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Eliminating Non-Value-Added Activities and Optimizing Manufacturing Processes Using Process Mining: A Stock of Challenges for Family SMEs

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Abstract: Family small and medium enterprises (FSMEs) differ from non-family SMEs regarding leadership type, human resource management practices, innovation orientation, change management, information and communication technology deployment, process maturity, and resource availability. These differences present challenges when leading any change. Process mining (PM) tools can optimize process value and eliminate non-added-value activities in FSMEs based on "Event Logs". The present study investigates how a PM project is implemented in an FSME operating in the agri-food sector, focusing on challenges faced in every project phase to extract the most appropriate process that eliminates all sources of waste and bottleneck cases. Drawing upon the L*Lifecycle methodology combined with quality and lean management tools such as the fishbone diagram, Pareto diagram, and overall equipment efficiency (OEE), this study applied a PM project to a manufacturing process for an FSME operating in the agri-food sector. To achieve theoretical production capacity (TPC) and customer satisfaction, the method was analyzed and optimized using Disco and ProM toolkits. The results analysis using Disco and ProM toolkits gave clues about the organizational and technical causes behind the manufacturing process's inefficiency. First, OEE showed that the studied FSME is struggling with equipment availability. Then, the implementation of the L*Lifecycle methodology allowed for the identification of five critical causes. An action plan to eliminate causes was proposed to the FSME managers.

Keywords: process mining (PM) project; family SME; Disco; ProM; event-logs; efficiency

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1. Introduction

As a rule of thumb, the ubiquity of small and medium enterprises (SMEs) in a given economy reflects that it is healthy since they increase economic diversity, contribute positively to a country's gross domestic produce (GDP), offer employment opportunities, anchor global supply chain operations, and strengthen a country's resilience during international crisis. In the same context, SMEs help build a country's identity and foster community service practices. The Kingdom of Saudi Arabia, through the ambitious "Vision-2030", is paying particular attention to this type of firm. The Small & Medium Enterprises General Authority (Monsha'at) in August 2023 reported incredible governmental support through investing in capital ventures and encouraging the private sector to pump investments into SMEs. The statistics show that the actual number of SMEs operating in the Saudi market is 1.27 million [1].

Considering the increasing competition in global markets and the evolving requirements of customers in terms of quality and delivery times, firms, nowadays, are striving to search for new and modern methods and approaches to lead work perfectly and achieve their goals in this complex and uncertain environment. Previous empirical research acknowledged the importance of lean management tools for SMEs to sustain their competitive advantage [2,3]. Lean management tools provide continuous improvement initiatives that concentrate on non-added-value operations along inter and intra-organizational processes. Lean tools are strongly linked with eliminating waste, variation, and bottleneck; reducing time cycles; achieving economies of scale; improving the flexibility of production; and increasing profitability [4]. Lean management englobes many tools such as Value Stream Mapping (VSM) to eliminate non-added-value activities, Just in Time (JIT) to optimize inventory levels, Quick Response Manufacturing (QRM) to enhance operations flexibility, Single Minute Exchange of Die (SMED) to reduce changing times, Event Flow Production (EFP) to improve operations flow, TPM (Total Preventative Maintenance), 5S, the Total Quality Management (TQM) approach, and the Six Sigma method to eliminate causes of non-quality continuously and systematically [5]. In the same context, PM is a strategic tool to design and build new efficient processes. PM is regarded as a diagnostic method to optimize processes' value by discovering the optimal way of processing operations. It begins with identifying, monitoring, and improving real processes through the use of event log data. This approach is a relatively recent area of research that connects data science and process science [6]. The goal of PM is to identify, track, and enhance actual processes—that is, processes that are not presumptive—by deriving insights from event logs that are easily accessible in most modern systems [7].

Previous research highlighted the multitude of uses of PM in SMEs to enable effective multi-product scheduling in manufacturing SMEs. Choueiri & Portela Santos [8] presented an algorithmic framework that extracts the underlying industrial process using process mining techniques. Lorenz et al. [9] proposed and empirically validated a procedure to improve productivity in make-to-stock manufacturing. The research shows that PM can take advantage of previously unrecognized opportunities to increase productivity. Agostinelli et al. [10] highlighted how PM techniques might be applied to get over the obstacles and difficulties related to structuring Big Data pipeline discovery tasks to be able to give value to collected and unused data (Dark Data). Our research consists of analyzing the manufacturing process of FSMEs operating in the agri-food sector.

Previous studies have identified several pre-requisite and key factors that determine the success of applying PM tools within SMEs (family and non-family SMEs). These challenges could be technical, such as incompatible systems, impracticable event-logs with mistakes, a lack of IS availability and data collection operations, process unaware IS, and incorrect PM algorithm configuration, or organizational, such as a lack of stakeholder support and involvement, lack of managers and staff technical experience and expertise, managers' lack of awareness in processing notion and quality tools, poor change management, poor project management, lack of training, scarcity of resources, and immaturity of processes [6,11–16].

The issue under examination can be summarized as follows: What benefits can process mining tools offer in enhancing process value and efficiency, and what obstacles might arise when applying them in a family small and medium enterprise (FSME)? To clarify how this method is applied and answer the previous question, this study is structured as follows: First, a theoretical framework is developed through a presentation of the PM approach as a technique that applies data mining principles in business process management. Then, the stages of conducting a PM project are discussed. Afterwards, a project of optimizing value along the production process in an industrial firm operating in the dairy sector using the PM approach is demonstrated.

The originality in studying the implementation of PM in family firms lies in the unique dynamics and characteristics of these organizations. Unlike larger corporations, family firms often have distinct organizational cultures, decision-making processes, and resource constraints. Therefore, investigating how PM is adopted and utilized within the context of family firms can provide valuable insights into the challenges, opportunities, and outcomes associated with its implementation in such settings.

2. PM Definition, Applications, and Project Execution

2.1. PM Definition: A Multidisciplinary Concept

A process refers to a field of research that involves the application of data analysis and computational intelligence techniques to extract insights from event logs of information systems. Its objective is to discover, monitor, and enhance processes [15,17]. PM is a technique that can help improve business process management. By analyzing data recorded by information systems, it is possible to gain a better understanding of how processes work. This can help identify any deviations from expected behavior and improve the accuracy of process models. Ultimately, this can lead to better performance and efficiency in business operations [7]. PM methods can help identify compliance issues, pinpoint bottlenecks, compare different versions of a process, and offer recommendations for process improvements [18].

Drawing upon the definitions above, two main perspectives are identified: organizational and technical dimensions. (1) From an organizational perspective, PM is a valuable tool for identifying inefficiencies and bottlenecks in business processes. Analyzing event logs and process data can provide insights into how work is being done, as opposed to how it is supposed to be done. This can help managers make informed decisions about where to focus improvement efforts and lead to increased process efficiency, cost savings, and better customer satisfaction. Additionally, PM can help organizations comply with regulations and standards, such as ISO 9001 [19], by providing evidence of process performance and identifying areas for improvement. Overall, PM offers a powerful way to gain visibility into business processes and drive process improvement initiatives. (2) From a technical perspective, PM involves using algorithms and advanced analytics to extract insights from event logs and other process data. It typically involves several steps, including data extraction, data cleaning, process discovery, conformance checking, and process enhancement. PM tools use a variety of techniques, such as process flow analysis, statistical analysis, and machine learning, to identify patterns, anomalies, and inefficiencies in business processes. These tools can help organizations visualize how processes are being executed, identify root causes of process variations, and optimize processes to improve efficiency and reduce costs. Additionally, PM can be integrated with other technologies, such as robotic process automation (RPA) and artificial intelligence (AI), to automate process improvement tasks and make them more efficient [20,21]. The manual processes, if replicated using RPA and AI, will eliminate process errors and help in handling large amounts of data for better managing the process of enhancing production volumes. Overall, PM offers a powerful way to gain insights into business processes from a technical perspective and drive continuous improvement initiatives that can lead to positive business outcomes.

PM provides an effective set of tools and techniques to generate appropriate knowledge from business processes based on historical data collected from different information systems databases. This approach consists of analyzing the entire business process (from end to end) to reengineer it and optimize its value [22]. For Graafmans et al. [23], PM offers a valuable set of tools for creating knowledge and insights based on historical data stemming from event logs. Their literature review recognizes the potential benefits of deploying PM techniques in lean management tools such as Six Sigma to improve process activities' value. Another lean management tool that is crucial for PM to succeed is VSM; this method consists of mapping the actual state of a series of processes that are required to produce a product or provide a service. PM could support VSM in analyzing business processes and sequences using event logs to come up with the optimal process [24]. PM is a relatively recent research system that exists between (1) artificial intelligence and data mining on the one hand and (2) process modeling and analysis on the other hand [6,25]. PM aims to extract practical knowledge from event logs that may arise from all types of information systems in an organization. Event logs usually contain information about the completion of the steps and activities of a particular process and link these tasks or processes with other metadata (resources). Process is a broad and very complex term both from an applied and a technical point of view [26]. PM success depends on the reliability and validity of event logs. To enable PM in diverse situations and environments, the data collected and classified based on all IS databases in an organization need to be translated into event logs. Diba et al. [22] show that the diversity of methods and techniques is suitable for creating a reliable event log with relevant data resources that are highly data correlated. As a consequence, it is noted that PM is a combination of data mining and business process management (BPM), as shown in Figure 1.

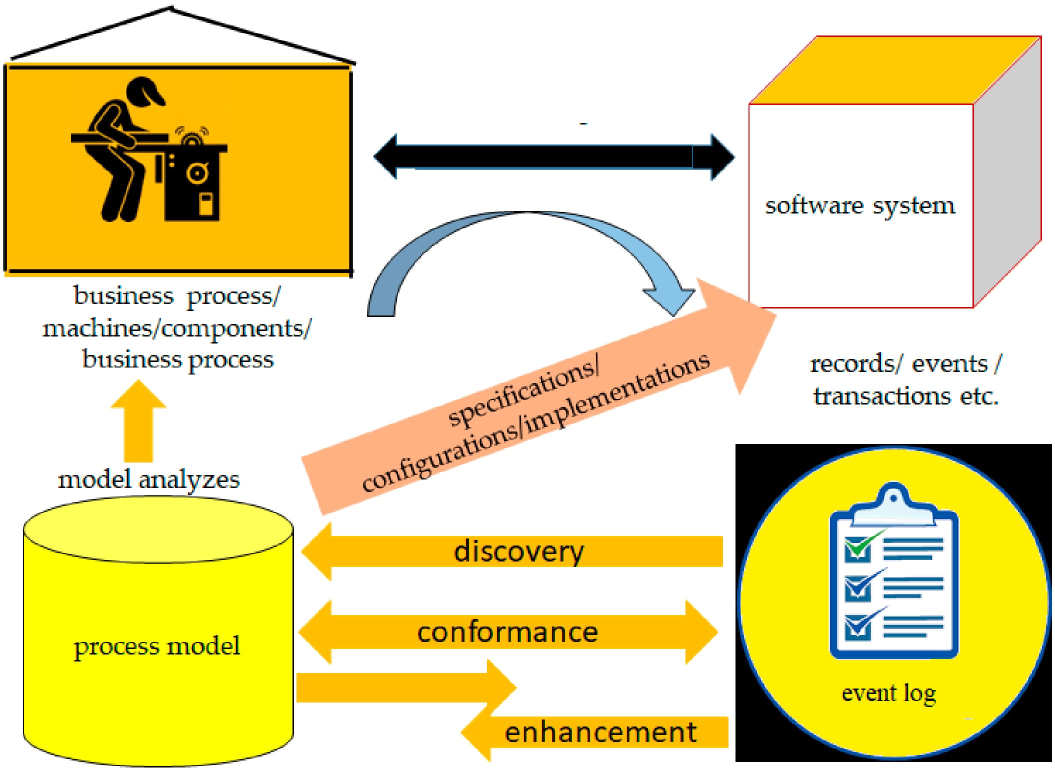

Figure 1. Process mining types, modified from [27].

The idea behind PM is to either (1) discover the optimal path (process), i.e., extract a model, namely, the best way of doing things; (2) check and monitor the conformance of the adopted model (process) with reality; or (3) enhance the actual processes or the previous model [11,13]. PM could be used in many situations, and, whatever the purpose, deploying this method should be conducted by extracting knowledge from previously recorded and available events in the current IS database. This idea is well illustrated in Figure 1.

It is important to note that to collect various information, an organization should utilize different activities and resources. This can provide knowledge about the process, and the organization's information systems can support and monitor this phase. An event log is created through the information systems, and the process model is subsequently created and analyzed based on the available data and information using three types of PM (discovery, conformance, and enhancement). The types of PM can be defined as follows: (1) Discovery: This technique involves using the event log to produce the process model without any pre-existing models. (2) Conformance: If a previous model exists, the previous process model can be compared with the event log of the same process. This type can be used to see if the reality matches the model and vice versa. (3) Enhancement: This type is used to improve the existing process model by using information about the actual process. It can detect errors and bottlenecks and allows for checking the alignment between the model and reality [27].

2.2. Applications of PM in FSMEs: A Literature Review

To develop an insightful literature review about the different challenges facing FSMEs when implementing PM projects, this study built on the research procedures provided by Paul et al. [28] and Paul & Criado [29]. The procedures are as follows: (1) Attentively select the research topic. For this, a topic was identified carefully and addressed "the aim of applying PM project by FSMEs and what are the challenges standing behind its success". (2) Select journals involving several criteria aimed at ensuring the relevance and quality of the research. Firstly, the focus should be on journals that specialize in topics related to family business, process optimization, and data analytics. Furthermore, prioritizing journals with rigorous peer-reviews introduced in well-known databases such as Scopus, Web of Sciences, Elsevier, Emerald, Springer, Tylor & Francis, Wiley, etc., ensures that the included studies meet scholarly standards. Finally, the accessibility and availability of the journals are of high priority to use the journal. (3) Collect relevant papers focusing on PM in family businesses, using keywords such as "Process Mining" or "Data mining", "Business Process Management", "SMEs", "Family SMEs", "Family firms", and "Family Business". (4) Search papers. The search here was limited to papers published as of 2015. Given the rapid evolution of the topic, our attention was directed towards recent papers to ensure relevance. (5) Structure the papers and organize them according to their importance and relationship to the research aim. For this, the analysis started by describing the reasons for and difficulties of implementing the PM method in SMEs—in general and then in family firms. (6) Summarize the studies' contributions, in tabular form, to easily identify the different challenges for SMEs and then show the specific characteristics in family SMEs regarding the success of PM projects.

Indeed, it might be difficult to use PM, especially for SMEs (family and non-family ones) due to their limited resources and lower process maturity [12]. The increasing capability to generate and store data and the growing fusion of the physical and digital worlds are fostering the use of PM. An organization can benefit from PM to remain competitive and gain further competitive advantages through reductions in throughput times, cutting costs, or increasing satisfaction among customers. Compared to large organizations, SMEs have fewer resources [30] and less mature procedures [31]. Investigation into the skills and knowledge needed to scale up and successfully apply PM is easily conducted by large companies, but SMEs have yet to address this issue [13]. From an organizational standpoint, SMEs are known to have immature processes, scarce resources, low formalization levels, limited assets, embedded cultures, short communication channels, a lack of managerial skills, and short-term-based planning [32].

Previous studies investigated the issue of applying the PM method in SMEs from different points of view. The research of Burattin [11] is angled towards understanding the problems that may occur when deploying a PM project. The research analyzed four types of companies that were categorized based on two main criteria, namely, company process-aware (unaware) and information system process-aware (unaware). For all scenarios, problems that hinder the success of the PM project can be divided into three types: (1) Problems occurring before the PM project (when preparing data). In this phase, the interoperability of systems (company IS and PM systems) seems to be crucial. This refers to the ability to exploit the data extracted by a company's information system by the PM tools. The second problem relates to the lack of awareness of IS for the process notion. In this situation, it becomes difficult to generate knowledge based on unaware IS. Moreover, in many cases, even though the IS is process-oriented, the data collected in the event logs lack accuracy and relevance, which means that the event logs provide data that mismatch with the reality of executed activities. (2) Problems occurring during the PM project (when actual PM is executed). In this phase, the entropy (noise) is associated with data processed by PM tools. The second problem occurs when the organization lacks specialized staff that can manipulate PM tools, which makes the configuration of PM algorithms difficult. (3) Problems occurring after the PM project, when the mined process is interpreted and evaluated and a judgment is made on its quality. The third problem in this phase relates to the ability to design a clean and simplified process model without complicated activities, tasks, or resources. The present study can take some insights from the study proposed by Almeida & Bernardino [33] since it is angled at the obstacles to SME data mining [33].

This research finds that the vast volume of data present in SME contexts is stronger than the actual data processing technologies and their applications. Also, the use of specific open-source data mining tools such as KEEL (Knowledge Extraction based on Evolutionary Learning), KNIME (Konstanz Information Miner), RapidMiner, and other open-source tools can bring a lot of advantages to SMEs in terms of generating knowledge and optimizing processes. Zeisler et al. [6] identified seven requirements for a PM to succeed in SMEs, namely, (1) organizational requirements, (2) process-related requirements, (3) IT-related requirements, (4) data-related requirements, (5) employee-related requirements, (6) legal requirements, and (7) means and resources. Nebiaj [34] exposed the technical challenge of developing a Workflow Management System for an ERP system by integrating process discovery and design to optimize business processes in SMEs. Stertz et al. [16] focused on the implementation phases of PM and how experts can exploit it in small and medium manufacturing companies. Drawing upon a focus group study, the researchers compared what is expected and experienced by staff at different levels during the implementation of a PM project. The study shows that transparency, error avoidance, and decreased effort in documenting (digitalization) are the most perceived benefits of PM projects, while appropriate infrastructure and data collection operations present the main challenges. Vom Brocke et al. [35] highlight that non-technical factors are also essential for the implementation and administration of PM, in addition to the creation and enhancement of algorithms. Drakoulogkonas & Apostolou [17] gave an overview of various software used as PM tool for its selection. Drawing upon a multi-criteria framework, three techniques were used, namely, ontology, decision trees, and AHP, to list and explain the parameters that can help compare instruments to choose which software product best meets a company's needs according to the challenges that organizations meet. Eggert & Dyong [12] recognized the challenging characteristics of applying PM for SMEs due to the scarcity of resources and immaturity of processes. This study looked into the use of PM and clarified the difficulties faced by an IT SME. The findings identified 13 PM challenges for SMEs and provided seven recommendations for resolving them. Mamudu et al. [15] showed that studies on critical success factors in PM are scarce. Furthermore, these studies only listed the variables; they did not include crucial information on the success elements and how they interact. Using a hybrid methodology, the study qualitatively examined 62 case studies on PM from several angles. Nine important success determinants for PM were identified, their link to the PM setting was explained, and their interrelationships concerning PM success were analyzed. These factors are, respectively, support and involvement of stakeholders, accessibility of information, technical proficiency, capabilities and features of PM tools, organized PM approaches, data and event log quality, skills in project management, training in PM project execution, and skills in change management. Kokkeler [14] bridged the gap related to PM in SMEs and proposed a methodology called PROcess MIning for SmEs (PROMISE) to successfully transform insights into actions. The research systematically analyzed 21 papers based on different criteria such as validation techniques, empirical evidence, the methodology adopted, types of algorithms, types of PM tools, examined processes, and types of results (i.e., analysis, implementation, framework, etc.). Based on Data Science Methodology (DSM), the methodology PROMISE was refined and validated through two case studies. The study highlighted some challenges when applying PM projects in SMEs such as the immaturity of processes, lack of managerial and internal skills that can help evolve the processes, high levels of informatization, low quality of documentation, lack of change management, and high levels of changing the workforce. Table 1 below summarizes all the challenges mentioned above.

Table 1. Application of PM method in family SMEs and associated challenges.

References	Challenges Reported by Family SMEs
[11]	The main problems of applying PM projects successfully are (1) lack of interoperability of systems, (2) irrelevant events log (noise), (3) configuration of PM algorithms, (4) evaluation of the mined process, and (5) the need for the company and IS to be process-aware. For SMEs, three components should be modeled using the appropriate tools: artifacts, control flow, and actors.
[32]	The main challenges are (1) immature processes, (2) scarce resources, (3) low formalization levels, (4) limited assets, (5) embedded cultures, (6) short communication channels, (7) lack of managerial skills, and (8) short-term-based planning.
[33]	The main obstacles are that (1) the vast volume of data present in SME contexts is stronger than the actual data processing technologies and their applications and (2) open-source data mining tools such as KEEL, KNIME, and RapidMiner can effectively benefit SMEs.
[6]	The main factors affecting PM project success are organizational, employees, legality, means and resources, processes, information technology, and data. (2) Processes, information technology, and data are the most important challenges.
[34]	The primary obstacle is the technical aspects of developing a Workflow Management System.
[16]	Transparency, error avoidance, and decreased effort in documenting (digitalization) are the most perceived benefits of PM projects, while appropriate infrastructure and data collection operations present the main challenges.
[17]	The primary difficulty is the alignment of software characteristics with an organization's needs.
[12]	The main barriers are (1) limited resources and (2) lower process maturity.
[15]	The main challenges are (1) support and involvement of stakeholders, (2) accessibility of information, (3) technical proficiency, (4) capabilities and features of PM tools, (5) organized PM approaches, (6) data and event log quality, (7) skills in project management, (8) training in PM project execution, and (9) skills in change management.
[14]	The study recognizes the same challenges as [12]: (1) the immaturity of processes, (2) lack of managerial and internal skills that can help evolve the processes, (3) high levels of informatization, (4) low quality of documentation, (5) lack of change management, and (6) high levels of changing the workforce.
[35]	The critical factors are that non-technical factors are also essential for the implementation and administration of PM and the creation and enhancement of algorithms.
[30]	The primary issue revolves around limited resources.
[31]	The primary challenge lies in less developed procedures.
[13]	The most important factor is the lack of skills and knowledge needed to scale up and successfully apply PM.

When it comes to family businesses, previous research has found that family SMEs tend to be relatively different from non-family SMEs regarding many aspects such as human resource management, innovation, leadership, and information systems. This difference is due to the embeddedness of the family dimension in the firm's management [36]. The owner-manager of family SMEs has a significant influence on the management style and organizational culture [37]. According to the findings provided by Chahal & Sharma [38], family-owned businesses do not demonstrate a significant performance advantage over non-family enterprises. According to Darby et al.'s results [39], family business characteristics are reflected in operations and supply chain management decision-making. Llach & Nordqvist [40] observed differences in the role of human, social, and marketing capital for innovation between family and non-family firms. Heinicke [41] recognized the influence of the family dimension and exchange of knowledge in developing a sophisticated control system that englobes key indicators of functions, operations, activities, and process performances. Giacosa et al. [42] identified cultural and cognitive aspects, values, and abilities that affect the company behavior of small and medium family firms in terms of BPM. Jacobs [43] justified the limited ability of family SMEs through their lack of BPM skills.

In the same context, while some research indicates that family firms are willing to execute innovation in business processes like production and distribution operations [44,45], other studies show that family firms invest less in research and development and that introducing change in processes and products is due to their flexibility [46]. Regarding the use of information technology and data organization in family SMEs, Dutot et al. [47] showed that FSMEs do not have mature, adequate management and use of ICT (information and communication technology). The reality highlights that FSMEs do not fully utilize the potential and advantages of information technologies in their operations and transactions [48]. Many researchers pointed out that FSMEs do not have BI (business intelligence) awareness for decision-making. Accordingly, FSMEs are not mature in terms of analyzing data and generating knowledge [49]. Management practices in family-owned businesses are less formal than in other types of firms. In family SMEs [50], roles are not clear and staff may have different and multiple activities to accomplish [51]. According to research by R. S. Reid & Adams [52], family-owned businesses employ HRM in a different way than their non-family competitors. They are "special cases" requiring particular instruction and growth.

As for strategic long-term vision, FSMEs' managers place less weight on employee training initiatives and strategic planning as they do on competitive advantages [53]. Learning and change processes in FSMEs are significantly impacted by the degree of family embeddedness, the size of the business, and the absence of formal processes and systems [54]. Additionally, certain familial traits like nepotism combined with the standard of corporate governance (structure, leadership style, and compensation) influence change processes. Furthermore, it is challenging to maintain the use of contemporary tools if management takes on an authoritarian and paternalistic management style [55]. Table 2 summarizes the specific characteristics of FSMEs compared to non-family SMEs.

Table 2. The main characteristics of family SMEs.

References	Specific Characteristics of Family SMEs
[36,55]	The embeddedness of the family dimension in the firm's management.
[37,42]	The owner has a significant influence on organizational cultural and cognitive aspects, values, and abilities affect the company's behavior.
[38]	Low performance levels compared to non-family businesses.
[39]	The reflection of family characteristics on operations and supply chain management decision-making.
[40]	The role of human, social, and marketing capital is weak.
[41]	The influence of the family dimension and exchange of knowledge in developing a sophisticated control system.
[43]	The lack of BPM skills.
[44–46]	Less research and development and change in processes and products.
[47–49]	Inadequate management and use of ICT, lack of BI, immature capabilities of analyzing data and generating knowledge.
[50–52]	Roles are not clear, staff may have different and multiple activities to accomplish.
[53]	Managers place less weight on employee training initiatives and strategic planning.
[54]	The absence of formal processes and systems.

2.3. PM Project

An operating methodology is necessary for a PM project to provide proper orientation. Several methodologies exist to apply PM tools in SMEs. This research provides an overview without intending to evaluate them. Zuidema-Tempel et al. [56] identified and critically reviewed four main PM methodologies as follows: (a) PM project methodology (PM2), proposed by Van Der Heijden [57]. This methodology consists of six phases as follows: (1) planning, (2) extraction, (3) data processing, (4) mining and analysis, (5) evaluation, and, finally, (6) process improvement and support. (b) PM project methodology (PMPM), proposed by Van Eck et al. [58]. This methodology also consists of six phases as follows: (1) scoping, (2) data understanding, (3) event log creation, (4) process mining, (5) evaluation, and (6) deployment. (c) PM project proposal (PMPP), proposed by Aguirre et al. [59]. This approach includes four phases as follows: (1) project definition, (2) data preparation, (3) process analysis, and (4) process redesign. (d) L* lifecycle model from van der Aalst [7]. This methodology has been adopted for the present research for many reasons. This methodology first outlines the PM activities and the tools that are used to support them, the outcomes, and the reason behind selecting the appropriate tool for each task. Second, compared to previous methods, this methodology outlines considerably explicit steps. Finally, both large and medium-sized businesses could use this methodology. Figure 2 summarizes all the stages for successful PM use. The description and details of each stage will be presented with the case study.

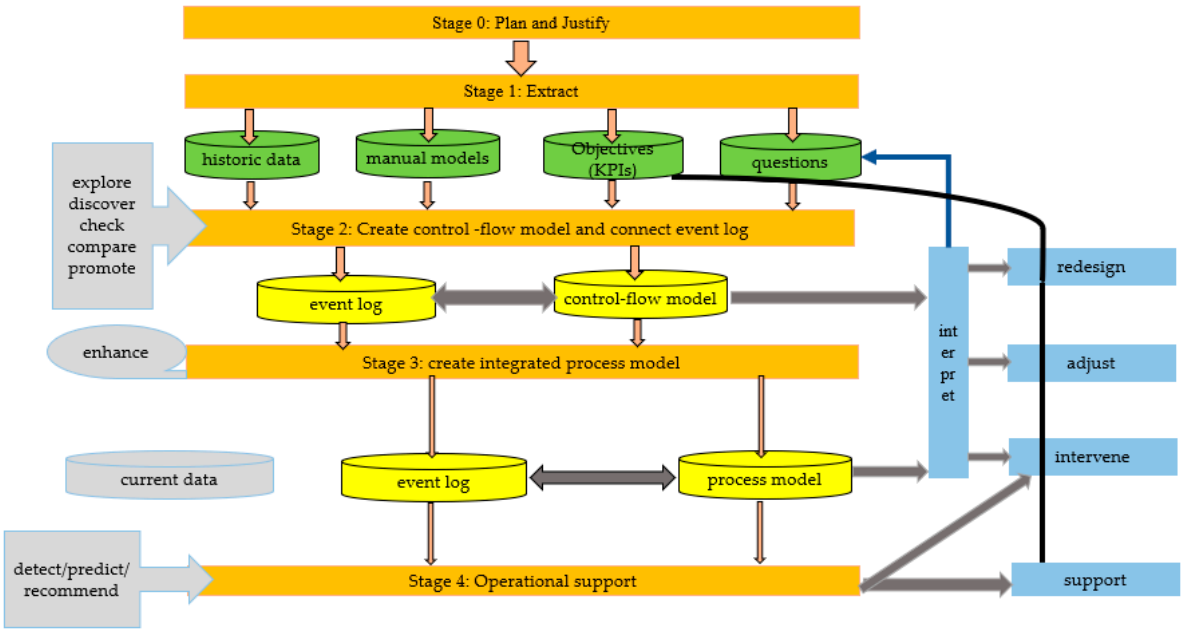

Figure 2. PM project stages, modified from [7].

3. PM Implementation in a Family SME

3.1. Firms' Challenges and Manufacturing Process Description

The studied company has two main activities: First, the import–export of food products that are generally oriented to be resold as is. The second activity is manufacturing dairy products, which was the subject of analysis in this study. The first advantage of this company is that the supply of raw products, mainly, milk powder, is ensured by the firm itself. Another advantage is the deeper understanding that the firm has of its business market, customers' needs, and diversified network of suppliers. Moreover, one of the conventional practices in the studied firm is that most employees are from the same family. This may represent an advantage since it gives the firm a more cohesive and committed workforce, which can lead to a greater level of participation and engagement in improvement initiatives. The firm gives more importance to family ties and blood relationships rather than people's knowledge, skills, and competencies. Most family members lack knowledge and skills in management and quality concepts, which makes their contribution restricted to simple initiatives rather than complicated projects such as PM tools. The firm's staff cannot help ensure that the PM results are accurately interpreted and appropriately acted upon. Consequently, the studied firm has intimate knowledge of their workflows, roles, and responsibilities that are highly overlapped among people, which can impede PM analysis. In this firm, the leadership spectrum varies between autocratic to laisser-faire style;

this latest style is usually applied with family members. On the other hand, an autocratic style makes it difficult for subordinates to suggest and implement change initiatives, even though the communication channel is short. Moreover, the studied firm is reluctant to adopt new technologies and processes, particularly if the owners are unfamiliar with them. The firm has a relatively reactive approach, namely, the managers are ready to adopt only technologies that have already been implemented and tested in other companies. This makes it challenging to successfully implement PM initiatives, which require significant cultural and organizational change.

As for the manufacturing process, this involves several precise steps to ensure product quality, hygiene, and efficiency. The packaging process includes filling aluminum pouches with milk powder and subsequently placing the pouches into boxes and then into larger cartons. To understand this, here is an overview of the manufacturing process: (1) Loading the packaging machine, weighing, and dispensing. The milk powder is accurately weighed and dispensed into the packaging line. This process ensures that each pouch receives the correct amount of milk powder. (2) Setting machines for production. This step refers to the process of configuring and adjusting machinery and equipment to ensure that they are ready and optimized for use. This is a crucial step in the production process and it involves fine-tuning various parameters and settings to achieve the desired output efficiently and accurately. The goal is to meet quality standards, maintain consistency, and improve overall productivity. The studied manufacturing unit has a semi-automatic packaging system that consists of the following machines: (a) a hopper that plays a crucial role in feeding the filling machine, (b) a milk powder filling machine, (c) conveyor systems, (d) a boxing/cartoning machine, (e) a labeling and coding machine, (f) a tape maker. (3) Pouch forming, filling, and sealing. The packaging material, in this case, aluminum foil, is fed into the filling machine. The machine forms the material into pouches of the desired size and shape, leaving an opening at the top for filling. Then, the milk powder is filled into the pre-formed pouches. This process is often automated to ensure precision and minimize the risk of contamination; then, the open end of the pouch is sealed to enclose the milk powder securely. (4) Boxing and closing. The pouches are placed manually into boxes according to the appropriate weight and then placed into the boxing machine to close them securely. (5) Controlling and labeling. Each box is coded with essential information such as manufacturing date, expiration date, batch number, and other relevant details. Labels with nutritional information, ingredients, and branding are also applied to the box. Then, the boxes undergo quality control checks to ensure that the packaging is intact, the correct weight of milk powder is present, and the coding and labeling are accurate. (6) Cartoning and palletizing. The cartons are typically designed to accommodate a specific number of boxes. The boxes are put into the relevant cartons, which are made manually and then closed using a tape machine. Then, the closed cartons are stacked manually on pallets and transported directly to the warehouse to ensure easy shipment and distribution.

Throughout the entire process, the firm must follow stringent hygiene standards to guarantee high quality from production to consumption. Unfortunately, many factors have hindered the packaging line from improving efficiency and minimizing errors. These factors will be discussed when demonstrating the PM stages.

3.2. Calculation of OEE

The studied firm operates in the sector of agri-food. As shown above, the main activities within the manufacturing unit are (1) loading, (2) setting machines, (3) filling and sealing, (4) boxing and closing, (5) controlling and labeling, and (6) cartoning and palletizing.

Data for the study were gathered through observation and interview techniques. To gain a thorough understanding of the activities, interviews with the production manager and sales manager were undertaken. Apart from conducting interviews, a thorough observation of several process activities was conducted. These activities included feeding the manufacturing unit, loading machines, packaging, palletizing, and warehousing. By relying upon managers' expertise, documentation and video recordings of the manufacturing process were examined. Then, an event log was made using these data.

Based on a sample of 50 working days, the OEE was determined to identify the primary dysfunctions in the unit and guarantee that the manufacturing process improvement project was oriented correctly. The OEE components are compiled in Table 3.

Table 3. OEE within the manufacturing unit.

Availability = (Operation Time/Loading Time) × 100%	287/350 = 0.82
Performance = (Actual Product X Ideal Cycle Time)/Operation Time × 100%	275.63/287 = 0.96
Quality = (Good Products − Total Defect)/Gross Products × 100%	257.11/275.63 = 0.93
OEE	0.82 × 0.96 × 0.93 = 0.73

At the production facility, the overall equipment efficiency was 73.44%. Over 85% is the minimum required. So, this was not a high rate. Improving the availability rate, which was the weakest aspect, was the problem. By removing every cause contributing to these flaws, the PM tool could address the manufacturing facility's lack of efficacy and efficiency. Finding the real business process was the first goal, followed by an attempt to improve it. To clarify the problem occurring in the manufacturing unit, real production levels were compared to average production and mean theoretical production capacity over 50 working days. The results showed a significant deviation between real production levels and the average (2520 units) and theoretical production capacity (3500 units/7 h as working time). The unit was unable to provide the required level of production during this period and struggled with meeting customer demand. Also, the results showed that the production level exceeded theoretical production capacity two times, but the data demonstrated that this was due to irregular double-shift work. Consequently, improving the manufacturing process by eliminating the causes and optimizing time is imperative for this firm to survive and continue in the market.

3.3. Presentation of PM Project Stages

Following a more than two-month analysis of the manufacturing unit's operations and performance, it could be concluded that the PM approach was pertinent in helping the manufacturing unit find solutions and enhance its business operations to reach the necessary level of production. The various actions depicted in Figure 2 above were used in the following manner:

Stage 0: Planning and justification

The PM project for the manufacturing unit was mainly oriented towards three main axes: discovery, answering questions, and achieving goals.

- Discovery project: This refers to the exploration of all the activities and processes involved in the production process and their nature to gain a better understanding of the value flow in the process. Therefore, the project aimed to detect all bottlenecks that the manufacturing unit experiences that result in a slowdown in the production process.
- Question-oriented project: By utilizing PM, a series of questions can be addressed. The primary inquiry in this research was the reason behind the daily variations in production volume. What factors contribute to this variability?
- Goal-oriented project: A number of objectives, including enhancing manufacturing performance, particularly in terms of quality and timeliness, could be accomplished through the PM project.

Stage 1: Data extraction

The company does not record the specifics of each activity; instead, it records the start and end of each working day, the amount of production, and any issues that arise. As a result, the focus at this point was on extracting details and information about the activities and the production process. Observing the manufacturing process, it was discovered that the personnel did not follow the procedures with rigor or respect, which resulted in many manufacturing errors. Furthermore, most of the unscheduled stops that caused the manufacturing process to stop were behind the company's inability to meet client demand. Two primary reasons were responsible for this outcome: The first reason was a lack of effective supply planning, which frequently resulted in raw material shortages and, in turn, delayed orders to the point where customers waited more than a week. Frequent power outages (power cuts) were another issue that hindered the ability to respond to client demand because they repeatedly forced production to halt, often for hours.

The aforementioned issues and the type of data gathered necessitated constant observation and tracking to determine how they affected the manufacturing process. This was the most crucial phase since the process can be examined and enhanced in light of the data. The main issues that the manufacturing unit faced are depicted in Figure 3 below. The Ishikawa diagram pinpoints several reasons why the performance was below par. The "Disco" program was used to analyze each of these issues in detail as well.

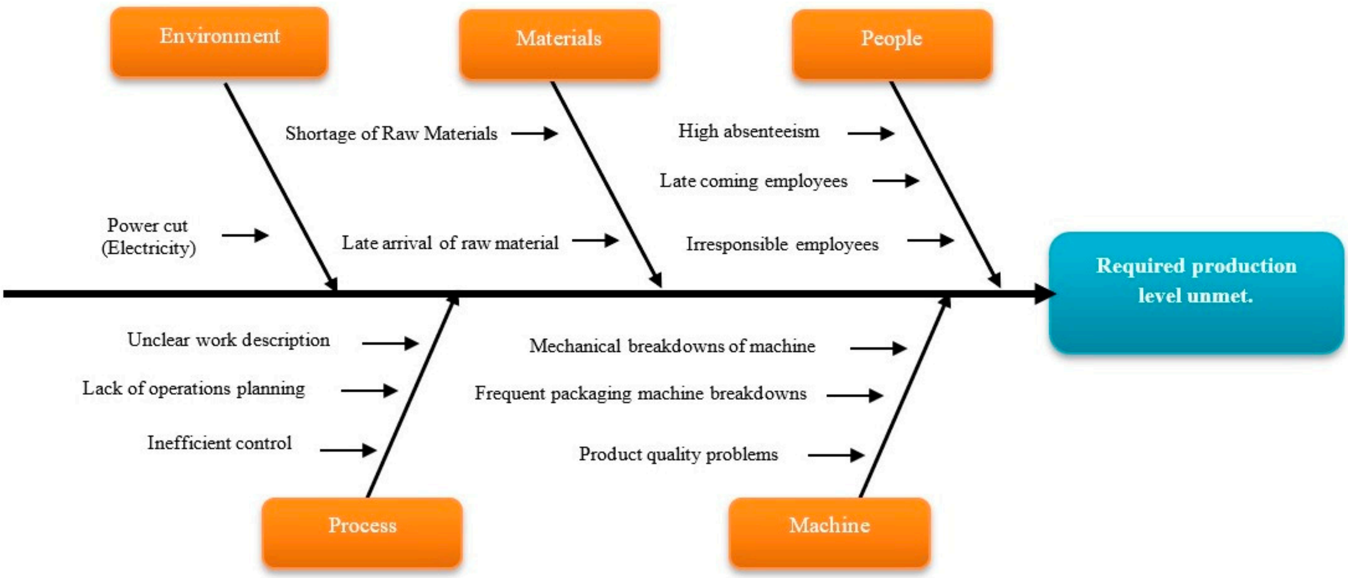

Figure 3. Cause and effect diagram at the manufacturing unit.

Stage 2: Creating the flow control model and making a connection to the event log

- Event log creation: The event log contained information about each batch produced during the day, with two batches produced in the morning and evening. Each batch was identified with a unique ID called a "Case ID". The log also included details about the production process stages, referred to as "Activity", along with the worker responsible for each stage, called "Resource". Moreover, the volume of production achieved and the problems faced by the manufacturing unit in each batch were also recorded. The start and end times of each stage of production in each batch were mentioned in the log. This information could be analyzed through the "Disco" program to identify bottlenecks that occurred at any stage and determine the time wasted in each stage of production. This analysis could help to improve the production process and achieve the desired level of production.
- Extraction of the current business process: The "Disco" program generated a model based on a 20-day sample. Each day contained batches, with 40 cases (batches) in total. Each case had around six activities, resulting in a total of 238 "Events". Figure 4 illustrates all the business process activities in the manufacturing unit.

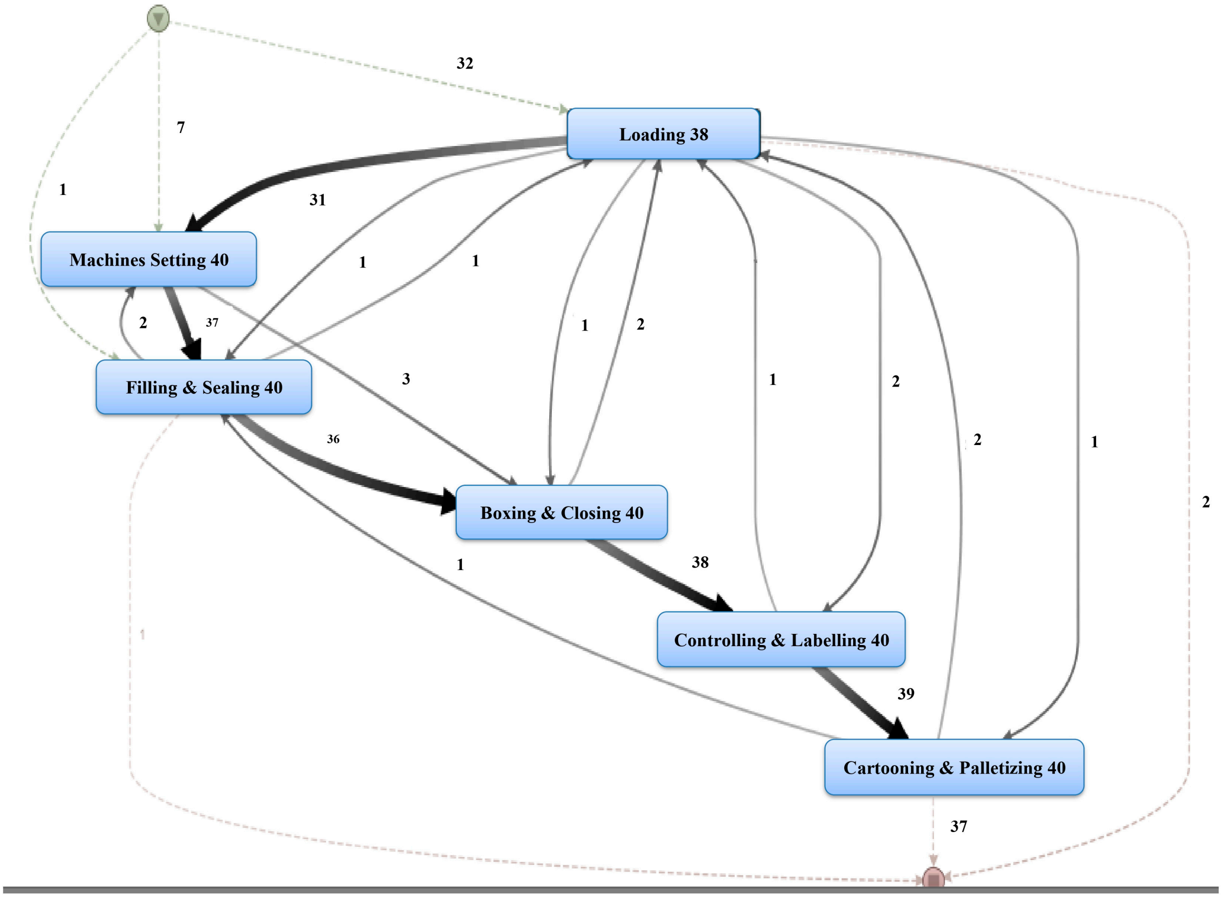

Figure 4. The actual manufacturing process.

Based on an analysis of the overall process activities, the current production model was constructed. However, there were a few instances where the process slowed down or halted due to certain activities. For example, if the stock of boxes, aluminum foil, or cartons ran out, then the workers needed to go back to the previous activity to resupply. On the other hand, if there was enough raw material available, the workers could directly start the machine setting stage without going back to the previous activity. One of the main factors that caused delays in the production process was machine failure, which may have been due to frequent power cuts or mechanical issues in any of the packaging machines, including the aluminum packaging machines.

To validate the order and consistency of the activities, the "ProM 6.12" software was utilized to create a "Dotted chart", which is a popular tool in PM. This chart provides a clear comprehension of the sequence of activities in the study's event log, where each point denotes a different activity and the lines indicate cases. Figure 5 demonstrates the sequence of activities.

It is evident from the diagram that there is consistency in the color sequence, except for a few instances where the sequence of points in the lines appears different. The manufacturing process and sequence of activities are presented straightforwardly due to the high degree of automation. The Disco 6.3.0 software provided a video that displays the entire manufacturing process, allowing for a clear identification of the primary bottlenecks in some cases that slow or halt production, resulting in a failure to achieve the required production level. This particular stage of the PM project is concerned with developing VSM, which focuses on identifying the primary sources of waste in the process to eliminate them and attain the desired production level.

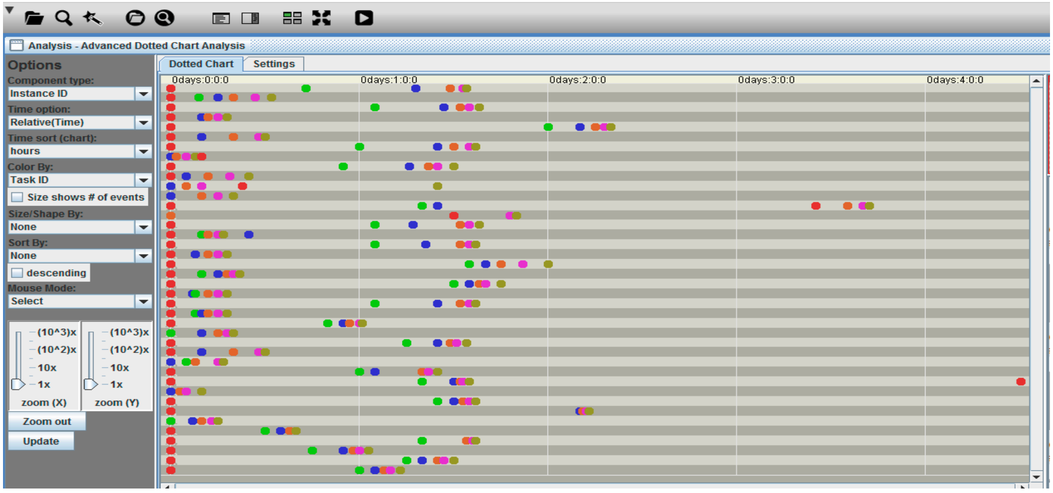

Figure 5. "Dotted Chart" shows the homogeneous sequences of business process activities.

There was no correlation between the amount of goods produced and the time spent producing them (R = 0.106). Additionally, there was inconsistency in the volume of production. For example, the production volume could range from 20 boxes per hour to less than that over a longer period. This indicated that there were many ways of conducting the activities, as well as a problem with the availability rate of 82%. The correlation coefficient indicated a problem with the manufacturing unit's performance rate of 96%, but this rate was not reflective of reality as there were many weak performances in January. There were also cases where the production process slowed down or stopped, with the Disco program showing the time spent on each case, from least to most time-consuming part of the workflow process.

All cases were organized based on the time spent on each case. It was found that the average time for all cases was 72.1 min. The analysis identified the cases that took the least amount of time under normal circumstances and those that took the longest amount of time due to issues during the process. These problematic cases were focused on by filtering and keeping only the cases that were identified as causing a slowdown in the production process. Next, bottlenecks were identified. The analysis showed that 7 cases out of a total of 40 cases (equivalent to 18% of events or 44 events) took at least 1 h and 38 min, which amounts to 17% of all cases. The process for these cases was reexamined and analyzed to identify the bottlenecks and the main reasons causing them. To determine the bottleneck causes, various times taken in the seven cases extracted from the process were presented. The time taken in the production process did not necessarily reflect that the process was slow until compared with the quantities produced in that case. The results showed that some cases that took the least amount of time had good production volumes compared to cases that took the longest amount of time but had low production volumes. This indicates that in addition to the problem encountered by the manufacturing unit in that batch, there was a problem with the pace of work, which was weak. Table 4 shows the details of the various extracted cases.

The discrepancy in the time taken in the production process compared to the amount of production achieved is very clear, and it is important to explain the causes that led to the differences in the quantities produced. Figure 6 shows an analysis of the workflow for the few cases in which bottlenecks were found, indicating the waiting time spent (average waiting time) between activities. The most time spent between activities is indicated by the prominent arrows in red in an attempt to focus on, reduce, and optimize this wasted time.

Table 4. Bottlenecks cases list.

Case	Batch	Date	Time Wasted	Production	Main Cause
5	1st	03-01	2 h 20 m	96	Delay in setting machines
13	1st	09-01	3 h 42 m	61	Shortage of aluminum foil
14	2nd	09-01	1 h 50 m	121	Malfunction in the packaging machine
19	1st	12-01	2 h	87	The slow pace of work
21	1st	15-01	1 h 45 m	128	Delay in setting machines
31	1st	23-01	4 h 30 m	171	Late-coming workers and slow performance
34	2nd	24-01	2 h 13 m	64	Late-coming workers

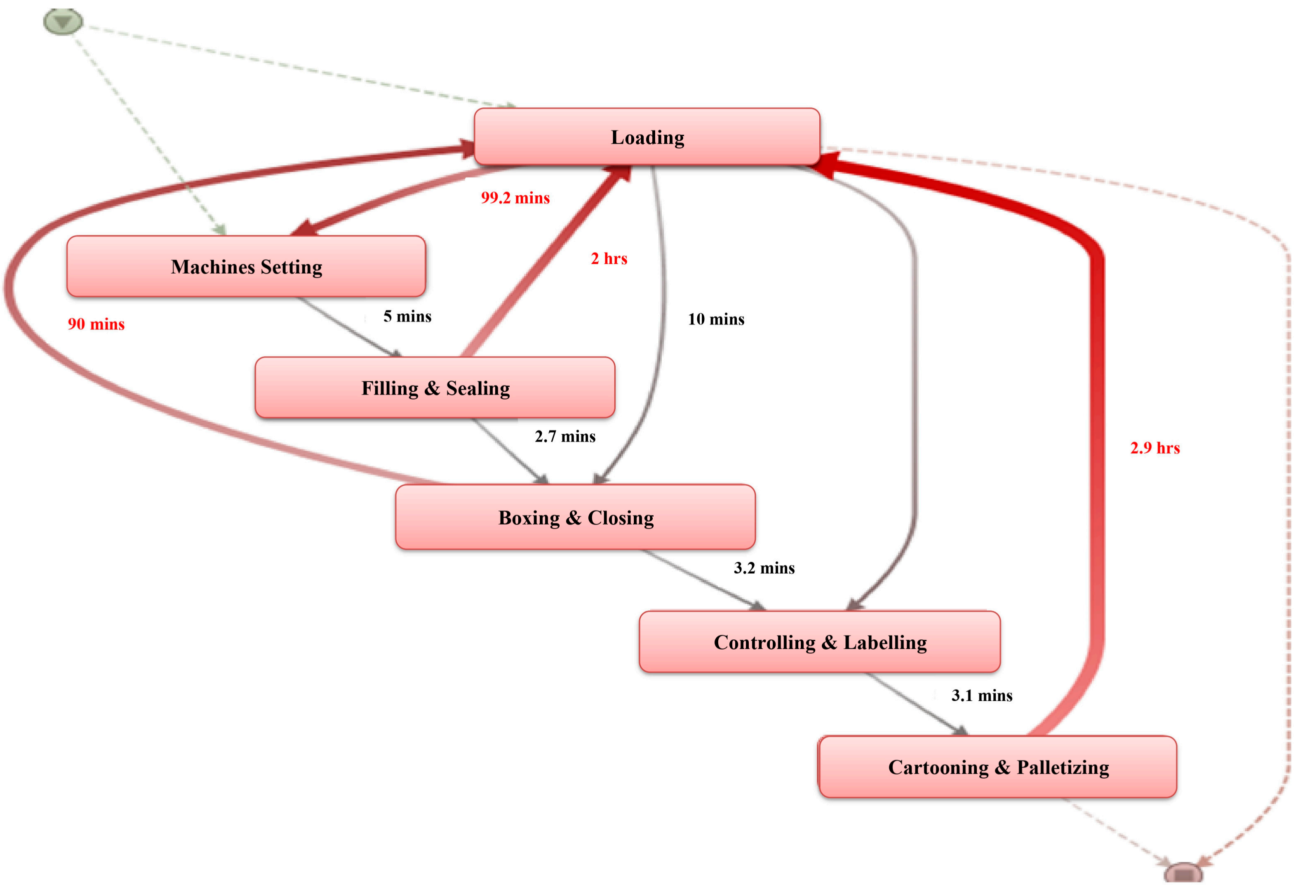

Figure 6. Average time spent in bottleneck situations.

4. Results Analysis and Discussion

Based on the information presented, the focus of the PM project was on extracting knowledge from recorded information and designing an optimal business model. However, after analyzing the manufacturing unit's process, it was evident that the current process is the most reliable path to follow. Therefore, designing an operations model in this case was not necessary. Instead, it was better to maintain the same process and make various improvements to eliminate the causes of production failure and achieve the theoretical production capacity of 350 boxes/h.

The primary focus, therefore, is on improving the business process at the manufacturing unit. This will be achieved by providing operational support, which is the last stage of the PM project. By analyzing the results and providing the necessary recommendations, the performance of the firm can be improved in the future. The various causes behind the production failure are shown in Figure 7, and they need to be addressed as they are sources of wasted time.

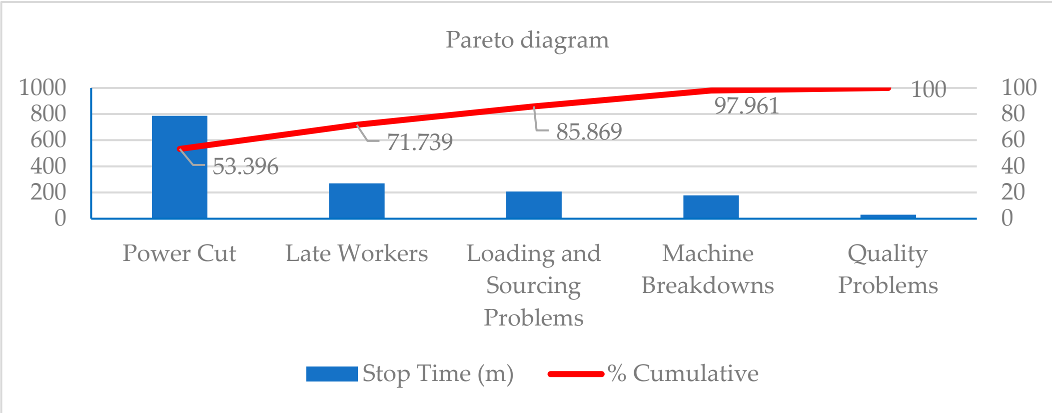

Figure 7. Pareto diagram.

In Figure 7, the frequency of each cause is displayed. The chart works on the principle of Pareto, which involves identifying the 20% of causes that are responsible for 80% of the problems. However, using this chart to determine the proportion of each problem based on frequency alone may not always be accurate. This is because it assumes that the effect of each cause is constant and, therefore, the repetition of causes has the same effect. To accurately determine the extent of the effect of the causes illustrated in the figure, it is better to use the weighting of causes method, where the duration of the stoppage is calculated for each cause. Table 5 provides information on the bottleneck cases.

Table 5. Main causes ranking.

Sr. No.	Causes	Stop Time (m)	Percentage	% Cumulative
1	Power Cut	786	53.396	53.396
2	Late Workers	270	18.342	71.739
3	Loading and Sourcing Problems	208	14.1304	85.869
4	Machine Breakdowns	178	12.092	97.961
5	Quality Problems	30	2.038	100
	Total	1472	100	100

The graph above displays the percentage breakdown of causes that impacted production. It can be observed that power cuts alone accounted for 53.39% of the problems during the first month. After brainstorming with the firm's managers, it was recommended that the company take quick action to resolve this issue to prevent production from stopping. This problem worsened in the following months. Additionally, the firm needed to address the issue of employees arriving late by implementing strict measures to ensure that they arrive on time and begin preparing for the production process without delay. To resolve the problem of sourcing raw materials, effective programming is required at two levels: (1) supply the unit with the necessary raw materials from the company's warehouse to avoid production halts and (2) plan and schedule the supply of raw materials from the suppliers.

5. Conclusions

The paper discussed the PM approach, which helps to optimize process value by extracting knowledge from historical data on current activities. This knowledge can then be used to eliminate waste and improve the final product to meet customer requirements. This paper covered several concepts related to lean management, including event logs, bottlenecks, data mining, business process management, value-added activities, value stream mapping, process discovery, conformance, and enhancement. Actually, PM helps optimize process value in different ways by (1) improving efficiency through eliminating redundant steps, delays, or bottlenecks; (2) rationalizing resource allocation through the effective usage of equipment and materials, labor management, etc.; (3) improving quality to eliminate defects, rework, etc.; and (4) automating processes to focus on value-added activities.

Furthermore, this paper provided an overview of the different stages involved in implementing a PM project, from planning and justification to final operational support. Various software programs were also mentioned, such as Disco for visually discovering the current process and associated bottlenecks and Prom 6 for testing the homogeneity of activity sequences and drawing value stream maps.

Based on the results obtained, it is important to review the various steps taken to complete the case study. Firstly, the OEE rate was calculated at the manufacturing unit level to gain a better understanding of equipment usage and specifically to identify any failure points, such as availability rate, performance rate, or quality. The results indicated that availability presented a challenge and was a priority area for improving the effectiveness and efficiency of the manufacturing unit. The OEE outputs provided a convincing justification for initiating a preventative maintenance project.

The second step in this study involved completing the stages of the PM project. The project's purpose was clarified at the outset and then various data associated with activity completion were extracted to understand the different causes underlying the low OEE rate. To this end, a cause-and-effect diagram (Ishikawa) was established to categorize the main and sub-causes. The second stage involved understanding how these causes affected the overall manufacturing process. To accomplish this, an event log was created, which statistically described the running of all activities. The current manufacturing process was then established using "Disco". This study relied on the most frequent sequence of activities using "Prom 6" to build a model process and improve it. The results showed a homogeneous sequence of activities, and all bottlenecks were identified along with their associated causes. For the studied unit, five main causes were identified. To address the most critical ones, a Pareto diagram was developed. The results indicated that power cuts and late-coming employees had a significant negative impact. Finally, several recommendations were made to optimize the manufacturing process value at the studied unit as follows: (1) Invest in a new electricity generator to eliminate the problem of frequent power cuts. (2) Invest in new machines to support the manufacturing process and address the issue of machine breakdowns. (3) Enhance employees' commitment by implementing a strict system that prevents tardiness and raises their awareness about the importance of meeting customer demand and achieving the required production level. Any actions that may slow down the unit's performance should also be avoided. (4) Improve sourcing activities planning to ensure the timely supply of raw materials to the firm or the manufacturing unit. (5) Provide necessary training to employees for taking timely corrective actions related to machines' maintenance without relying on external services. (6) Adopt an advanced information system that records all data related to the firm's activities and promotes the continuous improvement of operations.

The application of PM in family SMEs dealing in manufacturing holds significant promise for the future development of manufacturing companies. By leveraging PM tools, family SMEs can gain deep insights into their manufacturing processes, identifying inefficiencies, bottlenecks, and opportunities for improvement. This data-driven approach enables them to streamline operations, reduce waste, and enhance overall productivity. Moreover, the implementation of PM fosters a culture of continuous improvement within the organization, empowering employees to proactively identify and address process inefficiencies. As a result, family manufacturing companies can achieve higher levels of efficiency, quality, and competitiveness, positioning themselves for sustainable growth and success in the rapidly evolving manufacturing landscape.

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