 2012, Munir Ahmad identified and analyzed the interrelationships of important issues involved in the implementation of ERP in small and medium-sized companies. He examined critical success factors (CSFs), how these factors interact during the implementation process, and which factors and at what stages have the greatest impact on each other. The research results show that Business process reengineering (BPR) and Training new business processes are critical success factors (CSFs) in ERP projects. (Ahmad 2013)

In 2004, Hong conducted a risk assessment on ERP projects that identified failure to redesign business processes as one of the top 10 risks. (Huang et al. 2004) In 2022 Godwin Banafo Akrong et al. presented a comprehensive review between 2005-2020 to identify the challenges of enterprise resource planning. This study identified 65 challenges, and they have reported that ERP implementation failure rates range from 67% to 90%. Also, poor consultant efficiency, poor project management efficiency, poor quality business process reengineering (BPR), poor quality testing, and insufficient top management support were all cited as major failure factors. (Akrong et al. 2022)

Today, organizations must identify and manage their current processes for an effective approach. During these years, many definitions of business processes have been presented. A business process is a related group of steps or tasks that use people, information, and other resources to create value for internal or external customers. Workflow management systems are used to support business processes. Business process management (BPM) is a systematic and structured approach to analyzing, improving, controlling, and managing business processes, whose main goal is to improve the quality of products and services. Business process management is a management discipline that manages the organization's business processes and its application will lead to organizational improvement.
The management of business processes is rooted in the two sciences of management and information technology. This is the reason for the popularity and efficiency of this approach. With the growth and combination of these two sciences,

the concept of business process management has been created. Indeed, BPM was introduced after TQM and BPR approach in management and parallel after the emergence of RDBMS[1], ERP, and WFMS[2] to improve services and products. The meaning of improvement is all the operations and changes that are made in the processes to reduce the cost and speed of execution and increase the quality of the output of the process. (Chang et al. 2016).

Although the current WFMS support the design, configuration, execution, and control of the processes under their control, there are some deficiencies in the diagnosis phase. Process analysis methodology can be used to solve these deficiencies. Process analysis provides many more opportunities to support managers in modeling and managing processes. Analyzing deviations or identifying bottlenecks in the process can be easily done with commercial tools and provide deep insight into the structure of the process. (Van Der Aalst 2011)

To determine the position of process mining, in the life cycle of business process management according to Figure No.1, we examine the life cycle related to the production of the process model and its connection with process mining. In BPM, the first step is process design, the second step is configuration and implementation, the third step is monitoring and the fourth step is diagnosis. Also, models and data are two other entities of the cycle. As it is known, the models are related to the steps of design, configuration, and implementation (analytical steps of the process), and the data are related to the steps of monitoring and diagnosis (operational steps of the process). The most important weakness of the above cycle is that data which are produced in the third and fourth steps are not of much interest in the first and second steps. This is the point where process analysis enters the process model production cycle. Process mining uses the generated data in operational steps and tries to improve the process model. (Madah 2020)

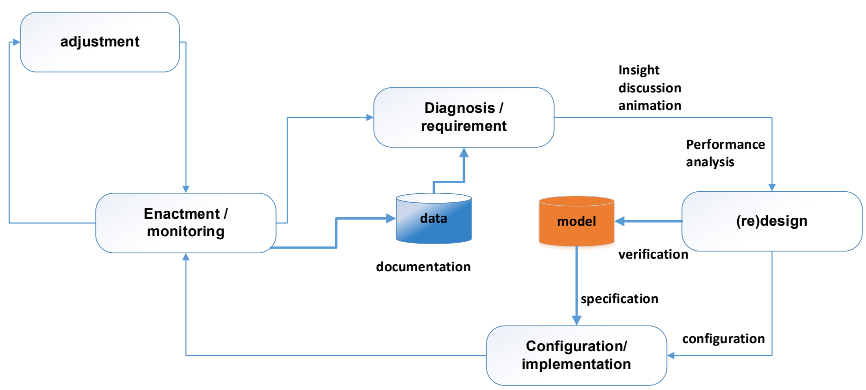


Figure 1. Process mining scope within the BPM life cycle

The concept of process mining was first introduced by Cook and Wolf and Agrawal et al. in 1998. This concept is taken from the text of the book "Analysis of Software Engineering Processes" written by Cook and Wolf. Then Agrawal et al. added process analysis to workflow management concepts. Their pioneering research was about discovering the workflow pattern. Their expertise in workflow management and machine learning led to the development of a new topic called process mining. Process mining is a relatively young field that has been introduced since 1998; However, the articles published in this field are facing an upward trend. (Baykasoğlu et al. 2018)

On the other hand, process mining infrastructure was first created by Vanderalst. He (2004) introduced the topic of process mining and by using several simple examples, the power of process mining was demonstrated, but many scientific challenges were also pointed out in this case, and it was mentioned as a new topic that would help solve some problems in business. It should be mentioned that the most important and original efforts made in this field by Vander Aalst and his fellow researchers at Eindhoven University in the Netherlands and through the development of data mining algorithms. His activities led to the emergence of a set of methods and tools that are available to experts in this field. One of the best definitions of process mining is comparing it to a bridge between the two fields of data science and process science, which were briefly mentioned in the previous two sections. With the emergence of process mining, the gap between data mining methods based on data and business process analysis with no regard to data has been filled. (Van Der Aalst 2016)

[1] relational database management system
[2] Workflow management systems

Process mining provides a solution based on extraction, analysis, diagnosis, and visualization of data recorded by information systems or business process management software during process execution. Process mining visualizes the activities recorded in the work execution process, which can be used to discover, assess compliance and identify possible improvements in the work being carried out. (Mahendrawathi et al. 2016) The basis of the process mining is the analysis of event files, which are records of real actions and related information such as execution time (Wisner et al. 2015).

This analysis gives a good insight into the dependence of the actual flow of data, and the use of resources for different statistical measures. One of the final products of process mining is the description of the work process in the form of a model. (Boersma et al. 2019) Many information systems automatically create a log of the input event of the mining process so that it is precisely determined what activity is performed at what time and by whom. (Rozinat 2018)

Process mining is an important bridge between data mining and business process analysis. Under the business intelligence umbrella, many terms such as BAM[3], CEP[4], CPM[5,] CPI[6], BPI[7], TQM[8], and 6σ[9] are defined, which are used to refer to reporting tools and management dashboards. The common feature of these methods is that in all of them, the process is put under the microscope to identify improvements if possible. Process mining is a new technology that enables the goals of 6σ, TQM, BPI, CPM, and similar methods. While these organizational intelligence tools are used to increase operational performance such as reducing circulation time and reducing defects, organizations have a special emphasis on managing companies, risks, and matching executive processes and modeled processes. Process mining techniques provide a tool to check compliance more closely and also check the validity and reliability of the information of the main processes of an organization. (Van Den Brand et al.2011)

During the last decade, with the provision of access to event diagrams, process analysis methods have matured. Process mining algorithms have been implemented in many academic and commercial systems. Currently, many researchers are busy researching this field. This topic is becoming a hot topic in the field of business process management. (Van der Aalst 2011)

Generally, in process mining, the following can be done by exploring the graph of events

- Identify the processes of an organization or business
- Identified the bottlenecks of different paths of the process
- Examined the degree of compliance of the running processes with the structures defined for it
- Made suggestions to improve the existing process

According to these points, process analysis can be divided into three main parts: process identification, compliance check, and process improvement. Process discovery allows process models to be extracted from input event graphs. Conformance check examines the deviations resulting from comparing a process model with an entered event diagram; To determine whether the event and model diagrams are compatible with each other or not. The upgrade also allows the existing process model to be developed or improved using information about the actual process recorded in the event graphs (Madah 2020).

According to the results presented in the review article on process mining applications by Dakik et al. (2018), the distribution of the application of process mining perspectives in the conducted research is such that all the articles in this field focus on process discovery, 60% on promotion and 42% on compliance review.

In this article, all three main parts of process mining are used. The exploration of perspectives from a flow control perspective, organizational perspective, time perspective, and process file perspective was done and the Replay approach was used to check the compliance of process analysis, in this approach, the event file and process model are

[3] Business Activity Monitoring
[4] Complex Event Processing
[5] Companies Productivity Management
[6] Continuous Process Improvement
[7] Business Process Improvement
[8] Total Quality Management
[9] Six Sigma

given as input to the algorithm. The event graphics file is tested on the input model and compliance is checked. Also, to improve the process, model upgrading techniques are used, in which they need a model and an event graph as input, and their output is a modified or developed model. (Van Der Aalst 2016)

By examining the research conducted on the failure factors of ERP projects (Eseryel et al. 2020, Ahmad 2013, Amid 2012 and Akrong et al. 2022), it has been determined that the problems related to the identification, implementation, improvement, and reengineering of the organization's processes are one of the most important challenges before and after the deployment. ERP approaches. Since 1994, numerous articles have been written on the application of process modeling in computer-related industries, as well as ERPs, and are continuously being developed by researchers (Reijers 2021), but it seems that the use of BPM alone has not been able to help reduce the risk of failure of ERP projects.
In this research, we are looking for the issue of whether there has been a specific approach to reduce the risk of failure of ERP projects due to problems related to the identification, implementation, and re-engineering of processes. And that the use of this approach has been able to reduce the risk of failure of ERP projects in practice.

According to the review of the published articles, we have noticed that many approaches have been presented for the deployment of ERP solutions. On the other hand, most of the articles have focused on the causes of the failure or success of ERP projects. And articles that introduce approaches that are specifically used to solve these causes are rare. Ultimately, to the best of the authors' knowledge, no single research study has used BPM, Process Mining, and Risk management approaches to reduce the risk of ERP projects' failure.

In this article, in the second section, a hybrid approach based on risk management, knowledge of business process management, and the use of process analysis solutions is introduced, which can be used in ERP projects (Both during design and after implementation) for reducing the risk of project failure. This modeling framework addresses the problems associated with identifying, implementing, improving, and re-engineering the organization's processes and it will ultimately increase the effectiveness and satisfaction of the stakeholders.

which can reduce the risk of project failure in ERP projects (both during design and after implementation) due to problems related to identifying, implementing, improving, and re-engineering the organization's processes, and finally increase the effectiveness and satisfaction of the stakeholders. In the continuation of the article, to ensure the correct performance of the proposed approach, a case study was conducted in one of the largest grain trading and related products manufacturing companies in Iran, which has ERP software .The results of this case study are reported in the third section. finally, in the fourth section, the discussion and conclusions of this research and future suggestions are discussed.

Methods

The main framework proposed in this research is designed with a special look at the life cycle of BPM and the place of the process mining in that. In this proposed approach, an attempt is made to design operational steps to establish a process and improve it by a combined methodology of BPM, FMEA, and process mining, which is named BPMPM for short. As can be seen in Figure No.2, through tools such as a meeting with the organization's experts and analyzing the state and effect of a system's failure, an overview of the organization and the considered process is discussed. After the design of the process and its deployment, the raw data resulting from the execution of the process will be collected during a certain period, and the graph of events, which is the input of any process analysis tool, will be prepared. Discovery, analysis, and review of process compliance by process analysis tool, suggestions for improvement are extracted through meeting with stakeholders of the process. The results of the research are reviewed with the management of the organization and the stakeholders of the process, and the final improvement suggestions are implemented after the approval of the management. Some of these improvement suggestions may lead to process redesign.

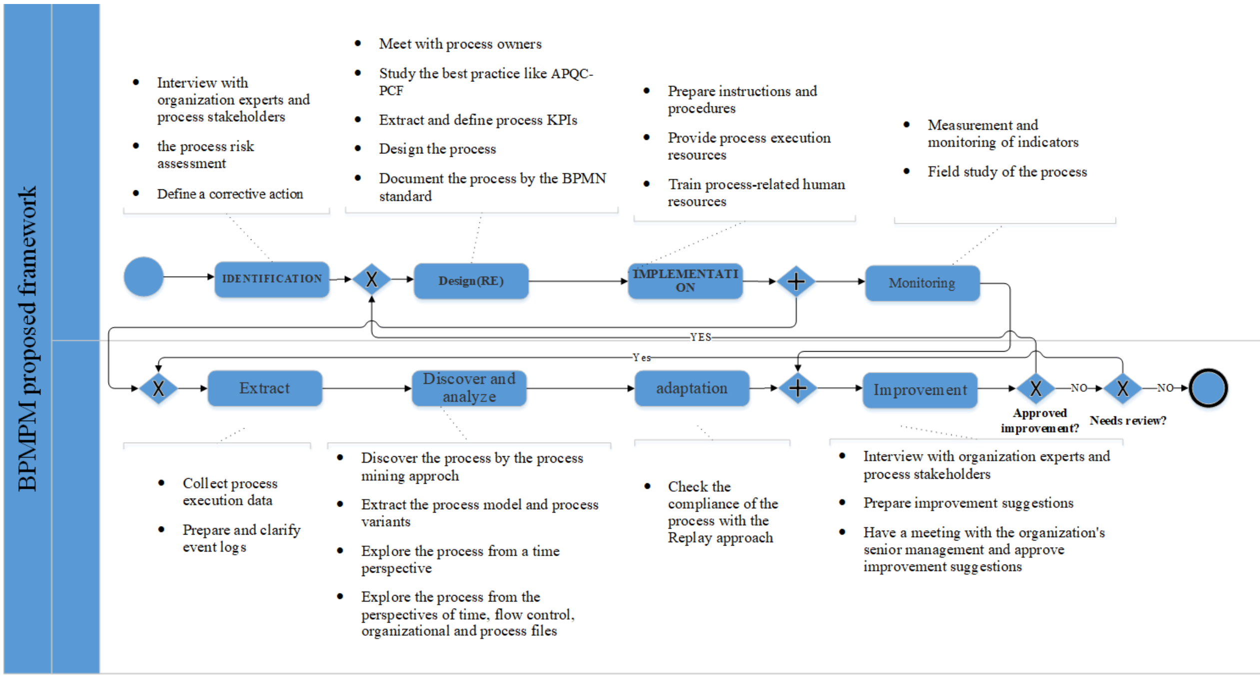


Figure 2. BPMPM proposed framework

The first step: a brief understanding of the organization and the considered process

To start the proposed approach, a meeting should be held with the organization's experts and stakeholders of the process and their needs and expectations should be listed. Today, the importance of risk management both from the perspective of the environment and from the perspective of the process in the organization has become increasingly serious. With the increment of risks that organizations face, their complexity and interdependence. The FMEA[10] method can be used to evaluate process risks more effectively. (Kardos et al. 2021)

FMEA is a systematic approach that focuses on analyzing a system's vulnerabilities, possible causes, potential effects, and potential corrective and preventive actions. Prioritization is done by calculating the risk level for each vulnerability, which is the RPN vulnerability priority number. RPN is the product of three variables: severity (S), occurrence (O), and diagnosis (D), for which experts give a score between 1 to 10 for each variable. (Arvanitoyannis and Varzakas 2008) After the process risks have been identified and evaluated, it is necessary to identify 20% of the risks that have the largest RPN number as unacceptable risks, and to correct it, corrective action needs to be defined. In Table.1, guidance is given to determine the severity number (S), occurrence (O), and diagnosis (D).

Table 1. Guide to DETERMINING the S, D, and O scores

Severity		
criterion	Description	Score
Very severe financial damage / very severe stress / damage to reputation and credit at the international level	Very High (disaster)	10
Very severe financial damage/very severe stress/damage to reputation and credit in the country	High (very dangerous)	9
Severe financial damage/severe stress/damage to reputation and credit in the country	High (very dangerous)	8
Severe financial damage/severe stress/damage to reputation and credit in the province	High (very dangerous)	7
Moderate financial damage/moderate stress/damage to reputation and credit in the province	Moderate (dangerous)	6
Moderate financial damage/moderate stress/damage to reputation and credit in the city	Moderate (dangerous)	5

[10] Failure Mode and Effect Analysis

Slight financial damage/moderate stress/damage to reputation and credit in the city	Low (Slight)	4
Slight financial damage / low stress / damage to reputation and credit in the city	Low (Slight)	3
Slight financial damage/slight stress/ no damage to reputation and credit	Low (Slight)	2
Insignificant financial damage/no damage to reputation and credit	Very Low (Insignificant)	1
Detection		
criterion	Description	Score
There is no control or, if there is, it is unable to detected the potential hazard	Absolutely nothing	10
There is a very unlikely that the hazard will be detected and revealed with existing controls	a bit	9
There is unlikely that the hazard will be detected and revealed with existing controls	insignificant	8
There is very little chance that the hazard will be detected and revealed with existing controls	very little	7
There is little chance that the hazard will be detected and reveal with existing controls	little	6
In half of the cases, it is likely that the potential hazard will be detected and revealed with existing controls	Moderate	5
There is relatively high probability that the potential hazard will be detected and revealed with existing controls	relatively high	4
There is high probability that the potential hazard will be detected and revealed with existing controls	high	3
There is very high probability that the potential hazard will be detected and revealed with existing controls	very high	2
The potential hazard will almost certainly be detected and revealed with existing controls	Almost certain	1
Occurrence		
criterion	Description	Score
Risk occurs one or more times a day. (There is a risk in every shift)	Very High (Unavoidable risk)	9 , 10
Risk occurs once or more per week. (there is a risk every week)	High (Repetitive risk)	7 , 8
Risk arises once or more in a month. (there is a risk every month)	Moderate (Case risk)	5 , 6
Risk arises once or more a year. (There is a risk every year)	Low (Rare risk)	3 , 4
Risk arises once every few years	Very Low (Impossible risk)	1 , 2

Second step: process design by Business Process Model and Notation

First, it is necessary to define a team of trustees or owners of the process, beneficiaries of the process, experts of the organization, and designers of the process, then by holding meetings with team members and also by the method of process field study, the necessary information of the process to complete the process is obtained. It is also recommended to model APQC-PCF as a best practice to break the process and define process indicators. In the next step, the process should be modeled according to the obtained information based on the BPMN language. BPMN is the standard business process modeling language developed and regulated by OMG. This standard is considered the main tool in BPM technology. It is also recommended to use APQC's Process Classification Framework as a best practice for process classification and defining process indicators. In the next step, the process should be modeled according to the obtained information based on BPMN2[11]. BPMN is the standard business process modeling language developed and regulated by OMG[12]. This standard is considered the main tool in BPM technology. (Rahnamafard et al. 2021)

Since around 1950, when computers and digital communications entered the world of business, many changes and improvements were made in businesses. The use of new technologies has made business processes very complicated and their dependence on information systems has increased. This complexity has made process modeling an integral part of business success. This point can be considered the place of entry and brilliance of process modeling in the field of business. The management of business processes requires a detailed description of the processes and their

[11] Business Process Model and Notation
[12] The Object Management Group

documentation. There are different methods such as Petri nets, BPMN, XPDL[13], C-nets, YAWL[14], and CMMN[15] to do this. Each of these standards has its specific applications and has advantages and disadvantages. Due to the greater use of the BPMN method in process mining, this standard has been chosen in this article. (Agrawal 1998)

BPMN which is developed and implemented by OMG is the standard language for modeling business processes. Business process symbol and modeling is a standard markup language that has sufficient ability to model and describe the process and refers to a set of signs and symbols in a standard way that can be used to describe business processes. In general, a business process that is modeled in BPMN consists of four main components; Event, activity, gateway, and communicator, each of which contains components. (Allweyer 2016)
Finally, this model must get the approval of the mentioned team by holding meetings and in this part, the design step of the process is finalized and the third step can start.

Third step: Implementation of the designed process
In this step, to clarify the method of implementing the process for its executors and to reduce the risks during the implementation of the process, the required implementation methods and instructions should be prepared and approved with the cooperation of the mentioned team during other meetings.
It is also necessary to identify the resources of the process implementation (including infrastructure, human resources, hardware, and software equipment) and prepare a schedule to provide it and get the approval of the senior manager of the organization. In this step, the schedule and necessary measures to train the process implementers on how to implement the process are made. Finally, the designed process is implemented and we go to the next step.

Fourth step: monitoring the designed process
The performance dimensions of a company's processes (time, cost, quality, and flexibility) can be attributed to some key performance indicators or KPIs. Process performance measurement is a value that can be transparently determined for a business process. This assumes, of course, that data are available to calculate this performance measure. Reference models can be used to define appropriate KPIs, one of the useful tools for identifying key process performance criteria is the use of the APQC process classification framework. The primary goal of this framework is to provide a standardized breakdown of processes in the organization with standardized names and definitions for these processes. As a complement to the PCF, APQC has developed sets of performance criteria for the processes included in the PCF and is a useful tool for identifying performance criteria. (Dumas 2013) In this step, it is necessary to analyze the process by monitoring the KPIs defined in the second step as well as the field investigation of the process, and its results are considered as input for the eighth step. Also, here is a lot of raw data from the process run, which is used as input to step five.

Fifth step: extract raw data and prepare the event diagram
As it was mentioned in the introduction of this article, there are deficiencies and shortcomings in the diagnosis phase in BPM, and process mining methodology can be used to fill these deficiencies. Process mining provides many more opportunities to support managers in modeling and managing processes. Analyzing deviations or identifying bottlenecks in the process can be easily conducted with commercial tools and provide a deep insight into the structure of the process. (Van Der Aalst 2011)

By evaluating real behaviors, process mining provides a realistic view of operational processes, which is useful and important in developing support systems or redesigning previous processes. The purpose of process mining is to extract non-obvious and practical information related to processes retrieved from the event logs. Event logs are recorded data related to events retrieved from the execution of a business process in an organization. An event log is a list of activities for which the time of their occurrence is recorded. For a process to be traceable, we also need a third member of the contents of the event diagram, which is registered as a file ID for each activity.

In this step, the raw data received from the previous step should be used as a graph of events, which needs to be converted into a readable format in process mining software. Currently, the standard format of event graphs for process analysis, which most process mining tools support, is the XES[16] format. XES was adopted in 2010 by the Process

[13] XML Process Definition Language
[14] Yet Another Workflow Language
[15] Case Management Model and Notation
[16] Extensible Event Stream

Mining Special Working Group in IEEE as the standard event mapping format. In addition to XES, other formats supported by process mining software are CSV and MXM files. Today, some mining process software can help in this short and sure step by connecting the connector to the integrated software of the organization.
At the end of this step, the Excel file containing the events resulting from the execution of the process based on the raw data of the software is extracted and we go to the sixth step.

The sixth step: discovery and analysis of the process in the process analysis tool

Process discovery is the most common technique of process mining. This technique takes an event graph as input and generates a process model without having any prior information. In this type of process mining, event graphs are analyzed and examined by process mining algorithms, and the desired process is modeled without any prior knowledge of the process. Modeling the process means determining what each of its activities are and which of these activities are related to each other and what is the sequence of entering the steps. In short, process discovery techniques receive an event graph as input and produce a model as output. The identified model will often be displayed as a process model such as Petri Net, EPC, UML, and BPMN. (16) With the preparation of the desired event graph, we will use process discovery algorithms to discover the main process. These algorithms determine how to build process models. The three main groups of these algorithms include deterministic algorithms, exploratory algorithms, and exploratory genetic algorithms. Analytical tools can be used to produce process models and other process analyses, which are the input event diagram and the corresponding output process models.

In this step, it is necessary to analyze the outputs of process mining tools. This analysis includes the review of process paths, process map, sequential path, unattractive activities and bottlenecks, operational time, number of files per activity, and review of rework in the process.

Seventh step: Check compliance

The second type of process mining is compliance review. In simple words, in this category of process mining, the main task of the algorithms is to check the compatibility between the existing model and the model extracted from an event graph. The most important goal of this type of process mining is to check whether what is happening, in reality, conforms to the model that has been developed. (Rozinat and Van der Aalst 2008) Compliance check technique requires an event graph and a model as input. The output contains diagnostic information that shows the differences and commonalities between the model and the image. (Van Den Brand et al.2011) In this step, he used play-in, play-out, and replay approaches to check the compliance of the process mining. Since the Replay approach is more complete than other approaches, it is recommended to use this approach in this step. In this approach, the event file and the process model are given as input to the algorithm. (Van Der Aalst 2016)

For this purpose, the event diagram prepared in the fifth step as well as the model designed in the second step are placed as the input of the process mining tool to check compliance with the implemented process; And the output of the process mining tool includes the percentage of compliance of the implemented process with the pre-designed model, as well as the number and type of deviations are analyzed. In this step, it is necessary to list all the deviations, the causes of the rooting deviation, and the measures to solve it to further investigate the deviations created. Then we go to the eighth step.

Eighth step: Improvement suggestions

The third part of process mining deals with developing or changing an existing model. The main idea is to improve or develop the current processes by using the available information about the actual processes running in the organizations that are recorded in the event graphs. Model enhancement techniques also require a model and an event graph as input. Their output is a modified or developed model. (Van Den Brand et al.2011)

In this step, the suggestions for improvement and corrective actions that were the result of the process mining in the fourth and sixth steps, as well as the results of the process compliance check in the seventh step, are reviewed in a meeting with the presence of organization experts and process owners. Then, suggestions for improvement are extracted and, if needed, the new process is simulated in the process analysis tool. Finally, the results obtained from the simulation output of the process analysis tool, as well as the improvement suggestions prepared, will be considered as input in a meeting with the senior managers of the organization.

Data Collection and Case Study

In grain trading companies, the logistics process is always one of the main processes with high financial value, and according to this, large and international grain trading companies use integrated information software to manage this process. But since integrated information systems in the logistics process still depend on humans with a high share, the amount of accidental and intentional errors in recording information such as weight information in the system by weighbridge employees can still be a significant financial risk.

With the emergence of ERP software solutions in the world, the possibility of this risk has decreased to some extent due to the integration in the purchasing, warehousing, financial, and sales processes. However, it seems that there is still a possibility of a security hole in ERP systems due to the presence of humans in the field of recording information on the net weight of goods entering and leaving the company, and these systems are not able to detect this violation. For example, in the purchase process, the weight of the purchased product is recorded in the system, and during the receipt process in the warehouse, the weight of the product received by the warehouseman is also recorded in the system. If this person records the amount of received load contrary to reality, the system is not able to identify this violation.

This case study intends to use the combined process mining and FMEA method to manage the entry and exit of bulk goods in such a way that the business process challenges raised are resolved. A case study is conducted in one of the largest grain trading and related products manufacturing companies in Iran called Zarmacaron, (Kamalzadeh and Haghighat 2021) which has an ERP software called SAP, and its results are reported.

The first step: a brief understanding of the organization and the considered process

Several meetings were held with organization experts and process stakeholders to start the proposed framework, and their needs and expectations were listed. It seemed that while the SAP system was current in the organization, this ERP software did not provide a solution for the traffic process to meet the requirements of the organization. This issue led to risk increment in the traffic process.

Companies active in the field of buying or selling bulk goods in Iran always face the following two possible problems:

1- The bulk goods are not received, but the financial documents are registered in the financial system.

2- The bulk goods are removed from the company, but the financial documents are not registered.

According to Figure No. 3, during the risk analysis which was performed by FMEA methodology, its RPN number had the highest value in the warehousing and logistics management process group (according to APQC), which the need to define a corrective action to create an exit process for the company's sold product was necessary.

Process risk identification and management form													
Process	Section	Failure Mode	Effects	Severity	Class	Causes	Control Methods				RPN	Recommended Action	
							Prevention Control	Occurrence	Detection Control	Detection		Action	Responsibility
Manage logistics and warehousing	Product warehouse	The goods have been removed from the company but the financial documents have not been registered.	Non-compliance occurs in warehousing and causes losses to the company	8	A	The weight of the goods is not specified exactly	Reference to issued input and output documents	7	monthly warehousing	6	336	Process redesign	Systems and methods unit
						Occurrence of human error in the entry and exit of vehicles	Control by surveillance cameras	5	Control by several people	6	160		Systems and methods unit

Figure 3. Risk analysis of warehousing and logistics management process

Second step: process design by Business Process Model and Notation

First, a team of process owners, process stakeholders, organization experts, and process designers (including systems and methods manager, planning manager, warehouse manager, logistics manager, sales manager, financial manager, quality manager, and factory manager) was defined. On the one hand, during meetings with team members and on the other hand, by field study of the process, the necessary information about the process of carrying out the process was obtained. Also, APQC-PCF was modeled as a best practice to identify the process and define process indicators. Then the process was modeled according to the obtained information based on the BPMN language (Figure No.4). In the next stage, this model was approved by the mentioned team during meetings and the design step of the process was finalized.

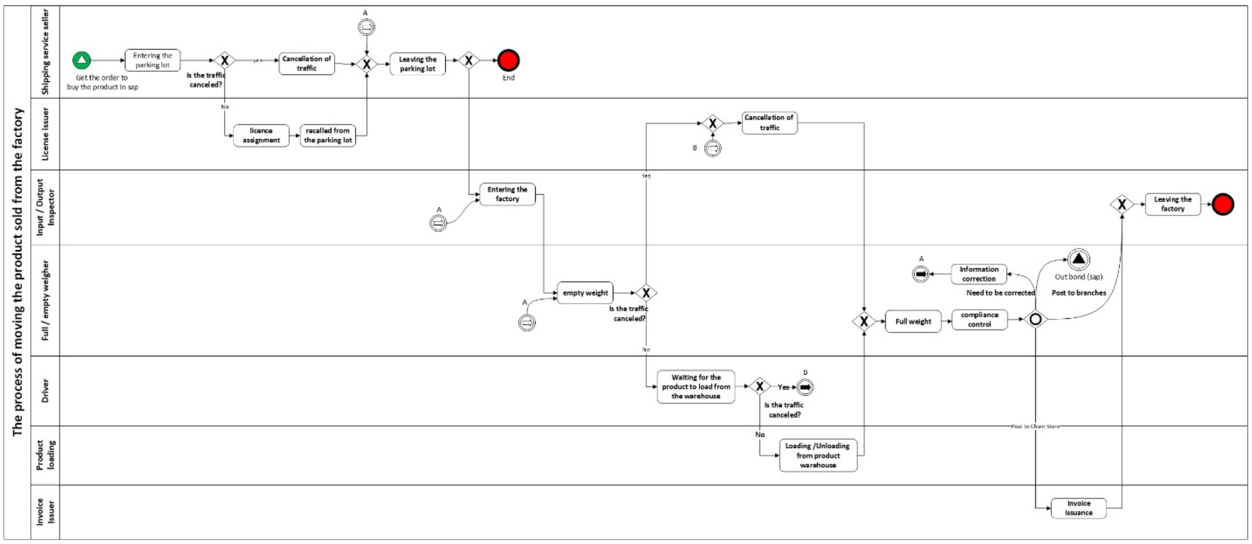


Figure 4. The reference business process model

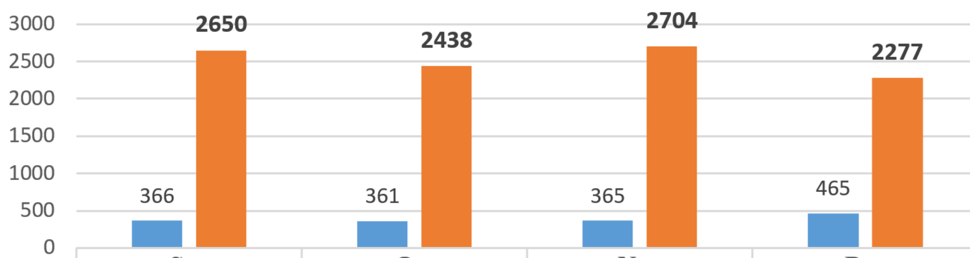
Third step: Implementation of the designed process

In this step, to clarify the implementation method of the process for its executives and reduce the risks during the implementation of the process, at first, implementation methods and relevant instructions were prepared and approved with the cooperation of the mentioned team during other meetings. Next, the process implementation resources (including infrastructure, human resources, hardware, and software equipment) were identified and the schedule for its provision was prepared and approved by the senior manager of the organization. Also, in this step, the schedule and necessary actions were taken to train the process implementers on how to implement the process. After about two months and the preparation of process implementation resources, the designed process was implemented.

Fourth step: monitoring the designed process

In this research, the time index of the average traffic duration for this process has been extracted. The results were monitored and analyzed in the form of charts No. 1 and 2 during three months. Also, the process was investigated in the field during this period and its results are considered as the input of the eighth step.

After examining the index trend at this stage, there was no significant relationship between the number of traffic, the type of transport vehicles, and the duration of traffic, but through process field study, the conclusion was that there can be many improvement opportunities for the process. It seems that the defined process indicator alone is not a suitable tool to identify the process failure points and improvement situations.



	Sep	Oct	Nov	Dec
Avg Time (min)	366	361	365	465
Qty	2650	2438	2704	2277

Avg Time (min) Qty

Chart No. 1 - Average travel time for all means of transportation

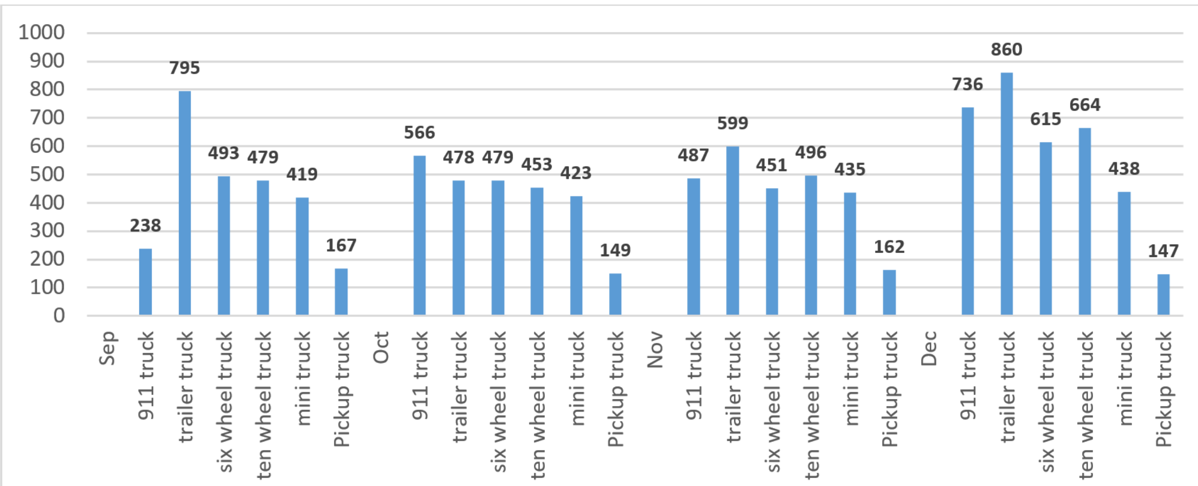


Chart No. 2 - Average travel time by type of transportation

Fifth step: extract raw data and prepare the event diagram

Because at the beginning of the project definition, following the proposed approach, the goal was to use process mining tools, the interface software used to control the traffic process was designed in such a way that it was possible to report and extract data. Also, data extraction from SAP was possible due to the possibility of creating a connector with Celonis. For this reason, not much time was spent on data collection. Also, the traffic code used in the traffic software was used as the file identifier. Finally, the Excel file containing the events of three months in 2022 was extracted from the raw data of the software. (Figure No. 5)

Case ID	Process name	Plate number	Vehicle	Activity	Timestamp
33487631	Sale of Zarmacaron product	4836732	six wheel truck	licence assignment	1400/07/03 06:53:14
33487631	Sale of Zarmacaron product	4836732	six wheel truck	Entering the parking lot	1400/07/03 17:23:28
33487631	Sale of Zarmacaron product	4836732	six wheel truck	case was overridden	1400/07/04 07:23:22
33487631	Sale of Zarmacaron product	4836732	six wheel truck	was recalled from the parking lot	1400/07/04 06:53:30
33620118	Sale of Zarmacaron product	7919778	ten wheel truck	licence assignment	1400/07/11 08:02:57
33620118	Sale of Zarmacaron product	7919778	ten wheel truck	Entering the parking lot	1400/07/11 07:56:04
33620118	Sale of Zarmacaron product	7919778	ten wheel truck	case was overridden	1400/07/11 08:07:24
33620118	Sale of Zarmacaron product	7919778	ten wheel truck	was recalled from the parking lot	1400/07/11 08:03:13
33676868	Sale of Zarmacaron product	wasn't read	Pickup truck	licence assignment	1400/07/15 01:27:11
33676868	Sale of Zarmacaron product	wasn't read	Pickup truck	Entering the parking lot	1400/07/15 01:25:13
33676868	Sale of Zarmacaron product	wasn't read	Pickup truck	aiting for the product to load from the warehou	1400/07/15 01:28:32
33676868	Sale of Zarmacaron product	wasn't read	Pickup truck	Loading from product warehouse	1400/07/15 01:29:10
33676868	Sale of Zarmacaron product	wasn't read	Pickup truck	Full weight	1400/07/15 01:29:57
33676868	Sale of Zarmacaron product	wasn't read	Pickup truck	empty weight	1400/07/15 01:28:00
33676868	Sale of Zarmacaron product	wasn't read	Pickup truck	Leaving the parking lot	1400/07/15 01:27:24
33676868	Sale of Zarmacaron product	wasn't read	Pickup truck	was recalled from the parking lot	1400/07/15 01:27:17
33676868	Sale of Zarmacaron product	wasn't read	Pickup truck	compliance control	1400/07/15 01:30:47
33676868	Sale of Zarmacaron product	wasn't read	Pickup truck	Entering the factory	1400/07/15 01:27:28
33688471	Sale of Zarmacaron product	2144621	Pickup truck	licence assignment	1400/07/17 07:05:20

Figure 5. Example of an extracted event from raw data

The sixth step: discovery and analysis of the process in the process analysis tool

The process analysis tool used in this research is called Celonis. According to the information written on the website of Celonis company, this company with more than one hundred thousand users of process analysis in more than 250 customer organizations and 25 different countries, has included process analysis of more than 15 industries and is connected to 70 extensive ERP systems in these organizations. In this section, all the outputs of the mining process have been presented.

Process Paths:

After entering the event image prepared in Celonis and using the innovative exploration algorithm of this software, the process map is designed with the selected detail mode in the most comprehensible way possible. Different activities are represented by nodes and interactions between activities are represented by edges. In general, the process in three months in 2022 includes 96 different paths.

In Figure No. 6, the display output of the process paths is presented in terms of coverage percentage. The first and second paths with 39% and 37% coverage, which are the normal and common paths of the process. Their difference is in the existence of invoice issuance activity according to the type of sale.

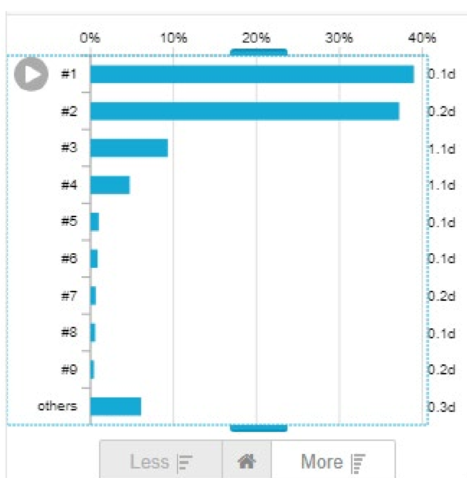


Figure 6. Percentage coverage of process paths

1- Process map:

In Figure No.7, the complete map of the selected process with maximum details extracted from the Celonis software can be seen. After comparing this map whit the reference business process model, the superiority of this map based on real data designed with the BPMN model is undeniable.

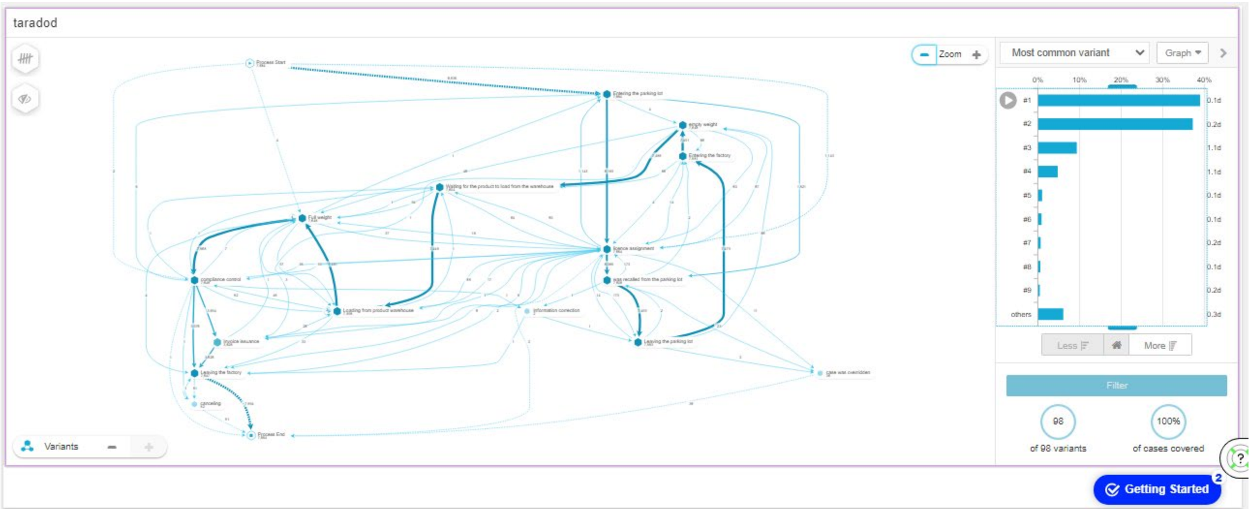


Figure 7. Warehousing and logistics management process map after implementation

As you can see, the process starts with entering the parking lot and ends with one of two activities: leaving the factory or leaving the parking lot. The numbers on this map, whether the numbers of activities or nodes or the number of paths or arcs indicate the number of files involved in each of the activities or paths.

2- Common process path:

After running the process mining in this software, the common path and the so-called Happy-path process are shown in Figure No.8. This path is the same as the first and most common process path presented in the previous section and covers 39% of all cases of the selected three-month period.

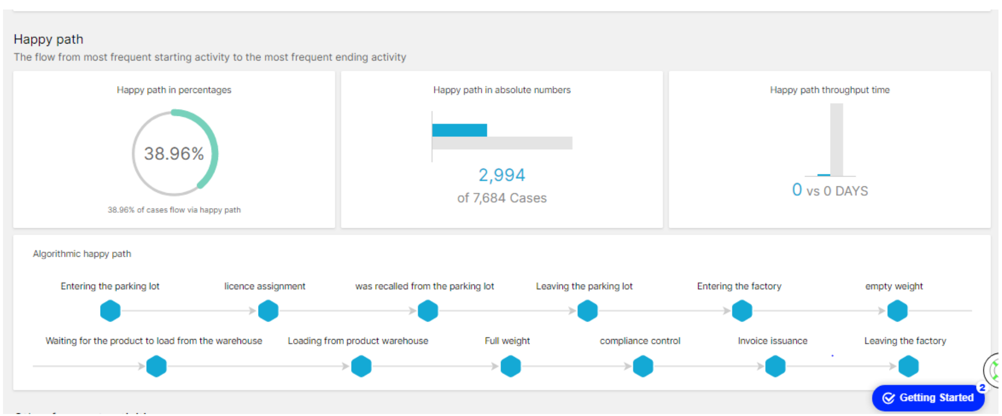


Figure 8. The common way of warehousing and logistics management process

3- Review of operating times and bottlenecks:

After the implementation of process mining in this software, the operating times of the researched process were studied according to Figure No.9. It can be seen that the average operating time of the process is 8 hours, that is, it takes an average of 8 hours to complete a process from zero to 100. Also, the average operating time is 4 hours. The minimum time for the process is 0 hours and the maximum time for the process is 505 hours. Regarding the loading stage, it is clear that according to the nature of the activity, the maximum time of the product exit process is related to this stage, and this issue completely depends on the loading tonnage.

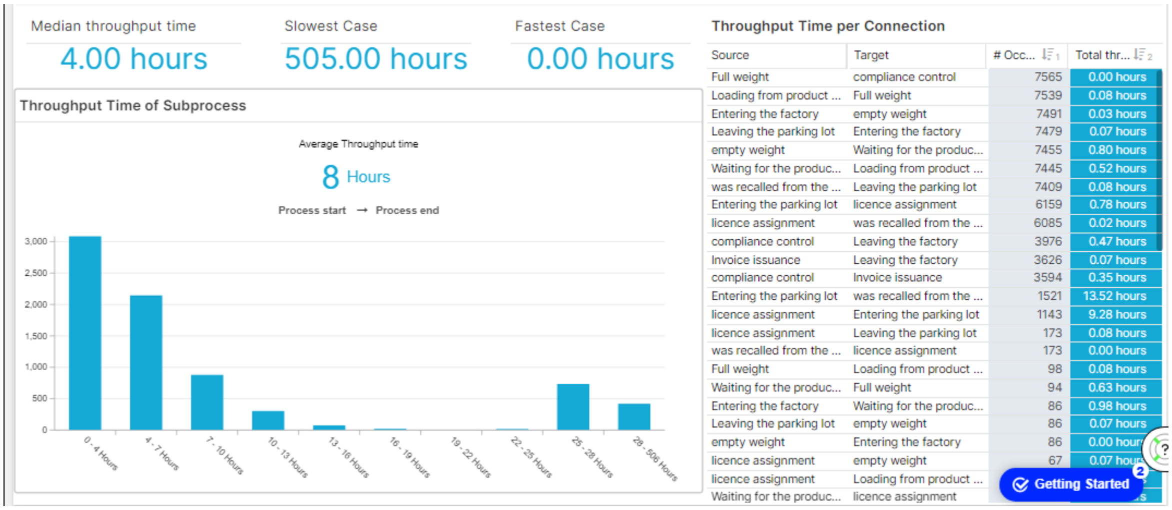


Figure 9. Total operating time

Also, some connections and relationships of activities that significantly increase the time of the process and create bottlenecks can be seen in Figure No.10.

Figure 10. Bottlenecks

In the fourth step, during the field study of the process and monitoring process indicators, we realized that the traffic of pickup trucks with other means of transportation is particularly important in terms of the time of leaving the company. So that all of them need to be loaded at 10 a.m. at the latest. For this purpose, operating times and process bottlenecks for pickup machines were studied separately and we concluded that the type of machine is ineffective in creating bottlenecks related to the waiting stage for loading. Also, in Figure No. 11, only due to the amount of loaded cargo and the time to do it, the duration of this stage has been reduced in traffic by pick-up cars. The maximum loading tonnage in pickup trucks is 2 tons, while in other means of transportation, the maximum loading tonnage can be up to 24 tons.

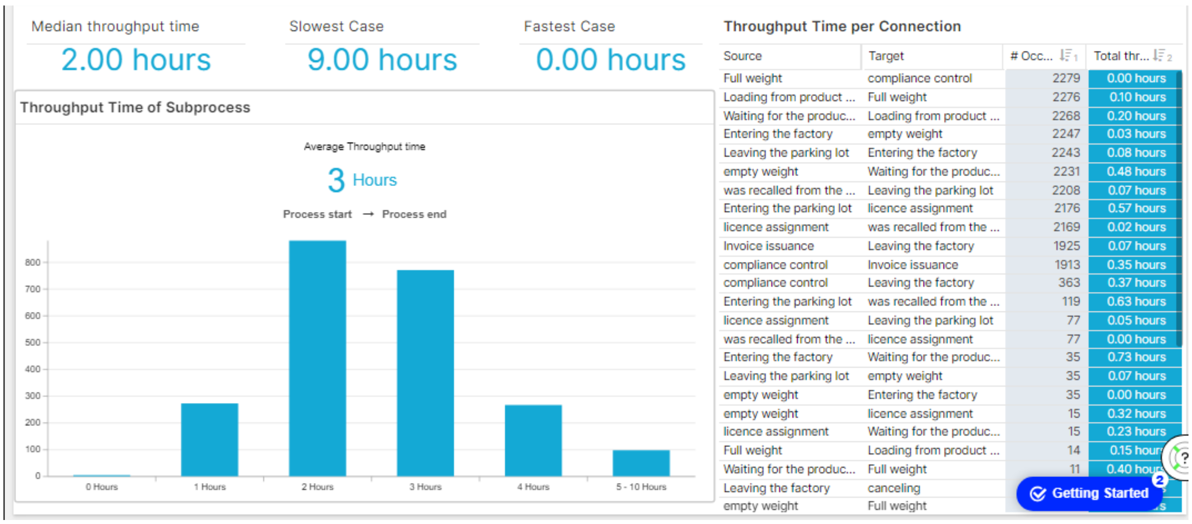


Figure 11. Operating time of the pickup truck

4- Study of rework in the traffic process

According to Figure No. 12, most of the rework has been done in the two stages of waiting for loading and unloading from the product warehouse, and according to the investigation, it was found that the type of transportation is not effective in creating a bottleneck in the waiting stage for loading, because by filtering the types of machines, the waiting stage for loading remains a bottleneck.

According to the review of reworked cases, 25 cases are related to sales to branches, and 37 cases are related to sales to chain stores, which shows that rework occurs in manual and pallet loading. It should be noted that in sales to chain stores, the means of transportation are loaded manually, and in sales to branches, the means of transportation are loaded by the pallet method. By studying the cases, six-wheel and ten-wheel trucks had the most rework, which considering that most of the transportation items were loaded by these trucks in this period, this number of rework seems acceptable. It should be noted that less than 1% of the rework occurred according to the type of transportation.

Figure 12. Most rework steps in the process

Seventh step: Check compliance

In this step, it is necessary to enter the model designed in the second step in the conformance section of Celonis software, to check compliance with the implemented process. In Table 2, the output results of the process compliance check can be seen, that the compliance percentage of the implemented process with the pre-designed model is 76% and has 24 types of violations.

Table 2. The results of the compliance check in the software

Statistics about conformance			
Conforming cases (%)	Conforming cases	Non-conforming cases	Violations
76%	5.86k	1.83 k	24

As can be seen in Table 3, all violations have been investigated. In this step, the root causes of these violations should be identified and actions to eliminate them should be listed and the results should be sent to the eighth step. The most inconsistency is related to the stage of license allocation before the start of the process.

Table 3 . Checking the type of violations in process compliance

Conformance overview			
Row	Violations	Conforming cases(%)	Conforming cases
1	compliance control is followed by leaving the factory	52.0%	3,974
2	license assignment executed as start activity	15.0%	1,143
3	Entering the parking lot is followed by was recalled from the parking lot	5.0%	378
4	Waiting for the product to load from the warehouse is followed by Full weight	1.0%	89
5	Leaving the parking lot is followed by empty weight	1.0%	88
6	license assignment is followed by empty weight	1.0%	63
7	Full weight is followed by loading from product warehouse	1.0%	59
8	empty weight is followed by full weight	1.0%	45
9	Loading from product warehouse is followed by leaving the factory	0.0%	33
10	was recalled from the parking lot is followed by case was overridden	0.0%	17
11	license assignment is followed by case was overridden	0.0%	11
12	Loading from product warehouse is followed by compliance control	0.0%	6
13	license assignment is followed by leaving the factory	0.0%	5
14	Entering the parking lot is followed by empty weight	0.0%	4
15	Full weight is followed by full weight	0.0%	4
16	Full weight is followed by leaving the factory	0.0%	4
17	Full weight executed as start activity	0.0%	4
18	license assignment is followed by loading from product warehouse	0.0%	2
19	Loading from product warehouse is followed by loading from product warehouse	0.0%	2
20	Leaving the parking lot is followed by case was overridden	0.0%	2
21	compliance control executed as start activity	0.0%	2
22	Incomplete case	0.0%	1
23	license assignment is followed by full weight	0.0%	1
24	Loading from product warehouse is followed by Invoice issuance	0.0%	1
25	empty weight is followed by loading from product warehouse	0.0%	1
26	was recalled from the parking lot is followed by Information correction	0.0%	1
27	compliance control is followed by loading from product warehouse	0.0%	1
28	compliance control is followed by full weight	0.0%	1
29	canceling is followed by leaving the factory	0.0%	1

Eighth step: Improvement suggestions

According to the output of the compliance check results, the designed process has high compliance with its implementation. In this step, the suggestions for improvement and corrective measures that were the result of the process analysis in the fourth and sixth steps, as well as the results of the process compliance check in the seventh step, were reviewed in a joint meeting with the presence of organization experts and process owners. The extracted improvement suggestions are as follows:

- It is suggested to carry out feasibility studies and loading times of various types of transport machines with different loading tonnages. Because with a more accurate estimate of the loading time, the recall notice can be registered on time.
- By carrying out this process mining, it was found that the cancellation and override procedures can be recorded in a floating form and at different times. For this reason, it is recommended to redesign the traffic software to control cancellations in such a way that in case of override, only the exit from the parking lot is recorded.
- Less than one percent of all cases that have been reworked were due to the mismatch of weight with traffic items during the investigation. According to this item, it is necessary to determine the final weight of the pallet. It is recommended to determine the final weight of the pallets using a scale and install the pallet weight specification label. In this case, the exact weight of each specific pallet and the amount of loading of each car is estimated based on this.
- According to the results of the process compliance check in the seventh step and a case-by-case review of several traffic files in the traffic software, it was found that the registration of the time and date of the steps on the server is accompanied by an error. This has been caused because some steps executed correctly in reality, but the information has been recorded incorrectly and has created a variant in the process, which should be corrected by the company's software team.
- Since the reason for the cancellation of vehicles cannot be reported, it is suggested that the traffic software be redesigned in such a way that the reason for the cancellation can be reported.

Conclusion and Future Research

After redesigning the warehousing and logistics management process using the proposed BPMPM framework and automating this process by traffic software, the results of the process mining and software logs show that the implementation of the compliance process is 76%. Also, after implementing the recommendations of the eighth step to calculate the effectiveness of the measures taken to reduce the risk of the warehouse and logistics management process, one more time the risk assessment of this process was done by the FMEA technique.

As can be seen in Figure 13, performing corrective action for automation and error proofing of the process led to the improvement of probability number, detection factor, and RPN, and the risk of the process was classified in the low-risk area. Considering the compliance of 76% and the new RPN number which is 16, the effectiveness of the redesign of the warehouse and logistics management process with the proposed BPMPM approach is evident, which led to the elimination of the possibility of leaving bulk goods without registering documents in the ERP system. This case greatly satisfied the stakeholders of the ERP system. As mentioned in the first part of this article, in ERP projects, problems related to the identification and implementation of organizational processes are one of the seven main groups of critical failure factors. The findings of the case study clearly show that the use of the proposed hybrid approach (BPMPM) based on risk management, knowledge of business process management, and the use of process mining solutions was able to reduce this risk and increase the effectiveness of the implemented ERP solution.

In this research, due to the time-consuming nature of the case study, one process was studied, it is recommended to use the proposed method for other processes, such as the order to cash, purchase to pay, account payable, and accounts receivable. Also, the proposed approach was used after the implementation of the ERP solution, it is suggested that researchers in this field also check the performance of the proposed approach before the implementation of ERP.

Process risk identification and management form																			
							Control Methods					Recommended		Result					
Process	Section	Failure Mode	Effects	Severity	Class	Causes	Prevention Control	Occurrence	Detection Control	Detection	RPN	Action	Responsibility	Severity	Prevention Control	Occurrence	Detection Control	Detection	RPN
Manage logistics and warehousing	Product warehouse	The goods have been removed from the company but the financial documents have not been registered.	Non-compliance occurs in warehousing and causes losses to the company	8	A	Wrong registration of weight information in the system by the user intentionally and inadvertently	We did training for the user / We defined work instructions	7	monthly warehousing / Perform periodic audits	6	336	Process redesign	Systems and methods unit	8	The weighing information of the scales is sent to the ERP system automatically	2	100% control by the system and Mistake proofing	1	16
						Leaving the car without registering in the system	Document control by output inspection manpower	5	Perform periodic audits	6	160		Systems and methods unit	8	Record the entry and exit of vehicles by the license plate reader camera nd automatic registration in the system	2	100% control by the system and Mistake proofing	1	16

Figure 13. Risk assessment of the redesigned process of warehousing and logistics management

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