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RESEARCH ARTICLE

Enhancing Procurement Performance in Project-Oriented Organizations: A Process Analysis Approach

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ABSTRACT Efficient procurement processes are critical for successful project execution in the construction industry. This study applies process mining techniques to analyze the procurement process of a project-oriented construction organization using the Behfalab platform. By leveraging real event log data extracted from the company's software system, the research aims to discover the actual procurement process execution, identify bottlenecks and deviations from the ideal process model, and propose data-driven improvement recommendations. The analysis reveals the predominant "happy path" followed in approximately 23.5% of cases examined during a 4.5-month period. It also uncovers the distribution of cases across various procurement activities, highlighting resource-intensive areas such as request handling, technical evaluations, and cost registration. Notably, significant bottlenecks are identified, including lengthy durations for tasks like purchase order processing on credit (average 12.8 working days), inquiry examination by workshop heads (11.6 working days), and cost registration (7.8 working days). Based on the findings and inputs from organizational experts, recommendations are proposed to enhance the procurement process. These include strengthening planning and resource allocation, establishing an authorized vendor list, promoting system thinking and software utilization, enhancing systematic cost registration and control mechanisms, and reinforcing the central procurement unit. The study contributes to the business process management domain by demonstrating the practical application of process mining for optimizing critical processes within project-oriented construction organizations.

INDEX TERMS Project-oriented organization, process mining, process analysis, event log, procurement process.

I. INTRODUCTION

The construction industry plays a vital role in shaping the built environment and contributing to economic growth [1]. It encompasses various activities such as designing, planning, constructing, and maintaining residential, commercial, and infrastructure projects. One crucial aspect of the construction industry is the procurement process, which holds significant importance in effectively managing construction projects [2], [3].

Procurement in the construction industry refers to the process of acquiring goods, services, and resources needed for a construction project [4]. It involves activities such as identifying project requirements, selecting suppliers or contractors, negotiating contracts, and ensuring timely delivery of materials and services [5]. The procurement process influences project outcomes, including cost, quality, schedule, and overall success [6], [7].

Today, it is imperative for organizations to recognize and oversee their existing procedures in order to adopt an efficient strategy [8]. Business processes are aided by workflow management systems [9]. While the current

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workflow management systems facilitate the creation, setup, implementation, and regulation of controlled processes, they have limitations when it comes to troubleshooting [10]. To address these shortcomings, process mining comes into play. Process mining acts as a connection between the realms of data science and process science [11]. The primary focus of process mining lies in the ''detection, tracking, and enhancement of tangible processes through the extraction of insights from event data'' readily available in modern-day systems [12].

Process mining provides a significant and indispensable viewpoint on operational procedures through the examination of real behaviors. This methodology is advantageous for creating supportive systems or reorganizing current processes. The fundamental aim of process mining is to derive meaningful and actionable insights regarding processes from the event graph. Event logs comprise recorded information relevant to occurrences throughout the implementation of a business process within a company. An essential feature of an event graph lies in its structure, formed by actual events. As a result, the event graph documents how a process evolves in reality, regardless of the organization's initial plans or process designs [12], [13].

The Procurement request process holds significant importance for the success of certain organizations [14]. By employing the process mining approach, the aim is to ensure effective time and cost management throughout the order registration and necessary steps for purchase. This program is strategically based on process mining as part of the organization's overall strategy. The primary objective of this process is to maximize profitability, meet demand, and attract/retain customers [13], [15].

In today's rapidly changing business landscape, adaptability is a fundamental principle that organizations must adhere to [16]. Accordingly, managers should modify their principles to align with prevailing environmental conditions [17]. Employing standardized methodologies for process design within large organizations facilitates the achievement of strategic objectives, including cost reduction and intellectual property protection [18], [19].

This article introduces a novel approach by applying process mining to analyze the procurement request process within a project-oriented organization. Furthermore, it investigates time metrics endorsed by APQC in the procurement process. Remarkably, there is a lack of prior research from this specific perspective. It is crucial to highlight that this article represents both a scientific inquiry and a practical endeavor. The analyses and outcomes rely on authentic data gathered from individual organizations, which may vary across entities. Nevertheless, the conclusions drawn can be extrapolated to organizations demonstrating comparable performance.

Upon completing the event diagram preparation, the process mining phase initiates, concurrently with the definition of relevant APQC-approved indicators. Subsequently, the organization is scrutinized from the standpoint of these indicators. Improvement suggestions are then gathered through interviews with experts involved in the procurement process and conveyed to the organization's management unit. This study primarily concentrates on process discovery, compliance review, and enhancement recommendations derived from semi-structured qualitative interviews with the organization's experts.

The current study distinguishes itself from past research on Project-Oriented Organizations in several key aspects. Firstly, it leverages advanced process mining techniques and the Behfaleb platform, which allows for a more detailed and data-driven analysis of procurement processes [20]. Secondly, this study focuses on the construction industry, which has unique challenges and complexities compared to other sectors studied in the past [21]. Thirdly, our research incorporates real-time data from actual project executions, providing insights that are more reflective of current industry practices. Lastly, this study places a strong emphasis on identifying and addressing bottlenecks in the procurement process, an aspect that has been less explored in previous research on Project-Oriented Organizations [22].

The research aims to address the following inquiries as part of our research objectives:

- Is it possible to achieve a logical and satisfactory solution for planning through process analysis utilizing real data?
- What is the predominant path followed in the procurement process of a project-oriented organization?
- How are the items (cases) distributed in the procurement process of the project-oriented organization?
- To what extent do the files align with the process model?
- What are the average, minimum, and maximum durations of the procurement process in a project-oriented organization?
- Which task exhibits the longest duration?

The subsequent sections of this õstusy unfold as follows: commencing with the Literature Review, we delve into an exploration of existing scholarly works. Subsequently, we elaborate on the chosen research methodology in the ensuing section. Moving forward, the fourth section delves into an in-depth analysis of the results derived from the empirical data collected during the case study. Transitioning to the fifth part, we engage in a comprehensive discussion of the findings. This discussion segues into the sixth section, where we draw conclusive remarks. Lastly, in the seventh part, we address the limitations encountered during the research endeavor and propose avenues for future research.

II. LITERATURE REVIEW

A. PROCESS MINING

Process mining is a relatively new and exciting field that involves analyzing data from various sources, including event logs, to discover, monitor, and improve business processes. This approach uses a range of techniques that are used to extract information from event logs, including data visualization, statistical analysis, and machine learning [19].

The process mining approach has gained popularity in recent years as organizations have increasingly recognized the need to improve their processes to remain competitive. By using process mining techniques, organizations can identify patterns and trends within their processes, which can then be used to optimize and improve performance [12].

One of the key benefits of process mining is that it allows for the identification of bottlenecks and inefficiencies within a process. These issues can then be addressed through targeted interventions, such as process redesign or automation, to remove unnecessary steps and streamline workflows [13].

Another benefit of process mining is that it provides an objective view of how processes are actually being executed, rather than relying on anecdotal evidence or assumptions. This can help to identify discrepancies between what is supposed to happen and what is actually happening, highlighting areas where improvements are needed [15].

There are several different techniques used in process mining, each with its strengths and weaknesses. Data visualization is one of the most common techniques, as it allows for the exploration of large datasets and the identification of patterns and trends. Statistical analysis is another important technique, as it can be used to identify correlations between different variables and to determine the likelihood of certain events occurring [12], [15].

Machine learning is also becoming increasingly important in process mining, as it can be used to automate the identification of patterns and trends, reducing the need for manual intervention. This can help organizations to scale up their process mining efforts and to derive insights more quickly and efficiently [12], [23].

In conclusion, process mining is an important field that is helping organizations improve their processes and stay competitive in an increasingly complex business environment [15]. By leveraging data from various sources, including event logs, process mining techniques allow organizations to identify bottlenecks and inefficiencies, optimize workflows, and ultimately improve performance [24].

B. APQC FRAMEWORK

APQC (American Productivity & Quality Center) is a globally recognized organization that provides valuable insights, benchmarks, and best practices in various business processes, including procurement. As a researcher investigating the procurement process using process mining, the utilization of APQC standards and indicators can significantly enhance the analysis and review of this essential business function [25].

APQC offers a comprehensive framework for evaluating and benchmarking procurement processes, enabling organizations to measure their performance and identify areas for improvement. By leveraging APQC's Procurement Process Classification Framework (PCF), researchers can categorize and assess the various stages and activities involved in the procurement process. The PCF provides a standardized and universally accepted structure, facilitating comparisons and enabling organizations to align their practices with industry standards [26].

In addition to the PCF, APQC offers a range of key performance indicators (KPIs) specifically tailored to procurement processes. These KPIs cover important aspects such as cycle time, cost savings, supplier performance, contract compliance, and quality. By incorporating APQC's KPIs into the process mining analysis, researchers can gain deeper insights into the efficiency, effectiveness, and overall performance of the procurement process [27].

Furthermore, APQC's extensive benchmarking database allows researchers to compare their organization's procurement performance against industry peers. This benchmarking capability provides valuable context and helps identify areas where the procurement process can be optimized and streamlined [28]. By aligning with APQC's best practices and leveraging their benchmarking resources, researchers can make informed recommendations for process improvement within the procurement function [27].

In summary, APQC plays a vital role in enhancing the analysis and review of the procurement process using process mining. By leveraging APQC's Procurement Process Classification Framework, KPIs, and benchmarking capabilities, researchers can ensure a comprehensive and standardized evaluation of the procurement process, enabling organizations to optimize their operations and achieve excellence in procurement performance.

C. RELATED WORKS

The Related Works section of a research paper delves into existing literature and studies pertinent to the investigated topic. In this section, we will scrutinize a range of articles and studies that have explored the application of process mining across diverse fields. Specifically, we will review research conducted in the purchasing process domain, as well as in supply chain management, education, human resources, healthcare, maintenance, and other industries.

In the purchasing process field, two articles were analyzed. The first article, titled "Application of Process Mining to Identify Delay Factors in the Internal Purchasing Process" [29], focused on the internal purchasing process of Quintal company. The study utilized Fluxicon Disco software to analyze 608 cases (9199 events) and identified an average delay of approximately 15 days. The study provided recommendations to increase efficiency, such as expanding personnel in the purchasing department. The second article, titled "Analysis of the Purchasing Process Using Process Mining in a Heavy Manufacturing Industry" [30], investigated the purchasing process of a marine and ship parts manufacturing company in Korea. Fluxicon Disco software was used to analyze 663 cases (9829 events), identifying delays and areas for improvement.

In the field of supply chain, [31] conducted a study using process mining techniques to analyze inter-organizational

TABLE 1. Summary of related works.

Article Title	*Year*	*Field of Application*	*Innovation*
Application of Process Mining to Identify Delay Factors in the Internal Purchasing Process	2019	Purchasing Process	Used Fluxicon Disco software to analyze the internal purchasing process of Quintal company, identifying delay factors and recommending expanding personnel in the purchasing department. Evaluated 608 cases (9199 events).
Analysis of the Purchasing Process Using Process Mining in a Heavy Manufacturing Industry	2018	Purchasing Process	Investigated the purchasing process of a marine and ship parts manufacturing company in Korea using Fluxicon Disco software. Identified delays, activities consuming significant time, and areas for improvement. Performance optimization by investigating root causes. Analyzed 663 cases (9829 events).
Evaluation of Supply Chain Performance Using Process Mining	2019	Supply Chain	Introduced a framework for assessing the performance of various business units. Ranked the performance of different branches of the Shahrvand chain store using a real dataset from process analysis. A comprehensive understanding of the process and performance indicators were utilized.
Comparison of Block Production Processes via Data Envelopment Analysis and Automatic Process Analysis Using Process Mining	2014	Supply Chain	Compared 19 block production processes at a Korean shipbuilding company using DEA. Used automatic process analysis results to measure performance indicators, including time, task count, and raw materials.
Utilizing process analysis to evaluate student performance	2017	Education	Improved the online learning experience of students through study. Analyzed students' response processes by examining computer logs.
Integrated Process Analysis Methodology for Assessing Job Performance	2018	Human Resources	Assessed the performance of various jobs by integrating process analysis methodology and factor evaluation systems. Strengthened the factor evaluation system's limitations using process mining.
Analysis of Emergency Room Department Performance	2019	Health	Examined emergency room department performance to enhance medical center services. Evaluated hospital information system performance through a case study using time indicators.
Linking Maintenance Management and Business Process Management	2022	Maintenance	Linked maintenance management and business process management through information systems. Proposed a conceptual module model based on CMMS to evaluate department synchronization within an organization.
Process Mining in the Food Industry	2021	Food Industry	Studied process mining in the food industry.
Investigating Purchase Order Process in the Paint Industry	2020	Purchasing Process in the Paint Industry	Investigated the purchase order process in the paint industry using process mining.
Discovering Process Models Based on Supervised Machine Learning Techniques	2022	Procurement	Proposed a framework for discovering process models based on supervised machine learning techniques. Examined differences between discovered process models and designed business processes using a real dataset from a logistics department, highlighting areas for improvement.

business processes and develop a framework for deriving business and economic insights from EDI data. Reference [12] presented a thesis on the evaluation of supply chain performance using process mining, which introduced a framework for assessing the performance of various business units.

Process mining has also been applied in education. Reference [32] conducted a study to improve the online learning experience of students, while [33] utilized process analysis to assess students' performance in computerized tests at a university.

In the field of human resources, [34] integrated process analysis methodology and factor evaluation systems to assess the performance of various jobs.

Several articles have explored the application of process mining in the field of health. Reference [35] examined emergency room department performance, [36]evaluated a hospital information system's performance, [37] studied data privacy and application requirements for healthcare process data.

In the maintenance field, [38] proposed a conceptual module model that links maintenance management and business process management through information systems.

Other industries have also been the subject of process mining studies. Reference [39] investigated process mining in the food industry, while [40] explored the purchase order process in the paint industry. Reference [41] examined the potential benefits of email logs for organizations and proposed a framework for discovering process models based on supervised machine-learning techniques in the procurement field.

Overall, the studies discussed in this section demonstrate the wide application of process mining in various fields, including purchasing, supply chain, education, human resources, health, maintenance, and other industries. These studies have contributed to the understanding of process analysis and performance evaluation in different contexts.

Table 1 provides a summary of similar works in this research.

III. METHODOLOGY

The article proposes a methodology for process mining, which is briefly presented in Figure 1. This comprehensive approach combines data-driven analysis with expert insights to thoroughly examine and improve the procurement process in a project-oriented organization. The methodology encompasses several interconnected steps, each

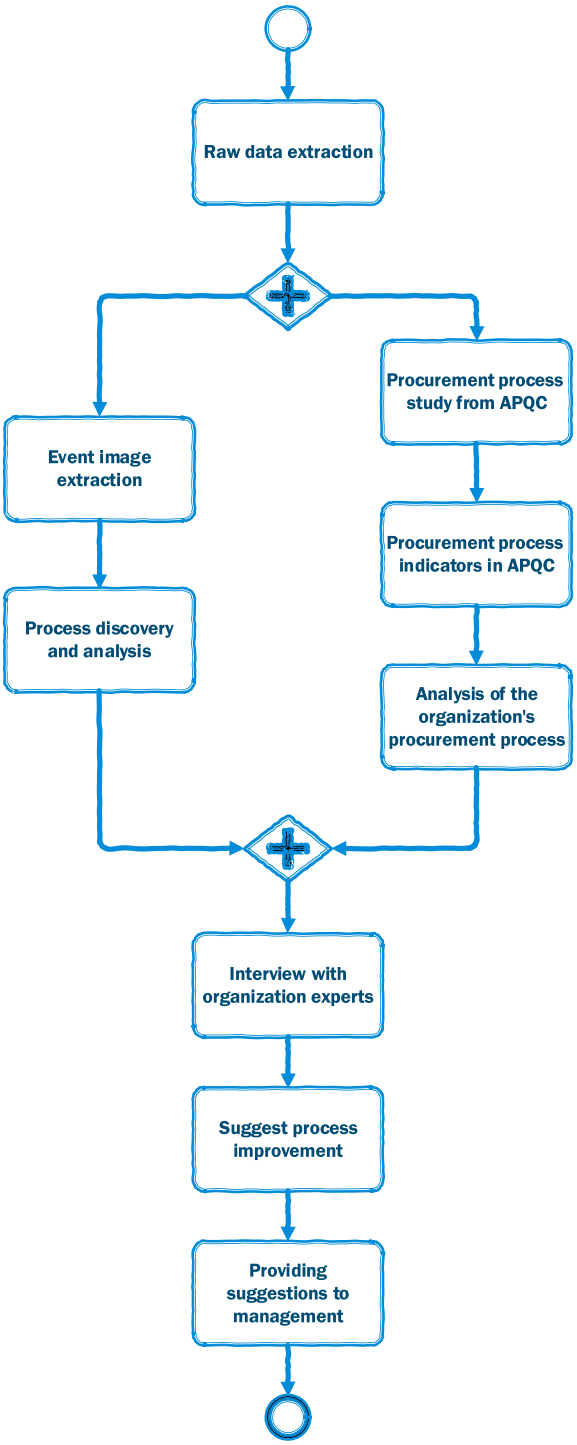


FIGURE 1. Research methodology.

contributing to a holistic understanding of the procurement process.

The initial steps focus on data extraction and preparation:

1. Raw Data Extraction: The initial phase involves extracting raw data from the company's existing software system. This data contains detailed information about the procurement process, including timestamps, activities, and involved parties.
2. Event Image Extraction: The raw data is carefully processed to extract event images. These event images serve as the primary input for the process mining tools and represent individual instances of the procurement process.

Following data preparation, the analysis phase begins:

3. Process Discovery and Analysis: Using the Behfaleb software, multiple process mining techniques are applied to the event diagram. This step aims to discover and analyze the various process paths that occurred during the specified study period. The analysis includes identifying common paths, bottlenecks, and deviations from the expected process flow.
4. APQC Framework Integration: Concurrently with the process mining analysis, relevant APQC (American Productivity & Quality Center) indicators are defined. These indicators provide a standardized framework for evaluating the procurement process from an organizational perspective.
5. Organizational Analysis: The procurement process is then studied from the perspective of the defined APQC indicators. This analysis helps to contextualize the process mining results within industry-standard metrics and benchmarks.

To complement the data-driven analysis, the methodology incorporates expert knowledge:

6. Expert Interviews: To gather valuable insights for process improvement, a series of semi-structured qualitative interviews are conducted with experts involved in the purchase process, as well as decision-makers occupying key positions within the organization. These interviews target procurement units, managers of PMO units, and financial units of workshops as the initial participants. Suggestions for enhancing the process are collected during these interviews.
7. Improvement Suggestions: Based on the combined results of the process mining analysis and expert interviews, a set of suggestions for improving the procurement process is formulated.
8. Management Review: The improvement suggestions are presented to the organization's management, including CEOs and project managers. This step allows for further refinement of the suggestions and ensures alignment with the organization's strategic objectives.
9. Final Recommendations: After incorporating management feedback, the final set of recommendations for enhancing the procurement process is developed.

This systematic approach ensures a thorough analysis of the procurement process, combining data-driven insights with expert knowledge to propose targeted improvements. By leveraging both quantitative process mining techniques and qualitative expert input, the methodology provides a robust framework for identifying inefficiencies, bottle-

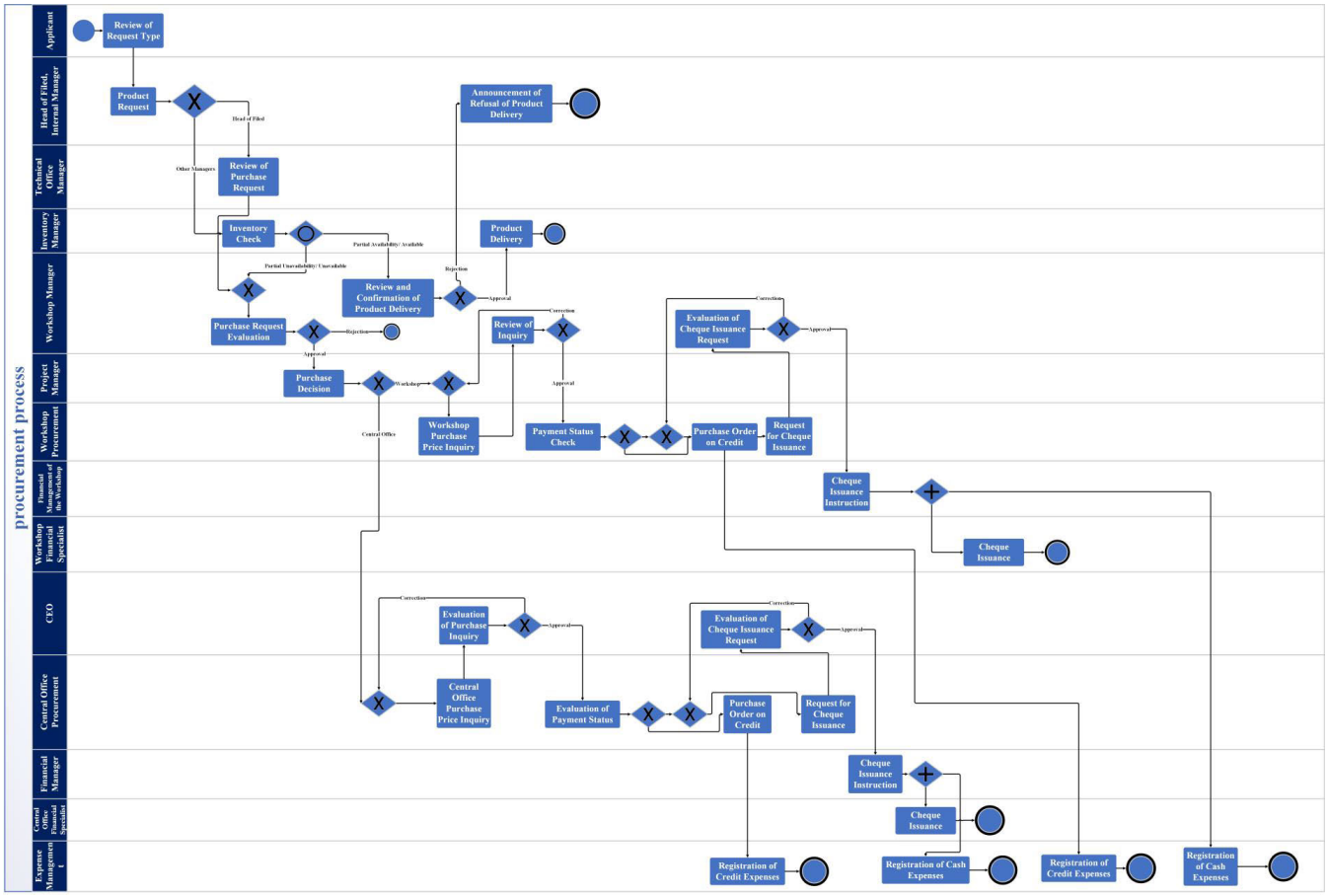


FIGURE 2. Procurement process.

necks, and areas for enhancement in the procurement process.

The integration of the APQC framework further strengthens the analysis by providing industry-standard metrics and benchmarks. This allows for a more contextualized understanding of the organization's performance relative to best practices in the field.

Ultimately, this methodology aims to deliver actionable recommendations that are both data-driven and practically feasible, aligning with the organization's strategic objectives and operational realities. The iterative nature of the process, involving multiple stakeholders from various organizational levels, ensures that the final recommendations are comprehensive, well-vetted, and tailored to the specific needs of the project-oriented organization.

IV. RESULT

The company under study was established in 1997 with a primary focus on executing infrastructure projects within the domains of road construction, building construction, and facilities. The procurement process of this company encompasses a series of steps, including request registration, request verification, inventory check by the warehouse, delivery of available goods, procurement unit's request for the purchase of non-existent goods, price inquiry, management approval, selection of payment method, issuance of a check or credit purchase, and ultimately, debt registration or crediting of the fee. Figure 2 visually presents the procurement process employed by the company

Within the procurement process of the organization under study, the initial step involves the applicant unit submitting a purchase request, which is subsequently reviewed and approved or rejected by the higher-level unit. It is important to note that for certain types of requested products, the purchase request may involve the technical unit's assessment. Moving forward, two distinct scenarios arise. The first scenario pertains to goods that do not require assessment by the technical unit. In this case, the warehouse unit conducts an inventory check and delivers the available goods upon obtaining permission from the workshop head. Conversely, non-existent goods undergo the standard procurement process. The second scenario involves goods that require evaluation by the technical unit and subsequent confirmation by the workshop head. Following the review of the purchase request, the workshop head either approves or rejects it. If approved, the request is forwarded to the project manager. At this stage, the project manager determines whether the procurement will be handled by the workshop's procurement unit or

TABLE 2. Raw data sample extracted from process maker software.

Part of the process steps			
	Check the request type	*Start*	*2020/12/07 9:23:03*
	Request goods	Start	2020/12/07 9:35:05
	Checking the purchase request by the official of the technical office	Start	2020/12/08 18:30:56
	Purchase Request review	Start	2020/12/09 10:57:27

the head office's workshop, based on workshop-specific conditions.

In both scenarios, the workshop or central office's procurement unit is responsible for conducting inquiries about the requested goods. These inquiries are then submitted to the workshop head or CEO for review and approval. Subsequently, the procurement unit selects the payment method for the purchase request, based on negotiations with the sellers, opting for either cash (check) or credit. In the case of cash payment, the request undergoes further approval from the project manager or CEO. The workshop or central office's financial unit then issues a check, and all expenses are recorded as cash expenses under the supervision of the cost control unit. On the other hand, if the credit payment method is chosen, the cost control unit directly records the transaction as credit costs.

A. DATA EXTRACTION

In this phase, the procurement process logs were meticulously extracted from the Process Maker software. The raw data obtained from this extraction is exemplified in Table 2.

Preparation of the Event Diagram for Mining Process

For this study, the code recorded in the software was employed as the unique identifier for the file.

Table 3 provides a sample event for reference, demonstrating the structure of the data.

B. PROCESS DISCOVERY AND ANALYSIS THROUGH PROCESS MINING

The process mining approach was employed to uncover and analyze the main process of the company under investigation. By visualizing the desired event using Behfaleb, the process models and other process analyses were generated. Behfaleb, a comprehensive analytical tool, served as the input for the event diagram and facilitated the creation of corresponding output process models.

C. PROCESS PATHS

Upon inputting the prepared event diagram into Behfaleb, a process map was constructed, emphasizing clarity and comprehensibility through the selection of an appropriate level of detail. Within the map, various activities were represented by nodes, while the interactions between these activities were depicted by edges. Specifically, the procurement process of the company during a 4-and-a-half-month period in 2020 exhibited a total of 44 distinct paths.

TABLE 3. A sample event extract from raw data.

date time	*File ID*	*Activity*
03/12/2020 11:39:20	7564	Check the request type
03/12/2020 11:39:24	7564	Request goods
03/12/2020 15:37:04	7564	Checking the purchase request by the official of the technical office
03/12/2020 16:01:09	7564	Purchase request review
05/12/2020 09:38:47	7564	Purchasing decision by workshop or head office
05/12/2020 10:46:45	7564	Inquiring about the purchase price of the central office
08/12/2020 09:51:41	7564	Review and approval of the purchase by the CEO
08/12/2020 09:55:48	7564	Check payment status by head office procurement
08/12/2020 10:13:56	7564	Notice of purchase approved by the head office
12/20/2020 15:31:15	7564	Check issuance request by the head office
12/21/2020 10:29:53	7564	Checking the check issuance request by the head office
12/22/2020 10:46:06	7564	Order to issue a check by the head office
12/21/2020 10:45:54	7564	Receive a request for the issuance of a certified check
12/21/2020 13:41:09	7564	Recording of cash expenses

Table 4 illustrates the representative output of the process paths, focusing on those with a coverage of 5% and above. These paths provide valuable insights into the overall process dynamics and highlight the most significant and frequently traversed routes.

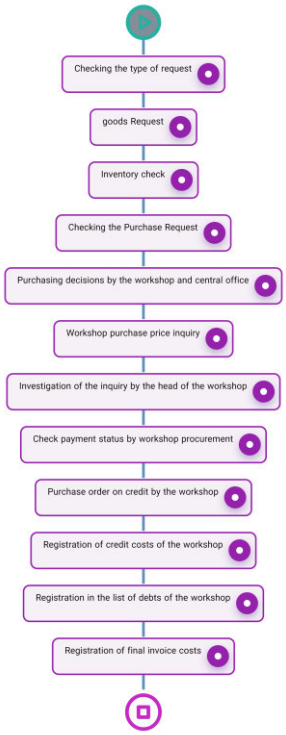
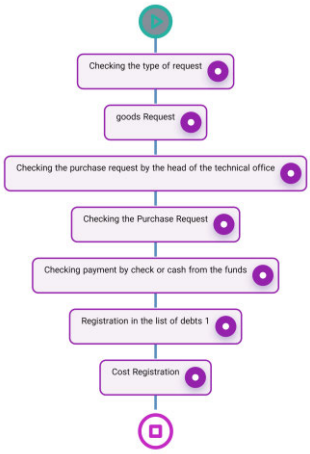
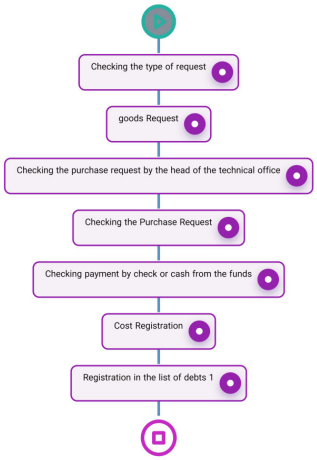
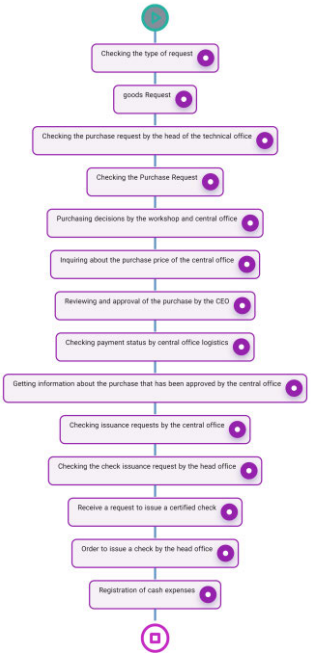
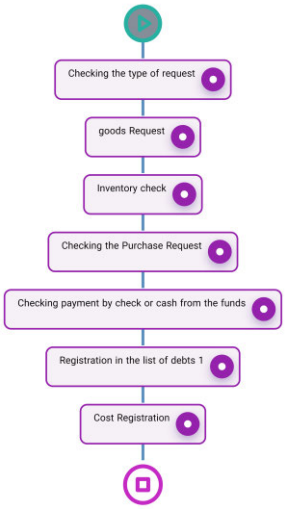
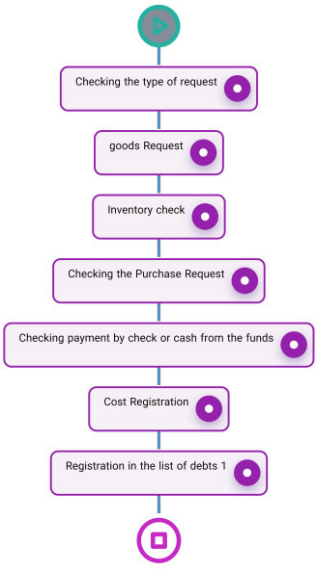
Based on Figure 3 and in accordance with the Pareto law, it is evident that variants 1 to 7 account for approximately 80% of the cases within this process.

D. PROCESS MAP

Figure 4 presents a comprehensive and detailed map of the selected process. The map is derived from real data and surpasses the provided BPMN model in terms of accuracy and representativeness. While the BPMN model showcases the ideal state of the process,[1] Figure 4 depicts the actual process execution model, encompassing all its execution paths and reflecting the reality of process execution.

[1] As-Is model.

TABLE 4. Process paths with more than 5% coverage.

Path 3: 9.8% coverage	Path 2: 17.8% coverage	Path 1: 23% coverage
		
Path 6: 5.2% coverage	**Path 5: 5.5% coverage**	**Path 4: 9.3% coverage**
		

E. COMMON PROCESS PATH

Figure 5 illustrates the common and often referred to as the ''Happy-path'' of the process within the software.

This path represents the initial and most prevalent route of the process discussed in the preceding section. It encompasses approximately 23.5% of the total

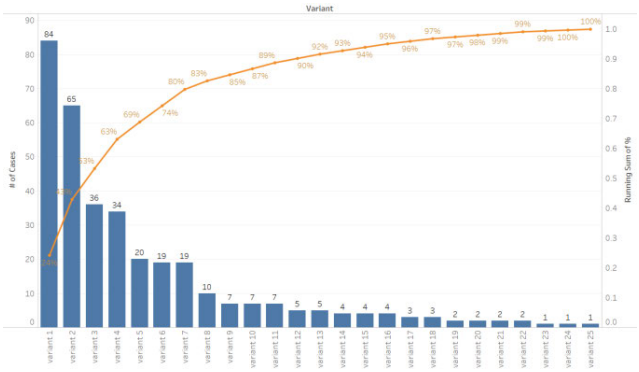


FIGURE 3. Variants.

cases observed during the reviewed 4-and-a-half-month period.

F. IDENTIFICATION OF BOTTLENECKS

During the analysis, several connections and activity relationships were identified as significant contributors to increased process transit time, resulting in bottlenecks. The following bottlenecks were observed:

- Purchase order on credit by the central office: This step had an average processing time of 12.8 working days in the examined files.
- Examination of the inquiry by the head of the workshop: This activity exhibited an average processing time of 11.6 working days in the files.
- Registration of fees: The registration process for fees took an average of 7.8 working days in the cases.
- Request for check issuance by the central office: This step demonstrated an average processing time of 6 working days in the cases.
- Registration in the list of debts: The registration process in the list of debts occurred with an average duration of 3.4 working days in the cases.

These bottlenecks highlight specific areas within the procurement process that experience delays and require attention for process optimization and improvement.

G. OPERATING TIME ANALYSIS

Based on the diagram presented in Figure 6, the average operating time for the process is determined to be 19 days. This indicates that, on average, it takes 19 days to complete the entire process from start to finish. Additionally, the average operational time within the process is calculated to be 13.9 days.

The analysis reveals that the minimum time recorded for completing the process is 1.1 days, representing the shortest duration observed. Conversely, the maximum time recorded for completing the process is 102 days, reflecting the longest duration observed within the analyzed data set.

TABLE 5. Activities with the most files.

Number of files	*Name of the activity*
366	Check the request type
366	Request goods
366	Purchase Request review
260	Checking the purchase request by the official of the technical office
225	Registration in the list of debts
213	Checking payment by check or cash from the salary
213	Cost Registration
153	Purchasing decisions by workshop or head office
106	Inventory check

H. NUMBER OF FILES PER ACTIVITY

Table 5 displays the key activities that require significant resource allocation. Notably, the activities of ''request type check,'' ''goods request,'' and ''purchase request check'' demonstrate a higher number of cases compared to other activities. This is followed by the activity of ''checking the purchase request by the technical office official,'' and subsequently, the activities of ''registering in the list of debts,'' ''checking payment by check or cash from the salary,'' and ''registering expenses.'' These findings offer valuable insights into the distribution of case volumes among different activities, shedding light on their relative importance and resource requirements within the broader process.

I. PROCESS IMPROVEMENT RECOMMENDATIONS

As outlined in the research methodology, the validation of the results was conducted by soliciting the insights of experts within the organization. These experts included CEOs, project managers, PMO unit managers, as well as key personnel involved in the procurement and financial units. Specifically, the experts from the company were actively engaged in the process flow from the purchase request stage to cost registration. Through this research, these experts gained a valuable understanding of process analysis within a project-oriented organization.

Table 6 provides an overview of the organization's interviewed experts, detailing their respective work experience and roles as proposers or approvers of improvement proposals. Their expertise and involvement were instrumental in the formulation of process improvement recommendations.

Based on the identified bottlenecks and the analysis conducted, the following recommendations were derived through interviews with experts from the organization:

1. Strengthen Planning and Resource Allocation: As a project-oriented organization, it is crucial to improve planning for items and equipment. Accurate allocation of resources such as human resources, machinery, materials, and equipment is essential for effective implementation. Utilizing project breakdown structure (WBS)

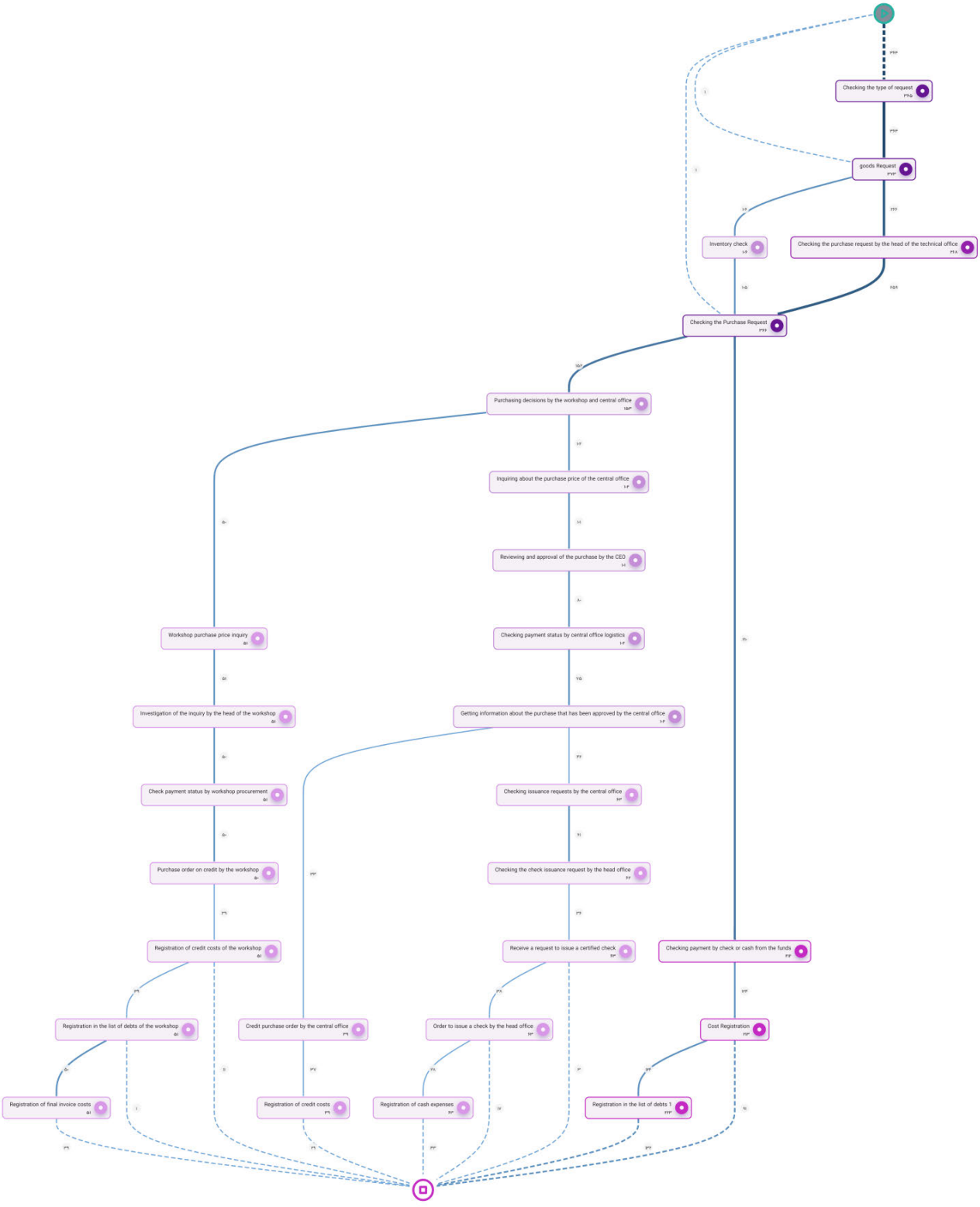


FIGURE 4. Procurement process map.

techniques can enhance purchasing planning for each activity within the predicted timeframe. Strengthening resource allocation and schedule updates will enhance project predictability, cost management, and overall efficiency. The company is advised to focus on proper purchasing planning.

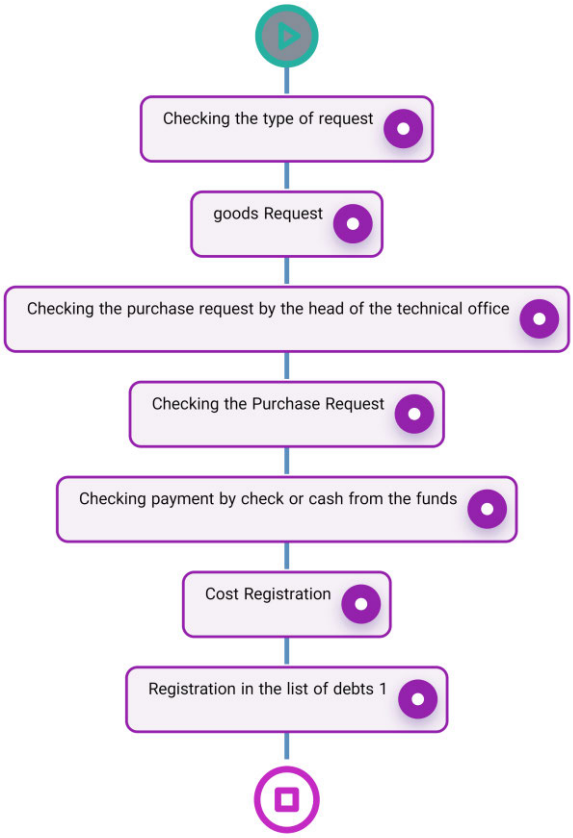


FIGURE 5. Happy-path process.

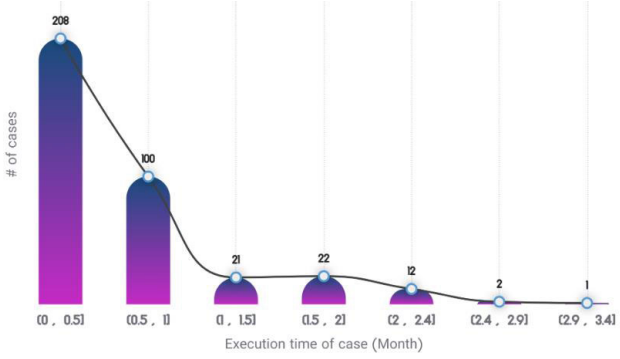


FIGURE 6. Number of files per time period (based on number).

TABLE 6. List of experts.

Row	*Organizational position*	*Work experience*	*Recommender/Approver*
1	CEO	27	Approver
2	Chairperson of the Board	28	Approver
3	Shiraz workshop project manager	20	Approver
4	Project manager of the Firozabadi workshop	17	Approver
5	Hamedan workshop project manager	18	Approver
6	Sirjan workshop project manager	15	Approver
7	Head Office PMO Manager	16	Recommender
8	Shiraz workshop supplies	10	Recommender
9	Firozabadi workshop supplies	8	Recommender
10	Hamadan workshop supplies	11	Recommender
11	Sirjan workshop supplies	8	Recommender
12	Kamal Shahr workshop supplies	8	Recommender
13	Babolsar workshop supplies	5	Recommender
14	Headquarters logistics	21	Recommender
15	PMO manager of Shiraz workshop	15	Recommender
16	PMO manager of Firouzabadi workshop	15	Recommender
17	Hamedan workshop PMO manager	12	Recommender
18	PMO manager of Sirjan workshop	14	Recommender
19	PMO manager of Kamal Shahr workshop	10	Recommender
20	PMO manager of Babolsar workshop	9	Recommender
21	Financial supervisor of Shiraz workshop	17	Recommender
22	Financial supervisor of Firouzabadi workshop	16	Recommender
23	Financial supervisor of Hamadan workshop	18	Recommender
24	Financial supervisor of Sirjan workshop	15	Recommender
25	Chief financial officer of the central office	35	Recommender

2. Establish an Authorized Vendor List: Evaluating suppliers and creating an approved list of reliable suppliers enables professional buyers to access specific products or services promptly, considering quality and standards. This vendor list, known as the Authorized Vendor List (AVL), also facilitates monitoring, evaluation, and procurement oversight by employer companies for EPC or PC project contractors. The absence of a list of suppliers meeting specified criteria in the company leads to delays in inquiries and decision-making, impacting senior management decision-making processes. Addressing this bottleneck requires the development of an AVL and the evaluation of suppliers based on key indicators such as ratings, creditworthiness, reputation, and quality.
3. Enhance System Thinking and Software Implementation: Strengthening system thinking within the organization is vital to ensure the procurement process is followed systematically with the aid of software.

Currently, some tasks are carried out in parallel on paper within the workshops, indicating a weak utilization of the software. Lack of expert utilization diminishes the motivation to use software and implement processes systematically. To address this, it is recommended to promote system thinking within the organization and employs experts to drive process implementation. Training programs should be conducted to enhance expertise. Creating a management dashboard for periodic reporting and identifying prolonged purchase processes can be instrumental in optimizing the system. Activating a warning system linked to users' mobile numbers or emails would remind users to complete pending tasks after two working days.

4. Enhance Cost Registration and Control: Cost registration is essential in project-oriented organizations like this company for comparing actual costs against planned values agreed upon between the employer and the contractor. Currently, the absence of a precise and systematic cost registration process results in delayed cost recording, as it is considered the final step of the process. This delay does not appear to disrupt employees' work. To address this, it is recommended to establish a dedicated cost control unit within the company, transferring cost control responsibility from individuals to the unit. The cost control process should be systematically designed to align with the output of the purchase process, ensuring timely cost registration. Periodic reporting on costs should be implemented to enforce timely recording. An alert system connected to the mobile numbers or emails of cost control unit users can be activated to remind them to complete pending tasks after two working days.
5. Strengthen the Procurement Unit in the Central Office: The company operates with six active workshops, and the purchasing process is repeated frequently across all workshops. The limited staffing in the procurement unit of the central office can slow down the process. Currently, two individuals handle both purchasing and delivery tasks simultaneously. To improve efficiency, it is recommended to add one to two more personnel specifically dedicated to logistics, ensuring the workload is distributed among them. Providing training on negotiation principles and techniques to the procurement unit can enhance bargaining power, leading to reduced agreement time between contractors and suppliers.

By implementing these recommendations, the company can enhance its procurement process, improve resource allocation, strengthen supplier relationships, optimize cost control, and streamline overall operations.

V. DISCUSSION

In this section, the study addresses the inquiries posited in the article's introduction, which effectively delineated the research objectives:

1. Is it possible to achieve a logical and satisfactory solution for planning through process analysis utilizing real data?

The study demonstrates that process analysis using real data from a project-oriented company can provide valuable insights for planning and improving the procurement process. By visualizing the actual process flows, bottlenecks, and deviations from the ideal process model, the researchers could identify areas requiring enhanced planning and resource allocation. The recommendations proposed, such as strengthening purchasing planning through techniques like Work Breakdown Structure (WBS), indicate that process mining facilitates the achievement of logical and satisfactory solutions for planning based on real process execution data.

2. What is the predominant path followed in the procurement process of a project-oriented organization?

The analysis revealed a ''Happy-path'' that represents the most common pathway followed in approximately 23.5% of the cases examined during the 4.5-month period. This path outlines the typical sequence of activities, from the initial purchase request to the delivery of goods or initiation of the procurement process for non-existent items. Understanding the predominant path is crucial for optimizing the most frequently executed process flow.

3. How are the items (cases) distributed in the procurement process of the project-oriented organization?

The study analyzed the distribution of cases across various activities within the procurement process. Activities such as ''request type check,'' ''goods request,'' and ''purchase request check'' exhibited the highest number of cases, indicating their significance and resource requirements. Other activities like ''checking the purchase request by the technical office official'' and cost/debt registration tasks also had considerable case volumes, highlighting the need for efficient resource allocation in these areas.

4. To what extent do the files align with the process model?

The analysis revealed deviations between the actual process execution and the provided BPMN (ideal) process model. The researchers generated a comprehensive process map based on real data, depicting all execution paths and reflecting the reality of process execution more accurately than the BPMN model. This finding underscores the importance of process mining in identifying conformance issues and aligning process models with actual execution data.

5. What are the average, minimum, and maximum durations of the procurement process in a project-oriented organization?

The study determined that the average duration for completing the entire procurement process was 19 days, with a minimum recorded time of 1.1 days and a maximum of 102 days. Additionally, the average operational time within the process was 13.9 days. These time indicators provide valuable insights into the overall process efficiency and

help identify areas that may require optimization to reduce excessive durations.

6. Which task exhibits the longest duration?

The analysis identified several bottlenecks, including tasks that contributed significantly to increased process transit time. The tasks with the longest durations were ''Purchase order on credit by the central office'' (average of 12.8 working days), ''Examination of the inquiry by the head of the workshop'' (average of 11.6 working days), and ''Registration of fees'' (average of 7.8 working days). Addressing these bottlenecks through process improvements could lead to substantial reductions in overall process duration.

VI. CONCLUSION

The construction industry plays a vital role in shaping the built environment and contributing to economic growth. Within this sector, efficient procurement processes are critical for successful project execution. This study focused on applying process mining techniques to analyze the procurement process of a project-oriented organization in the construction industry. By leveraging real process data and event logs, the research provided valuable insights into the actual execution of the procurement process, deviations from the ideal process model, and opportunities for improvement.

The analysis identified the predominant process path, referred to as the ''Happy-path,'' which accounted for approximately 23.5% of the examined cases. Furthermore, the study revealed the distribution of cases across various activities, highlighting resource-intensive areas such as request handling, technical evaluations, and cost/debt registration. Notably, the investigation uncovered significant bottlenecks, including lengthy durations for tasks like purchase order processing, inquiry examination, and cost registration. These bottlenecks contributed to increased process transit times and inefficiencies.

Based on the findings and expert inputs from the organization's personnel, a set of recommendations was formulated to enhance the procurement process. These recommendations include strengthening planning and resource allocation, establishing an authorized vendor list, promoting system thinking and software implementation, enhancing cost registration and control, and reinforcing the procurement unit in the central office. Implementing these recommendations can lead to improved process efficiency, cost optimization, stronger supplier relationships, and streamlined operations within the project-oriented organization.

The study contributes to the field of business process management by demonstrating the practical application of process mining techniques in optimizing critical processes within project-oriented organizations. By leveraging real-world data and event logs, the research provides a comprehensive understanding of process execution, conformance, and performance, enabling targeted interventions for process improvement.

In conclusion, this study highlights the significance of process mining as a valuable tool for understanding, analyzing, and optimizing critical processes within project-oriented organizations. By embracing data-driven approaches and leveraging process mining techniques, organizations can gain actionable insights, streamline operations, and ultimately enhance their competitiveness in the dynamic construction industry.

A. LIMITATIONS AND FUTURE RESEARCH

While this study offers valuable insights into process mining and analysis of the procurement process in a project-oriented organization, certain limitations exist, which pave the way for future research opportunities.

Firstly, the scope of this research was limited to the procurement process within a single organization. To further validate and generalize the findings, future studies could expand the analysis to other critical processes within project-oriented organizations, such as cost control processes, tender participation processes, and supplier evaluation processes. By applying similar methodologies to these processes, researchers can gain a more comprehensive understanding of process dynamics and optimization opportunities across various business units.

Additionally, this study was constrained by limited access to cost data during the analysis. Incorporating cost data into the event diagram could provide valuable insights into the cost implications of process inefficiencies and bottlenecks. Future research could define additional activities or leverage existing activities to capture cost data alongside time and quantity data. By defining cost indicators and utilizing dashboards in process analysis software, researchers could conduct performance analyses from a cost perspective, enabling more informed decision-making and cost optimization strategies.

Furthermore, to validate and implement the proposed process improvement recommendations, future research could employ simulation and queuing theory techniques. By simulating the effects of the recommended changes, researchers can assess the potential impact on process performance and identify any unintended consequences. Additionally, the utilization of software tools, such as Visual Paradigm, and the exploration of different algorithms could enhance the reliability and generalizability of the research findings.

Finally, while process mining provides valuable insights into internal process dynamics, it is essential to acknowledge the influence of external factors on organizational processes. Many processes are interconnected and dependent on external factors, such as supplier performance, regulatory changes, or market conditions. Future research could explore methods to incorporate external data sources and factors into the process mining analysis, providing a more holistic understanding of process performance and improvement opportunities. In cases where access to external data is limited, researchers could consider employing complemen-

tary methods alongside process mining to account for these external influences.

By addressing these limitations and exploring the proposed future research avenues, researchers can contribute to advancing the field of business process management, particularly within the context of project-oriented organizations. Such efforts will facilitate the development of more robust, data-driven, and comprehensive process optimization strategies, ultimately enhancing the competitiveness and operational excellence of these organizations.

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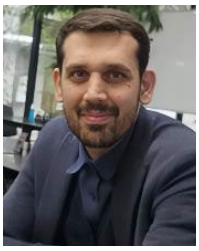

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