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Providing Business Package Services to SMES Using Lean Manufacturing and Digital Technologies

Güler Zengin [a*], Harika Umut Ergün [a] and Deniz Efendioğlu [a*]

[a] *Industrial Engineering Department, Faculty of Natural Science & Engineering, Ankara Yıldırım Beyazıt University, Ankara, Turkey*

Abstract

This study investigates the effect of lean production systems on the performance of businesses. Lean manufacturing is a production philosophy that aims to reduce waste, increase efficiency and maximize customer satisfaction. The aim of the research is to evaluate the contribution of lean production principles to business performance and to understand the impact of these system applications on business processes. This study was carried out in cooperation with the Ankara model factory affiliated with the Ministry of Industry. It includes improvements that can be made in the application areas used within the Model Factory, based on the lean production principles of this organization for small and medium-sized (SME's) enterprises. Lean manufacturing principles were extensively researched using current literature sources and their potential benefits were determined through practical training within the Model Factory. In this study, by creating four work packages, the benefits they provide and their contribution to the Model Factory will be examined. The Standard Operation Combination Table (SOCT) study showed that a 200% increase in profitability was achieved by reducing the number of workers from three to one in the first work package. The regression analysis of the milling machine's sensor data revealed strong correlations between various variables. High R-squared values between current and voltage pairs and between noise and temperature indicate robust relationships in the second work package. Sensor technology, IoT, cloud computing, and tools like Node-RED have been studied, their output are extracted and used for anomaly detection for third work package. Based on the survey results, the current digital maturity levels of SMEs will be determined and areas that need improvement will be identified and digital transformation strategies are proposed as the fourth work package.

Keywords: Small & Medium-Sized Enterprises; Regression Analysis; Standard Operation Combination Table; Anomaly Detection; Digital Maturity Levels.

1. Introduction & Background

Lean manufacturing focuses on improving efficiency, flexibility, and customer satisfaction by eliminating waste, reducing costs, and enhancing quality. Its core principles include adding value based on customer expectations, creating a value stream by eliminating non-value-adding activities, using a pull system to align production with demand, fostering continuous improvement for faster value creation, and striving for excellence through measurable goals. These principles apply across various organizational processes, aiming to optimize resource use and maximize customer benefits.

Waste minimization is central to lean philosophy, targeting overproduction, waiting, transportation, processing, excess stock, unnecessary movement, repairs, and information waste. By identifying and addressing these inefficiencies, lean

*Corresponding author email address: defendioglu@aybu.edu.tr
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manufacturing ensures ongoing improvements and sustainable competitive advantages. The subjects of lean manufacturing stated below are more related part for this study.

- **Detection & Stopping:** It is an error prevention tool and stops the line in case of an error. The table below includes some methods and their definitions used to prevent errors.
- **Workload Balance (Yamazumi):** Yamazumi analysis is used especially in production processes to distribute the workload equally and ensure a balanced distribution of employees. In this way overloaded stations and workers can be identified and appropriate measures can be taken to improve them.
- **SOCT (Standard Operation Combination Table):** The Standard Operation Combination Table (SOCT) is designed to detail each production process step-by-step. It defines standard operating procedures, specifying how tasks are completed and the time required for each step. This helps assess and improve production line efficiency. SOCT also aids in resource management by identifying labor and material usage for each step, optimizing these requirements, and tracking performance metrics to align actual processes with standards, ultimately enhancing operational performance.
- **Digital Transformation in Business:** Today, digital transformation practices are of great importance in businesses. Digital transformation means businesses use technology to optimize business processes to provide a more efficient and effective competitive advantage.

The study explores four work packages, each contributing to the improvement of the Model Factory. Here is a summarized Table-1 highlighting the key results and achievements from each work package.

Table 1. Work Packages, Key Findings & Main Achievement

Work Package	Key Findings	Main Achievement
Work Package 1	SOCT analysis revealed a 200% increase in profitability by reducing workforce from three to one, demonstrating improved operational efficiency.	Achieved significant gains in operational efficiency by optimizing workforce and reducing labor costs.
Work Package 2	Regression analysis of milling machine sensor data showed strong correlations, with high R-squared values for current/voltage and noise/temperature, indicating predictive maintenance potential.	Demonstrated the potential for predictive maintenance through data-driven insights and correlations.
Work Package 3	Integration of sensor technology, IoT, cloud computing, and Node-RED for anomaly detection improved real-time monitoring and fault detection.	Enhanced system efficiency and fault detection with integrated technologies for better anomaly detection.
Work Package 4	Survey results assessed SMEs' digital maturity levels, highlighting areas for improvement, and digital transformation strategies were proposed.	Identified areas for digital transformation and proposed strategies to help SMEs optimize processes and increase competitiveness.

Each work package addresses a key aspect of operational optimization, from workforce management and data analysis to technology integration and digital maturity improvement, offering clear and measurable outcomes. Overall, the study emphasizes the role of advanced technologies in streamlining operations, improving profitability, and driving digital transformation in SMEs.

2. Literature Review

Lean manufacturing allows making production processes more efficient. Thanks to lean production, machines can be used more efficiently. Work hours of operators can be calculated. Updates may be made according to the adjustment times of the machines. Lean manufacturing has multiple sub-models and all of them can be used in different areas according to needs. A literature review was conducted to examine lean production in the industrial field.

2.1. Lean Production Techniques

Several studies have successfully applied lean manufacturing principles to optimize workflows and minimize inefficiencies in production processes. Hüseyin et al. (2022) reduced preparation times in a biscuit production line, significantly enhancing efficiency. Birgün & Gülen (2006) used value stream mapping to decrease lead times from 21 to 3.5 days and increased inventory turnover sixfold. In Gaza, El-Namrouty & AbuShaaban (2013) demonstrated lean production's effectiveness in reducing scrap, rework, and waste, while Berber & Deste (2021) implemented methods like Kaizen and 5S to improve production in an ice cream factor. These studies underscore lean methodologies' role in eliminating waste and achieving operational excellence.

Some studies highlight the transformative impact of data-driven innovation and digital integration on lean manufacturing. When we are considering them, Singh, Mehta, and Vasudev (2024) explore the role of sensitivity analysis in enhancing multiple-attribute decision-making within lean production, offering a systematic method to address complex manufacturing challenges. Building on this foundation, Pozzi, Cannas, and Rossi (2024) illustrate how data science tools seamlessly integrate with lean principles, enabling organizations to uncover insights that drive operational efficiency. Complementing these findings, Kassem et al. (2024) review how Industry 4.0 technologies such as IoT and AI synergize with lean production, advancing adaptability and minimizing waste.

2.2. Process Optimization

Optimization of production processes has been a focus in various industries, leveraging simulation, data analysis, and systemic evaluations. Sütçü et al. (2019) addressed production bottlenecks in a furniture facility, leading to a 30% reduction in lead time. Similarly, Noor et al. (2012) improved facility layouts in an automotive company through simulation, enhancing performance. Balaji et al. (2016) achieved significant gains in efficiency by optimizing cycle times, while Matic et al. (2023) balanced assembly lines using MTM and simulation software, resulting in a performance boost of 11.4%. These studies highlight how structured approaches and technological tools enhance production efficiency.

In the topic of process optimization within the topic of lean manufacturing, demonstrate the transformative impact of lean methodologies in diverse sectors, emphasizing their role in achieving operational excellence while balancing efficiency with environmental and managerial sustainability. Du et al. (2023) examine lean manufacturing in prefabricated construction, showcasing its ability to minimize waste, boost efficiency, and address specific industry challenges. Rasheed et al. (2023) expand on this by exploring the synergy of sustainability management and lean practices, identifying process optimization as crucial for improving supply chain performance in SMEs.

2.3. Setup Time Reduction

Minimizing setup times is crucial in manufacturing for maintaining continuity and productivity. Akyurt & Eren (2019) and Çelik & Taşkın (2019) successfully implemented the SMED methodology to reduce setup times in automotive production lines, achieving substantial cost savings and operational improvements. Similarly, Siti et al. (2020) optimized operator cycle times by developing a standardized work combination table, reducing idle times. These examples emphasize the importance of reducing setup inefficiencies to streamline manufacturing processes. Under some other headline, they illustrate the application of innovative strategies—be it in sustainable chemical production or manufacturing processes—to optimize efficiency and sustainability across industries. Tian et al. (2023) explore strategies for the sustainable production of hydrogen peroxide via the oxygen reduction reaction, emphasizing advancements in catalyst design and device configurations to enhance efficiency and scalability. In a different industrial context, Habib et al. (2023) present a case study on implementing lean manufacturing in a labeling and packaging plant, demonstrating significant improvements in operational performance.

2.4. Workplace Organization and Safety

Creating organized and safe workplaces has been addressed through various methods. Keleş et al. (2013) implemented the 5S system in a steel company, promoting resource optimization and cleanliness. Kahraman & Demirel (2010) applied FMEA to identify occupational risks, focusing on enhancing workplace safety and productivity. Aksoy (2019) highlighted the importance of visual management systems, particularly andons, in detecting and resolving issues quickly. These efforts demonstrate how workplace organization and safety measures directly contribute to operational efficiency and worker well-being. Jindal et al. (2024) investigate the mediating role of psychological safety in the relationship between workplace support and organizational performance within the Indian IT sector. The findings emphasize the critical importance of nurturing psychological safety as a key factor in achieving sustainable performance improvements in competitive industries.

2.5. Inventory and Supply Chain Management

Efficient inventory and supply chain management are pivotal for cost control and resource utilization. Reçel et al. (2011) implemented a pull and milkrun system to streamline stock management in an automotive sub-industry, optimizing labor and costs. Harun (2023) developed a recycling-based supply chain model, which significantly reduced total inventory costs. These studies illustrate how effective supply chain strategies can improve overall production sustainability.

2.6. Digital and Data-Driven Methods

Incorporating digital tools and data analysis into manufacturing has become increasingly significant in the context of Industry 4.0. Tatar & Ingaldi (2022) demonstrated how digital data collection can help identify the relationship between machine speed and error rates, reducing usability issues. Naufal et al. (2016) enhanced productivity in an automotive jack assembly line using digital tools integrated with lean techniques. These studies showcase the transformative role of digital technologies in modernizing and improving manufacturing processes.

By categorizing these studies, it becomes evident how different approaches—ranging from lean methods and process optimizations to digital interventions—drive significant advancements in manufacturing efficiency and sustainability.

2.7. Industry 4.0 & Digital Development

Industry 4.0 has also brought digitalization. Technologies such as artificial intelligence, machine learning, VR technologies and cloud technologies, which are among the innovations of digital, make our lives easier. Digitalization is very important in the production and service sectors, and if used together with lean production, work can be done more efficiently to eliminate waste.

Table 2. Results of Research

Name of the research	The method used	Result of the research
Estimation of the Amount of Materials Used in the Desulfurization Process Using Machine Learning Techniques (Özcan & Sonuç, 2022)	Linear Regression, Neighbors Regressor, Decision Tree Regressor	Machine learning reached accuracy values of 85%, 95.4%, and 80.14% for three raw materials.
Crisis management training using discrete-event simulation and virtual reality techniques (Pak et. al., 2019)	Simulation, VR Technology	The study's conclusions demonstrated that the VCST intervention was an appropriate method for employing the hazard simulation system to train crisis managers.
As a Reflection of the Designer's Mind; "Artificial intelligence" (Ardatürk, 2022)	Coding and programming experiments were made, machine learning diagrams were tried to be written, test servers were created.	Put another way, the methodical multi-plane thinking of artificial intelligence, the creation of machinery that enables qualified labor, and the construction of infrastructure that allows the technology to grow as a result of its learned knowledge; One may argue that formalism is an expression of the designer's mentality and that, in terms of approach and workflow, he acts like a craftsman.
Digital Transformation of SMEs (Dündar, 2020)	Explanatory Factor analysis, multiple regression analysis	Although the results of many variables are given, it is obvious that more than half of them cannot meet the lower requirements of digital.
SENSOR applications with additive manufacturing in industry 4.0 (Çelebi & Koda 2021)	CAD, 3D printer	The place of sensors in the production sector has gained importance.

As a result, lean production has many sub-methods and are used to increase the efficiency of the process and production. This is the purpose of the digital age. Digital enables the work to be done faster, safer, more thoughtful and more efficient in many ways. In this part of the literature review, articles related to digital are mentioned and their connection with lean production is explained. Research has been conducted on strengthening the place of small and medium-sized enterprises (SME's) in the market by using digital technologies along with lean production.
In the Table-2, information about digital research is given. The name of the research, the method used and the research results are explained.
Table-3 gives information about research conducted on lean manufacturing. The name of the research, the date of the research, the method used and the country where the research was conducted are given.

Table 3. Methods of Research

Name of the Research	Country of Publication	Year of Publication	Methods Used
Process improvement application in a food business: Ice cream factory example	Turkey	2021	Brainstorming, Cause Effect Diagram (Fishbone), Kaizen, poke yoke analysis, flow diagram
An application of the lean production tool standard work (Sara & Eric, 2015)	Portugal	2015	Skill matrix, sequence diagram, cause-effect diagram, and spaghetti diagram
Analysis Work Standardization Using The Standardized Work Combination Table on CNC of Mission Case Line Process at PT Astra Otoparts, Tbk - Nusametal Division	Indonesia	2020	Work analysis, 5S
Digitization of processes in manufacturing SMEs - value stream mapping and OEE analysis	Poland	2022	Value stream mapping, OEE, process visualization
Assembly Line Optimization Using MTM Time Standard and Simulation Modeling - A Case Study	Slovenia	2023	Lean - MTM, simulation (Simio), work analysis
Lean tool used in the automotive industry (Ingaldi & Kocik, 2014)	Poland	2014	Work analysis, Yamazumi, MTM method, arM (Machine Motion Analysis)
Optimization of Cycle Time by Lean Manufacturing Techniques-Line Balancing Approach	India	2016	Yamazumi, line balancing
Improvement of overall efficiency of production line by using line balancing	Malaysia	2016	Yamazumi, work analysis, Kaizen, line balancing
Simulation of Integrated Total Quality Management (TQM) with Lean Manufacturing (LM) Practices in Forming Process Using Delmia Quest	Malaysia	2012	Simulation, Yamazumi, work analysis
Seven wastes elimination targeted by lean manufacturing case study "Gaza strip manufacturing firms"	Palestine	2013	Drawing and analysis, brainstorming
Effect of SMED application on setting time and unit cost: Peeling bright steel production line application	Turkey	2019	SMED, OEE, value-added product detection
Kaizen Maliyetlendirme Yönteminin Üretim Maliyetlerini Azaltmadaki Rolü ve Uygulanabilirliği Üzerine Bir Araştırma (Enver & Suphi, 2011)	Türkiye	2011	Anket yöntemi
Ahşap Makara Üretiminde Ahşap Boyutlarının Belirlenmesi: Hammadde Kaybını Azaltan Bir Karar Destek Modeli (Harun, 2023)	Türkiye	2020	5S

Table 3. Methods of Research (*Continued*)

İki Aşamalı Yeşil Tedarik Zincirinde Envanter Kontrolü	Türkiye	2023	Matematiksel modelleme
HEIJUNKA, Yalın Üretim Araçlarından Biri ve Tekstil Uygulamaları (İşler & Güner, 2014)	Türkiye	2014	Heijunka
İleri Üretim Teknolojileri ve Andon Uyarı Sistemleri	Türkiye	2019	Jidoka
5S Sistematik Aşamaları ve Bir Örnek Uygulama	Türkiye	2013	5S
Çekme Sistemleri İçin Karar Destek Sistemi Önerisi ve Karşılaştırmalı Bir Çalışma (Erozan, 2019)	Türkiye	2019	Kanban ve çekme sistemi
Bir İşletmede Tam Zamanında Üretim Sistemi Uygulaması (Esin, 2004)	Türkiye	2004	JIT
SMED Yöntemi ile Hazırlık Süresini Azaltma Uygulaması	Türkiye	2019	SMED, 5S
Yalın Üretime Geçişte Değer Akış Haritalama Tekniği Kullanımı: Üretim Sektöründe Bir Uygulama	Türkiye	2016	Değer akış haritalama, 5S
OHSAS 18001 Kapsamında FMEA Uygulaması	Türkiye	2010	FMEA
Yalın Tedarik Zincirinde Optimizasyon (Özçakar, 2010)	Türkiye	2010	Yalın ve matematiksel modelleme
Bir Otomotiv Yan Sanayi Firmasında Çekme ve Milkrun Sistemi Uygulaması	Türkiye	2011	FIFO, milk-run

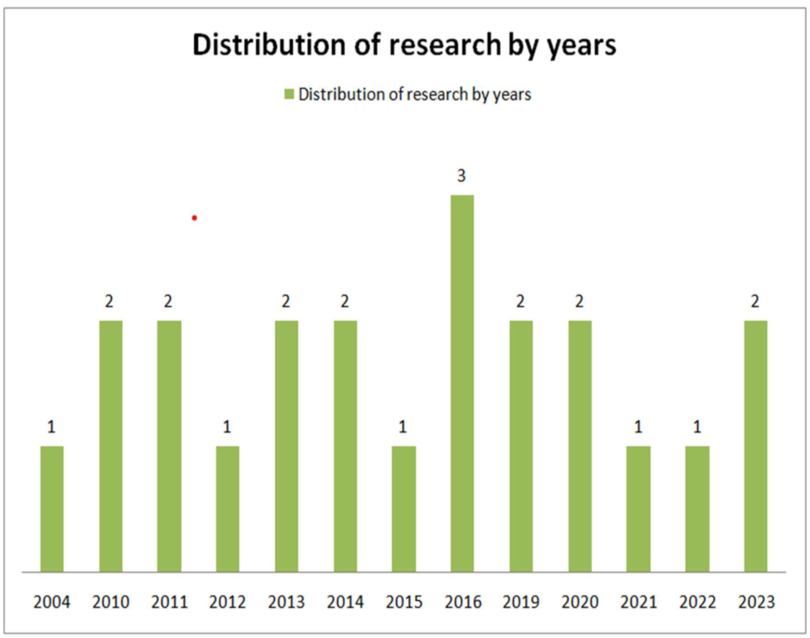

Figure 1. Distribution of research by years

The years and countries in which research on lean manufacturing was written are shown in the Figure 1 and Figure 2.

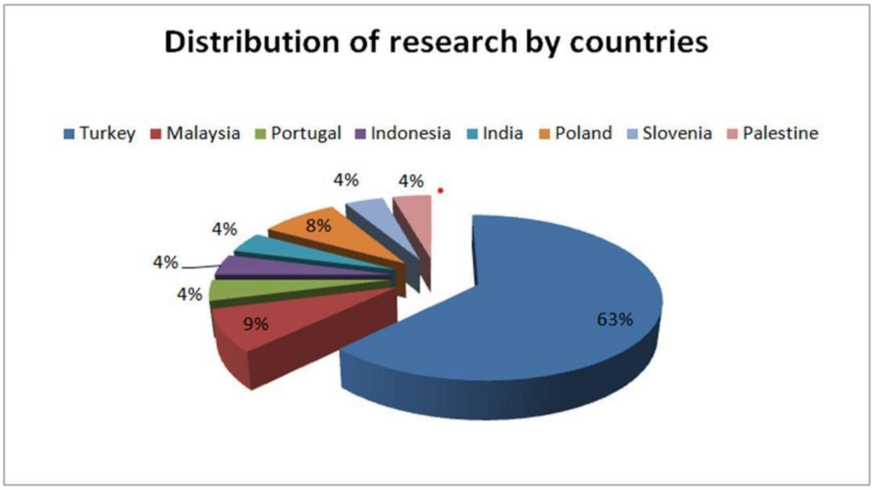

Figure 2. Distribution of research by countries

3. Materials-Methodology & Results

Today, small and medium-sized enterprises (SMEs) are in great need of innovative production solutions to gain competitive advantage, reduce costs and increase efficiency. In this context, introducing lean production principles through applied training through Model Factories affiliated with the Ministries of Industry and Technology helps these companies optimize their operational processes and gain competitive advantage.

This study was written in collaboration with Ankara Model Factory, affiliated with the Ministry of Industry. It includes improvements that can be made in the application areas used within the Model Factory, based on the lean production principles of this organization for small and medium-sized enterprises.

Work packages will be created for these improvements. Lean work packages are an important tool used to make business processes more efficient and effective. These packages, based on the lean management philosophy, aim to reduce waste, increase efficiency and be customer-focused. With lean business packages, businesses can better understand and improve their processes. These packages aim to reduce costs by ensuring efficient use of resources while improving the quality of products and services. In this study, by creating Lean and digital Business packages, the benefits they provide and their contribution to the Model Factory will be examined.

The structure of the study follows a clear classification in which each section begins by discussing the tools used, followed by the methodology applied, and then the results obtained. Initially, the focus was on the methodology related to digital maturity, where the findings were presented. In the next methodology, the tools were primarily sensors, and the software used for data collection and analysis were highlighted. Following this, the study delved into statistical methods, specifically regression analysis and data mining techniques such as anomaly detection. Finally, the study concluded with a lean manufacturing methodology, focusing on the Standard Operation Combination Table (SOCT), and the findings derived from this analysis.

The structure of the study begins by describing the tools used in each section, followed by the methodology applied and the results obtained. The first methodology focuses on digital maturity, with the findings related to this approach presented. The next methodology emphasizes the use of sensors and the software involved in data collection and analysis. Subsequently, statistical methods, including regression analysis and data mining techniques for anomaly detection, are explored. Lastly, a lean manufacturing methodology is used, specifically the Standard Operation Combination Table (SOCT), with the corresponding results provided.

3.1. Digital Maturity

A measurement known as "digital maturity" conveys the ability of an organization to accept and apply digital tactics and technologies. This rating demonstrates how well and quickly businesses can employ digital tools and technologies. Businesses with a high degree of digital maturity are better able to adapt to changing market conditions, comprehend client needs more thoroughly, and maintain a competitive edge through continuous process improvement.

Digital maturity measures an organization's ability to adopt and utilize digital technologies effectively, impacting its adaptability, customer understanding, and competitiveness. Key elements include integrating technology into business strategies, fostering a culture of innovation, optimizing organizational processes, and leveraging advanced technological infrastructure.

Small and medium-sized enterprises (SMEs) face unique challenges due to resource limitations. Digital maturity assessments help SMEs identify strengths and weaknesses, providing a roadmap for targeted digital transformation. These evaluations highlight areas for improvement, such as customer relationship management, operational streamlining, and data security.

The benefits of digital maturity include strategic resource allocation, competitive market positioning, enhanced customer satisfaction through personalized services, improved internal processes, and robust risk management. Steps to enhance digital maturity involve investing in technology, training staff, utilizing data analytics, and collaborating with digital partners.

Digital transformation is an ongoing journey, requiring regular assessment and refinement. By committing to continuous improvement, SMEs can build a resilient foundation for long-term success in the digital era.

3.1.1 Methodology for Surveying Digital Maturity

A survey with questions in specific categories was created in order to gauge the degree of digital maturity. The purpose of this poll was to determine the stage of digital transformation that SMEs are at. Survey questions were gathered under the following categories to examine how organizations were doing with digitization across various business processes:

- Structure of Organizations
- Client Administration
- Development of Products and Packages
- Production Management
- Supply and Storage
- Calculation
- Upkeep
- Superior Unit

3.1.1.1. Structure of Organizations

The company's efficiency, flexibility, and adaptability are increased by the incorporation of digital technologies into the organizational structure. Digital technologies facilitate the enhancement of transparency, traceability, and efficiency in business processes. As an illustration:

- Digital Communication Tools: Tools for video conferences, instant messaging, and email allow for efficient and quick communication amongst staff members.
- Cloud Computing: Information access and collaboration are facilitated by storing and managing data and apps in a cloud environment.
- Corporate Management Software: By integrating all corporate processes, ERP (Enterprise Resource Planning) solutions make management and control easier.

3.1.1.2. Customer Management

Digital technologies improve customer relationship management (CRM), which in turn increases client happiness and loyalty. Customer data may be gathered, examined, and utilized more efficiently with the use of digital tools. As an illustration:

- CRM Systems: Sales and marketing procedures are optimized when customer data is gathered and managed centrally.
- Social Media Management: Getting input from customers and fostering more contact with them are made possible by using social media platforms effectively.

- Data Analytics: Personalized marketing strategies can be developed by analyzing the behavior and preferences of customers.

3.1.1.3. Product: Development of Packages

By speeding up the process of developing new products and packaging, digital technologies promote creativity. When it comes to product development procedures, digital tools offer quicker and more effective alternatives. As an illustration:

- CAD Software: Prototyping expenses are decreased and product design procedures are accelerated with computer-aided design software.
- 3D Printing: Thanks to advancements in technology, product prototypes may now be produced quickly and affordably.
- Data analytics: Processes for developing new products are guided by analysis of consumer demands and market trends.

3.1.1.4. Manufacturing oversight

Digital technologies optimize industrial processes, resulting in increased efficiency and quality. Production processes can be more traceable and controlled thanks to digital solutions. As an illustration:

- Automation Systems: Production lines and robotic automation speed up operations while reducing human error.

3.1.1.5. Supply and Storage

Digital technologies boost supply chain management and warehouse efficiency, which lowers costs. Procurement and inventory management procedures are streamlined by digital technologies. For instance, real-time inventory management and monitoring with Warehouse Management Systems (WMS) improves storage efficiency.

- RFID Technology: Accurate and fast inventory movement tracking is provided by radio frequency identification devices.
- Supply Chain Management Software: Supply processes are optimized by end-to-end supply chain monitoring and management.

3.1.1.6. IT

Through the improvement of information processing procedures, digital technologies lay the groundwork for the digital transformation of enterprises. Being digitally mature requires having a robust IT infrastructure. As an illustration:

- Cybersecurity: To safeguard digital assets and guarantee data security and privacy, cybersecurity solutions are employed.
- Data Backup and Storage: Ensuring the safety and integrity of data is essential for maintaining corporate operations.

3.1.1.7. Maintenance

By streamlining maintenance procedures, digital technologies lower expenses and downtime. The use of digital planning and monitoring technologies improves the efficiency of maintenance procedures. As an illustration, consider the following:

- Predictive maintenance is made possible by IoT and sensor technologies, which gather data on the condition of equipment in real time.
- Software for maintenance management: By organizing and tracking maintenance procedures, operational effectiveness is increased.
- Digital Twins: Virtual representations of tangible assets that mimic and enhance maintenance procedures.

3.1.1.8. Quality Test

Digital technologies improve quality control procedures, which raises the caliber of goods and services. Processes for quality control are easier to track and manage thanks to digital technologies. As an illustration:

- Quality Administration Systems (QMS): Enhancing quality is possible through digital administration and monitoring of quality control procedures.
- Data Analytics: Processes for improving quality are driven by the analysis of production and quality data.
- Automatic Control Systems: Testing and control systems that operate automatically speed up quality control procedures.

3.1.2. Inquiries for Survey

3.1.2.1. Structure of Organizations

Organizational structure assesses the degree of digital technology integration and the management of digital transformation processes within the company. Here, the following inquiries were utilized:

- Exist uniform business procedures? Standardizing corporate procedures boosts productivity and lays the groundwork for a successful digital transformation.
- Do staff members receive training in digital development? Enhancing workers' digital competencies is essential to the success of the digital shift.
- Is there a digital office for the company? A primary organization for organizing and carrying out plans for digital transformation is the digital office.
- Is the data stored instantly? The company can make quick, precise judgments thanks to instantaneous data tracking.
- Is money set aside for initiatives related to digital transformation? Setting aside money for digital transformation guarantees that strategic planning and execution will be successful.
- Do the factory's units communicate with one another? For digital transformation operations to be carried out effectively, communication between units is required.
- Is money set aside for research of efficiency? The business becomes more competitive due to the budget allotted for efficiency research.
- Exists communication between the lean production office and other units? Process optimization in production is made possible by the lean production office's contact with other departments.

3.1.2.2. Client Administration

Customer relationship management and the application of digital technologies in these operations are assessed by customer management. In this case, the following queries were asked:

- When identifying your clientele, what factors do you consider? The business's marketing techniques are determined by the selection criteria used for customers.
- How do customers follow project steps? Using digital tools to monitor project management procedures improves customer satisfaction.
- Is distributor companies' performance tracked? The efficiency of the supply chain is increased by keeping an eye on distributor companies' performance.
- How are estimates for sales made? Using digital tools to make sales projections helps to maximize marketing and sales tactics.
- Do you receive consumer feedback? Customer feedback evaluation and receipt enhances the caliber of goods and services.

3.1.2.3. Product: Development of Packages

- Do you own an R&D department? Having a research and development section is crucial for creating novel products and solutions.

- Is there a budget set aside for developing the product package? Product development spending boosts both product quality and innovation.
- Is there communication between the R&D section and other departments? The R&D unit's communication with other divisions expedites the process of developing new products. Do you design products with digital compatibility in mind when developing them? Product design that works with digital platforms effectively satisfies consumer demands.

3.1.2.4. Supply and Storage

- When a mistake occurs in the supply or storage flow, what should you do? Error control increases the effectiveness of the supply chain.
- Does it make capacity plans? Supply and storage process optimization is made possible by capacity planning.
- Are supply and storage units in communication with one another? Improved communication among units facilitates more effective process management.

3.1.2.5. Information Technology Unit

The information technology unit assesses the application of computational procedures in the digital transformation. In this case, the following queries were asked:

- Does the factory have a unit dedicated to ensuring cyber security? Digital assets are protected thanks to the efforts of the cyber security section.
- Is money set aside for projects involving information technology? Processes of digital transformation are made successful by the funding allotted to IT projects.

3.1.2.6. Maintenance

- Does the machinery have a timetable for maintenance? Regular and planned machine
- Who keeps the machines maintained? Establishing who is responsible for maintenance guarantees efficient process management.

3.1.2.7. The Quality Unit

- What is the plan for the quality process? Product and service quality is increased through the use of digital tools in quality process planning.
- How should quality control data be assessed? Processes for improvement are guided by quality data analysis.

3.1.3. Survey on Digital Maturity Measurement: Potential Responses and Assessment

- **Structure of Organizations**
    - Exist uniform business procedures?
        - Some procedures are somewhat standardized (Medium maturity);
        - All processes are standardized (High maturity).
        - Standardized processes are not present (low maturity).
    - How should quality control data be assessed? Processes for improvement are guided by quality data analysis.
        - In certain cases, training is given only when necessary (middle maturity);
        - In other cases, it is given on a regular basis (high maturity).
        - No, there was no instruction given (low maturity)
    - Is there a digital office for the company?
        - Somewhat, certain portions use it (medium maturity);
        - Yes, it is extensively employed (high maturity).
        - Digital office not to be had (low maturity)
    - Is the data stored instantly?
        - Partially, some data is saved instantly (Medium maturity);

    - Yes, all data is kept instantly (High maturity).
    - No, information is not retained instantly (low maturity).
  - Is money set aside for initiatives related to digital transformation?
    - Yes, there is regular budget allocation (high maturity);
    - There is partial budget allocation during specific times (medium maturity).
    - No, there is no budget (low maturity) allocated.
  - Do the factory's units communicate with one another?
    - Yes, there is good communication (high maturity).
    - There is some inter-unit communication (Medium maturity), but not much.
    - No, inadequate communication; immature
  - Is money set aside for research of efficiency?
    - Absolutely, there is regular budget allocation (High maturity)
    - A portion of the budget is set aside during specific times (Medium maturity)
    - No, there is no budget (low maturity) allocated.
  - Exists communication between the lean production office and other units?
    - Yes, in an active manner (high maturity);
    - Yes, in part through interactions with some units (mid maturity).
- **Client Administration**
  - When identifying your clientele, what factors do you consider?
    - Information about past purchases, demographics, and behavior (high maturity)
    - Middle-maturity demographic data
    - Selection at random (low maturity)
  - How do customers follow project steps?
    - Using email and basic digital tools (Medium maturity)
    - Using digital project management tools (High maturity)
    - Through physical means (low maturity)
  - Is distributor companies' performance tracked?
    - Certainly, using highly developed digital performance monitoring systems.
    - In part, based on a few fundamental standards (Medium maturity)
    - Not under observation (low maturity)
  - How are sales forecasts determined?
    - With data analytics and machine learning methods (High maturity)
    - Based on historical sales data (Medium maturity)
    - Guessing and manual methods (Low maturity)
  - Do you get feedback from customers?
    - Yes, with regular surveys and digital feedback systems (High maturity)
    - Sometimes, in certain periods (Middle maturity)
    - No, no feedback is received (Low maturity)
- **Product - Package Development**
  - Do you have an R&D unit?
    - Yes, actively working (High maturity)
    - Partially works on specific projects (Medium maturity)
    - No, not available (Low maturity)
  - Do you have a budget for product package development?
    - Yes, budget is allocated regularly (High maturity)
    - Partially, budget is allocated to certain projects (Medium maturity)
    - No, no budget is allocated (Low maturity)
  - Is there communication between the R&D section and other departments?
    - Yes, there is continuous cooperation and communication (high maturity);
    - in some projects, there is some communication (medium maturity).
    - No, inadequate communication; immature
  - Do you design products with digital compatibility in mind when developing them?

        - Certain products have partial digital compatibility (Medium maturity);
        - All products have full digital compatibility (High maturity).
        - No, there is no consideration of digital adaption (low maturity).

- **Manufacturing oversight**
    - How do laborers receive work orders for production?
        - Using highly mature digital systems and displays
        - Through printed materials or email (Medium maturity)
        - Through manual or verbal means (low maturity)
    - Are procedures for production being followed?
        - In part, using certain fundamental measures (Medium maturity);
        - Absolutely, with digital monitoring systems (High maturity).
        - No, not adhered to (insufficient maturity)
    - During production, are machines under observation?
        - With digital sensors and the Internet of Things, yes (High maturity)
        - No, not under observation (low maturity);
        - Only partially, with a few fundamental systems (medium maturity).
    - Are workers under observation while producing?
        - Definitely, using sensors and digital systems (High maturity)
        - In part, using a few simple techniques (Medium maturity)
        - Not under observation (low maturity)
    - How is the production area's material flow guaranteed?
        - With manual and semi-automated methods (Medium maturity);
        - With digital systems and automatic guidance (High maturity);
        - With manual methods only (Low maturity).
    - How do production processes decide on batch sizes?
        - With historical data and projections (High maturity);
        - With data analytics and demand estimates (Medium maturity);
        - With guesswork and manual techniques (Low maturity).

- **Supply and Storage**
    - When a mistake occurs in the supply or storage flow, what should you do?
        - Correction through use of digital solutions and analysis of the root cause of the error (High maturity)
        - Using manual and reactive fixes (low maturity);
        - Using fundamental error correction techniques (medium maturity).
    - Does it make capacity plans?
        - In part, using certain fundamental planning tools (Medium maturity)
        - Absolutely, with digital planning tools (High maturity)
        - No, using crude techniques (low maturity)
    - Are supply and storage units in communication with one another?
        - Absolutely, with highly developed digital communication technologies.
        - No, inadequate communication (low maturity);
        - Partially, using some fundamental communication techniques (medium maturity).
- **IT**
    - Does the factory have a unit dedicated to ensuring cyber security?
        - A specialized cyber security unit does exist (High maturity)
        - Cybersecurity measures exist in part (Medium maturity)
        - No, unique unit not needed (low maturity)
    - Is money set aside for projects involving information technology?
        - Yes, there is regular budget allocation (high maturity);
        - There is some budget allocation for particular projects (medium maturity).
        - No, there is no budget (low maturity) allocated.

- **Maintenance**
  - Do the equipment have a schedule for maintenance?
    - In part, with a few simple charts (Medium maturity);
    - Absolutely, with computerized maintenance schedules (High maturity).
    - No manual or sporadic upkeep (low maturity)
  - Who keeps the machines maintained?
    - No, generally by staff members (low maturity);
    - By an expert care team (high maturity);
    - By certain primary care personnel (medium maturity);
- **Quality Unit**
  - What is the plan for the quality process?
    - With some basic planning tools (Medium maturity);
    - With digital quality management systems (High maturity).
    - No, using crude techniques (low maturity)
  - How should quality control data be assessed?
    - With digital systems and data analytics (high maturity);
    - With manual and simple procedures (medium maturity);
    - Without any of these; (low maturity)

3.2. Sensors & Data

Automation is being used more and more in modern manufacturing settings in an effort to improve productivity and attain operational excellence. Within this framework, enterprises can continuously check on the condition of their equipment by extracting data from devices via sensors. The machine is equipped with a number of sensors that gather data in real time on temperature, pressure, vibration, speed, and many other vital operating factors. This information is gathered in a central system and prepared for examination.

Sensors detect environmental or physical changes and convert them into electrical signals for measurement, control, and automation. They are widely used in monitoring systems to measure variables like temperature, pressure, or humidity, providing data for efficient decision-making. In automation and control, sensors play a vital role in managing systems such as industrial processes, fire detection, and medical devices. Their applications span various sectors, including automotive safety with airbags, industrial automation, smart home systems, and healthcare monitoring. By enabling data collection and operational efficiency, sensors are fundamental to modern technology's advancements in analysis and decision-making.

Sensors detect environmental or physical changes, convert them into electrical signals, and are integral to modern technology. They measure various physical quantities like temperature, pressure, and motion, providing critical data for applications such as industrial automation, fire detection, medical devices, and smart home systems. Sensors enhance decision-making, data analysis, and system automation across sectors, including automotive safety and healthcare.

3.2.1. Types of Sensors and Their Applications in IoT and Industrial Systems

Sensors are essential components in modern industrial systems, converting physical measurements into electrical signals for various applications. Specific sensor types are tailored to measure different variables:

- **Temperature Sensors**: These track ambient temperature changes and include resistance thermometers, thermoelectric sensors, and heat detectors.
- **Pressure Sensors**: Used to measure liquid or gas pressure, they come in resistive, capacitive, magnetic, and piezoelectric forms.
- **Motion Sensors**: Detect vibrations or movement using technologies like PIR (Passive Infrared), microwave, ultrasonic, and magnetic sensors.
- **Humidity Sensors**: Measure air moisture content and are available as resistive, capacitive, or thermal types.
- **Position and Speed Sensors**: Determine an object's position or velocity, including GPS, magnetic, and ultrasonic varieties.

- **Magnetic Field Sensors**: Identify magnetic fields through technologies such as magnetic resonance, Hall effect, and regenerative sensors.
- **Gas Sensors**: Detect gas concentrations using semiconductor, optical, thermal conductivity, and electrochemical sensors.

IoT sensors offer advanced features compared to traditional sensors, particularly in data communication and management. Traditional sensors often rely on local or wired connections and are standalone, whereas IoT sensors leverage wireless protocols like Wi-Fi, Bluetooth, Zigbee, and LoRaWAN for broader coverage and remote interaction. IoT sensors also facilitate enhanced data analysis and integration, enabling real-time management and remote monitoring for advanced industrial applications.

3.2.2. Gathering and Processing Data from Machine Sensors

3.2.2.1. Extracting Data from Sensors

Acquiring data from machine sensors involves several key steps. First, sensors need to be identified and properly connected to the system, ensuring compatibility with any required libraries or drivers. Once connected, data is read using interfaces like analog-to-digital converters (ADC) for analog signals or digital protocols such as I2C, SPI, or UART. The retrieved raw data is then processed into a usable form, such as converting a voltage reading from a temperature sensor into temperature values in Celsius or Fahrenheit. Processed data can be stored in databases, shared via software applications, or displayed on dashboards. To ensure data security, encryption and authentication methods are often employed, particularly when dealing with sensitive information. Error monitoring and control systems are essential for maintaining the accuracy and reliability of the data.

3.2.2.2. Processing Sensor Data

The processing of sensor data typically begins with its collection, often involving storage in local or cloud-based systems. Preprocessing steps like noise reduction or signal conversion refine the data for subsequent analysis. Advanced algorithms analyze and interpret the data, enabling decision-making and automation based on predefined criteria. For example, a temperature sensor detecting a high reading could trigger cooling systems or send alerts. Data visualization tools, including graphs and dashboards, facilitate understanding and reporting for users and administrators. Finally, feedback loops allow systems to evaluate performance and implement continuous improvements for efficiency and effectiveness.

3.2.3. Docker

Their dependencies and usage are combined in Docker containers. This guarantees that programs function properly in any setting. Code, runtime, libraries, dependencies, and configuration files are all included in a Docker container, which is all an application needs to run. Moving Docker containers between test, production, and development environments is simple. This ensures dependability and trouble-free performance in various settings. Quick Deployment Containers can be created and launched with Docker. Applications can be deployed and scaled more quickly as a result. The operating system is shared and each container does not have its own operating system, so containers boot faster than virtual machines. Containers can be used to quickly create and balance multiple instances of a service, providing high availability and scalability. Security and isolation of Docker containers is done at the operating system level. This allows one box to operate separately from the others. Isolation prevents applications from interfering and creates a more reliable environment. When one container is damaged, other containers are not damaged. Docker provides a set of security measures that are constantly updated to increase application and infrastructure security.

3.2.4. Resource Usage

In comparison to virtual machines, Docker containers consume less power. This lowers infrastructure expenses by enabling the execution of several apps on a single host. It is not necessary for each container to have its own file system and operating system instance. The underlying operating system is shared by containers. Development is accelerated using Docker's Rapid Development Process. Docker containers can be customized by developers to meet their runtime environments. This lessens the likelihood of problems such as "your employee is not working on my machine" and guarantees a consistent environment for everyone. Docker speeds up the development, deployment, and updating of programs by facilitating continuous integration and continuous deployment (CI/CD) procedures. Applications can be packaged in a modular fashion thanks to Docker containers. This facilitates the updating, scalability, and replacement of application components.

3.2.5. Node-RED

Node-RED is widely used for managing data flows and facilitating the integration of Internet of Things (IoT) devices and sensors. It enables seamless data processing, routing, and analysis from various sources, such as sensors and devices, making it ideal for applications like home automation and industrial IoT. Through Node-RED, data can easily be transferred between systems, such as from an MQTT server to a visualization tool or from a database to web services. Additionally, it supports web services integration by handling HTTP requests and responses, which is essential for developing web-based applications. In smart home systems, Node-RED is used for controlling devices like lights and security cameras while also processing data from environmental sensors like temperature and humidity sensors. One of its standout features is the ability to visualize real-time data streams, providing immediate insights into operations. Furthermore, Node-RED allows intelligent automation and control, enabling automated responses to specific events, such as triggering alerts when certain conditions, like temperature thresholds, are met. Its flexibility and ease of use make it suitable for a wide range of industries, offering developers the ability to create customized solutions that meet specific needs.

3.2.6. MQTT (Message Queuing Telemetry Transport)

MQTT is a lightweight messaging protocol designed for low-bandwidth, low-power applications, making it ideal for IoT (Internet of Things) and M2M (Machine to Machine) communication. MQTT operates on a publish/subscribe model, where devices and applications subscribe to specific topics to receive messages and publish data. It is known for its flexibility, supporting a wide variety of systems and devices over TCP/IP, and it is built to ensure data security through TLS/SSL encryption, authentication, and authorization mechanisms. MQTT also offers durability, ensuring that messages are not lost during connection failures, which is crucial for reliable communication between devices.

MQTT is applied across various domains, including smart home systems, where it enables communication between devices like light switches, thermostats, and security cameras. In industrial automation, it facilitates data collection from sensors and controllers, improving monitoring and productivity. It is also used in traffic monitoring to manage congestion, remote telemetry for collecting data from distant devices like weather stations, and energy management to optimize the use of power generation and distribution systems.

The process of using MQTT involves selecting an MQTT broker (server), such as EMQ X, HiveMQ, or Mosquitto, which facilitates the communication between devices. After establishing a client on the device or application, it connects to the broker to send and receive messages. The client can process incoming data based on predefined rules, such as triggering actions when specific sensor data, like temperature readings, exceeds set thresholds. Once the interaction is complete, the client disconnects to free up resources.

To collect data from sensors using MQTT, a broker is set up where sensors send their data, and subscribers receive it. Sensors connect to the broker via MQTT clients, often developed using platforms like Python or Arduino. The collected data is processed by the subscribing application, which can use the information for real-time actions or store it for further analysis. After data transmission, connections can be closed to enhance security and conserve resources. These steps make MQTT an efficient and flexible choice for managing IoT and M2M communications in various industries.

3.2.7. Automating the Gathering and Analysis of Data: Employing MQTT and Node-RED

This section delves into the specifics of how IoT-based data gathering and processing operations are automated using the Node-RED platform and MQTT protocol. As technology advances, fast and efficient data processing from a variety of sensors becomes increasingly important for data-driven decision-making.

Node-RED is a flow-based programming tool used for Internet of Things applications and real-time data processing. A lightweight messaging system called MQTT (Message Queuing Telemetry Transport) enables dependable device-to-device communication in low-bandwidth situations. This study discusses the processing of sensor data received via MQTT using Node-RED.

- Setting up the Flow Starting Point (Timestamp): The timestamp node, which is activated at predetermined intervals, serves as the automation process's launchpad.
- Data Processing (Function Nodes): Using functional nodes, raw data from sensors is prepared and processed in accordance with preset business requirements.
- Data Storage (GSheet - Append): For analysis and reporting needs, processed data is moved to Google Sheets documents.
- Debugging Nodes: To monitor whether the system is operating correctly or not, debug nodes are installed at each stage of the process.
- The MQTT protocol is used to receive sensor data, which is then processed based on predetermined filtering standards. This procedure makes it possible to control data flow and prevent pointless data traffic, which makes it possible to utilize system resources efficiently. The project defines three primary functional nodes for processing and storing sensor data:
- Function 1: The initial data collection is processed using fundamental procedures.
- Functions 2 and 3: These nodes carry out sophisticated data processing and analysis tasks.
- Data Enrichment: This method adds a timestamp to the incoming raw sensor data in addition to processing it and determining when it was obtained.
- Subject Routing: This helps to promote more consistent and well-organized data consumption by guiding the processed data to a certain subject, which guarantees that the data reaches the intended recipient.

3.3. Regression Analysis

The relationship between parameters have been investigated and the results have been stated below have been found.

- Current1 and Voltage1: An R-squared score of 92% indicated a significant correlation between Current1 and Voltage1 according to regression analysis. This indicates a substantial correlation between variations in Voltage1 and variations in Current1. In particular, their direct proportionality is demonstrated by the fact that a 1% rise in Current1 causes a comparable 0.85% increase in Voltage1.
- Current2 and Voltage2: With an R-squared value of 91%, Current2 and Voltage2 also showed a strong correlation. This demonstrates the strong relationship between changes in Voltage2 and Current2, with a 1% rise in Current2 translating into a 0.88% increase in Voltage2.
- Current3 and Voltage3: With an R-squared value of 90.5%, the link between Current3 and Voltage3 also showed a good correlation. This demonstrates that a 1% rise in Current3 results in a 0.86% increase in Voltage3, supporting the pattern seen in other current and voltage couples.
- Temperature and Noise: With an R-squared value of 93%, the analysis showed a substantial association between temperature (Temperature) and noise levels (Noise). This demonstrates how temperature variations have a big impact on noise levels. There is a clear and substantial correlation between these two factors, as evidenced by the fact that a 1°C increase in temperature results in a 1.2 dB increase in noise levels.

Between Current1 and Temperature (91% R^2 value) and Current2 and Temperature (90% R^2 value), there was a significant association. According to these results, the current readings fluctuate along with the milling machine's temperature. The data indicates a significant reliance of current on temperature, with a 1°C rise in temperature resulting in a 0.9% increase in Current1 and a 0.87% increase in Current2.

Not insignificant was the correlation between Voltage1 and Noise (R^2 = 92%) and Voltage2 and Noise (R^2 = 91%). Accordingly, variations in voltage are probably going to have an impact on the machine's noise output. In other words, noise increases by 0.9 dB for every 1% rise in Voltage1 and 0.88 dB for every 1% increase in Voltage2.

3.4. Anomaly Detection

The process of finding unanticipated, aberrant, or unwanted variations in gathered data is called anomaly detection. This technique is employed to anticipate costly outages, system problems, and mechanical faults. The following actions are involved in anomaly detection:

- **Data collection:** An ongoing process involves moving sensor-derived data to a data storage system. This data offers detailed information about the performance and operating circumstances of the machine.

- **Preprocessing of the data:** Unprocessed data is frequently noisy or contains missing values. The preprocessing stage of data involves cleaning, standardizing, and preparing the data for analysis.
- **Creating a model for anomaly detection:** After identifying the machine's typical operating characteristics, a machine learning model is created to identify deviations from these values. Through the use of previous data, this model is taught to understand what is expected of the machine.
- **Real-time monitoring and alarm system:** When anomalous circumstances are identified, the model immediately notifies the appropriate individuals after continuously analyzing incoming data.

Anomaly detection offers critical advantages for industries, including early warnings to prevent costly failures, reduced maintenance costs through condition-based strategies, enhanced operational efficiency by optimizing machine performance, and data-driven decision-making. These benefits make anomaly detection essential for SMEs striving to digitize and implement lean manufacturing, helping to streamline production and stay competitive.

Key tools used in anomaly detection include sensor technology, which monitors parameters like vibration, pressure, and temperature in real-time, enabling early issue identification. IoT devices collect and transmit this sensor data to cloud platforms, where it is stored and analyzed. Cloud computing enhances the capacity for processing large datasets and enables real-time insights.

Industrially, anomaly detection has broad applications. In manufacturing, it ensures continuous operation by identifying faults on production lines early. In the energy sector, it boosts system performance and reduces losses, particularly in renewable energy setups. In transportation, monitoring critical vehicle components enhances safety and minimizes maintenance costs by addressing issues proactively, such as detecting engine anomalies in aviation and rail systems.

3.4.1. Anomaly Analysis of Data from Milling Machines

The purpose of this study was to ascertain the correlations between different sensor data obtained from the milling machine in the factory setting. Temperature (Temp), noise levels (Noise), voltage measurements (Voltage1, Voltage2, Voltage3), and current measurements (Current1, Current2, Current3) were all included in the data. I ran regression analyses, both bivariate and multivariate, on each of these variables to find the strength of the associations and look for any anomalies.

Following the regression analysis, a number of noteworthy correlations with R-squared values greater than 90%, which suggests a strong correlation are found. The variables with the greatest R-squared values in both the bivariate and multivariate analyses are highlighted in the following sections, which provide an overview of the regression analysis's results.

Combining Current1, Voltage1, and Temperature results in an R-square value of 94%, which shows a very strong link. The results of this investigation demonstrate the strong combined impacts of Voltage1 and Current1 on Temperature. Specifically, the majority of the temperature variability may be explained by changes in Current1 and Voltage1 combined.

An R-squared value of 93% was found when the three variables—current, voltage, and noise—were analyzed together, indicating a great degree of interdependence. This demonstrates how adjustments to Current2 and Voltage2 together have a major impact on the machine's noise levels.

The R-square value for the four-variable regression analysis attained 95% for Current, Voltage, Temperature, and Noise. This demonstrates how these four factors work together to produce a very potent combined effect that fully explains the behavior of the machine. In particular, almost all of the system's variability can be explained by the interaction of Current, Voltage, Temperature, and Noise, demonstrating the intricate relationships and interdependencies among these variables.

The milling machine's sensor data showed numerous robust correlations between variables when subjected to regression analysis. Strong correlations were shown by the high R-squared values of the current and voltage pairs (Current1-Voltage1, Current2-Voltage2, and Current3-Voltage3). Furthermore, there was a noteworthy correlation between noise and temperature. These results demonstrate that keeping an eye on these variables might yield useful insights into the machine's operation and facilitate the identification of irregularities.

Even greater connections were shown by additional research, including multivariate regression, suggesting intricate interdependencies between several parameters. The R-squared value of the four-variable model (Current3, Voltage3, Temperature, and Noise) was 95%, whereas the combined effects of Current1, Voltage1, and Temperature had an R-squared value of 94%.

This thorough analysis emphasizes how crucial it is to comprehend how various machine characteristics are interdependent in order to guarantee predictive maintenance and effective manufacturing procedures. By making use of this data, we can raise overall productivity, decrease downtime, and enhance the milling machine's performance and dependability.

3.5. Optimization of Worker Distribution in Case of Simultaneous Operation of Three Machines SOCT Study

Standard Operation Combination Table (SOCT) is a tool that shows the sequence and duration of operations in a business process. This table is used to determine the operators' work procedure and perform work in an orderly manner.

3.5.1 Definition and Purpose

SOCT shows the order of workstations on a production line and the job times at each station. Its aim is to optimize work, increase efficiency and reduce waste in the process. Elements:

- Workstations: Represent each step in the production line.
- Work Times: Refers to the time spent at each workstation.
- Work Order: Determines the order of workstations.

3.5.2 How to Create?

- Workstations and times are determined.
- Workstations are listed in order.
- The work time of each station is added to the table.

3.5.3 Benefits

- It makes things neat and repeatable.
- Clarifies the order of workstations.
- Visually displays job times.

3.5.4 Why is SOCT important?

Standard Operation Combination Table (SOCT) is a tool that shows the sequence and duration of operations in a business process. The importance of SOKT is as follows:

- Orderliness and Repeatability: SOKT makes things orderly and repeatable. It clarifies the order of workstations and allows operators to follow the procedure for doing work.
- Productivity Increase: Reduces unnecessary waiting times by visually displaying work times. This increases efficiency.
- Waste Reduction: SOKT optimizes transitions between workstations. In this way, it reduces waste in business processes.
- Basic Tool for Continuous Improvement: SOKT is frequently used in lean production and continuous improvement approaches. It plays an important role in the House of Toyota and is an essential tool for continuous improvement.

3.5.5. How is SOCT prepared?

Standard Operations Combination Table (SOCT) is a tool used to manage business processes more effectively and efficiently. Here are some steps on how to use SOKT:

- Define Business Processes: First, define business processes and operations. This is important to understand what type of work employees do and what steps they follow.

- List Business Steps: List the steps of each business process. This should include all stages from the beginning to the end of the job.
- Time and Sequence Arrangement: Arrange job steps according to takt time. Takt time determines how long it takes to complete the job. Sort the tasks according to this time period.

3.6. SOCT: A Real Case

The three main machines in our production process are designed to produce specific products. The workforce structure, which was initially arranged with one worker per machine, is planned to be optimized according to the working hours of the machines. This optimization aims to increase production efficiency by minimizing wasted time of workers.

- Working Times and Labor Requirements of Machines:
  - First Machine: Produces white cover and red apparatus. For the white cover, 35 seconds of processing time and 20 seconds of labor time are required, and for the red apparatus, 44 seconds of processing time and 13 seconds of labor time are required.
  - Second Machine: Produces red cover and transparent apparatus. A processing time of 35 seconds is required for the red cap and 27 seconds for the transparent apparatus. For the red cover, 35 seconds of processing time and 15 seconds of labor time are required, and for the transparent apparatus, 27 seconds of processing time and 8 seconds of labor time are required.
  - Third Machine: It produces white caps in a different function and requires 39 seconds of processing time and 10 seconds of labor.

This dynamic worker guidance system aims to reduce idle time and maximize labor efficiency. This ensures that each worker moves between machines efficiently, ensuring a continuous production flow and saving labor costs.
The three main machines in our production process are optimized for the production of different semi-finished products. Four different production scenarios were defined in this process, each containing various combinations of semi-finished products. These scenarios are planned in detail with the aim of increasing production capacity and worker productivity.

- Scenario 1
  - First Machine:
    - First, the work of the white cover begins. Once the workmanship is completed, processing time begins.
    - As soon as the processing time begins, the worker moves to the third machine and starts working on the white cover.
    - After the workmanship on the third machine is completed, the worker moves to the second machine and starts the workmanship of the red cap.
  - Second Machine:
    - Once the crafting of the red cover is completed, the processing time begins. Meanwhile, the worker returns to the first machine and starts work on the second product.
  - Third Machine:
    - After the white cover work is completed, the processing time begins. During this period, the worker waits for five seconds and continues work again.

Thanks to this dynamic worker orientation, a continuous workflow between machines is ensured and machine capacities are optimized as follows:

- First Machine: It operates with 100% efficiency.
- Second Machine: It operates with 50% efficiency and continues production with 15-second waits.
- Third Machine: It operates with 75% efficiency.

With this strategy, the number of operators was reduced from three to one, resulting in a 200% more profitable production process. The transfer of workers between machines has increased the continuity and efficiency of the production process while minimizing idle time.

- Scenario 2
  - Worker Orientation Plan:
    - Second Machine: The crafting process starts with the red cover. After the labor is completed, the worker moves to the first machine.
    - First Machine: The worker starts crafting the red apparatus here. When the labor is completed, the worker moves to the third machine.
    - Third Machine: Labor is done for the white cover. After the labor is completed, the worker moves to the second machine again.
  - Machine Efficiency:
    - First Machine: 100% efficiency is achieved with this strategy.
    - Second and Third Machine: Both machines operate at 50% efficiency. This is due to the loss of time in worker transitions.
  - Optimization and Number of Workers:
    - With this method, a 200% profit increase is achieved by reducing the number of workers from three to one. However, considering worker transition times and waiting times, adding a second worker can increase machine efficiency and shorten overall production time, especially during peak production hours or when machine capacities must be fully utilized.
- Scenario 3
  - Worker Orientation and Machine Working Plan:
    - First Machine: The crafting process starts with the white cover. Once the labor is completed, processing time begins. The worker moves to the second machine during this period.
    - Second Machine: Worker begins crafting for the transparent apparatus. When the workmanship is completed, the processing time of the white cover begins. The worker moves to the third machine during this period.
    - Third Machine: Labor is done for the white cover. After the labor is completed, the worker moves to the first machine again and starts labor for the second product. During this time, there is a 15-second wait on the second machine and a 5-second wait on the third machine.
  - Machine Efficiency and Labor Optimization:
    - First Machine: It operates with 100% efficiency.
    - Second Machine: It operates with 25% efficiency, but efficiency decreases when waiting time is taken into account.
    - Third Machine: It operates at 50% efficiency.
  - Number of Operators and Profitability Analysis:
    - By reducing the number of workers from three to one, a 200% profit increase was achieved. However, machine waiting times and worker transition times are factors that affect overall productivity.
- Scenario 4
  - Worker Orientation and Machine Working Plan:
    - Second Machine: The worker starts with the transparent apparatus. Once the workmanship is completed, the transparent apparatus processing time begins. The worker moves to the first machine during this time.
    - First Machine: The crafting process begins for the red apparatus. Once the labor is completed, processing time begins. The worker moves to the third machine during this period.
    - Third Machine: Labor is done for the white cover. After the labor is completed, the worker moves to the second machine again and starts labor for the second product. During this

time, there is a 15-second wait on the second machine and a 5-second wait on the third machine.

- Machine Efficiency and Labor Optimization:
  - First Machine: It operates with 100% efficiency.
  - Second Machine: It operates with 25% efficiency, but efficiency decreases when waiting time is taken into account.
  - Third Machine: It operates with 50% efficiency.
- Number of Operators and Profitability Analysis:
  - By reducing the number of workers from three to one, a 200% profit increase was achieved. However, machine waiting times and worker transition times are factors that affect overall productivity.

Conclusion

This project aims to provide business package services to SMEs using lean production and digital technologies. While lean production increases efficiency by eliminating waste, digital technologies increase the traceability and controllability of processes. This combination allows businesses to reduce their costs, increase their competitiveness and ensure customer satisfaction. The project aims to provide infrastructure and knowledge that will help SMEs achieve sustainable growth and competitive advantage. The project includes four product packages:

- **Work Package 1**: This study aims to optimize worker distribution in a production process where three machines operate simultaneously. Work stations and work times were determined using the Standard Operation Combination Table (SOCT), ensuring that workers acted efficiently. Four scenarios were examined and worker transitions and machine efficiencies were analyzed for each. The results showed that a 200% increase in profitability was achieved by reducing the number of workers from three to one. However, worker transition times and waiting times affect overall productivity. This study highlights the importance of dynamic worker guidance system to increase the continuity and efficiency of the production process.

- **Work Package 2:** The regression analysis of the milling machine's sensor data revealed strong correlations between various variables. High R-squared values between current and voltage pairs (Current1-Voltage1, Current2-Voltage2, Current3-Voltage3) and between noise and temperature indicate robust relationships. These insights are crucial for understanding the machine's operation and for identifying anomalies. Further multivariate regression analysis suggests even greater connections, emphasizing the complex interdependencies between multiple parameters. This comprehensive analysis highlights the importance of understanding these interdependencies for predictive maintenance and efficient manufacturing processes. By leveraging this data, we can enhance overall productivity, reduce downtime, and improve the performance and reliability of the milling machine.

- **Work Package 3:** Automation is increasingly used to increase efficiency and ensure operational excellence in modern manufacturing environments. In this context, businesses can constantly monitor the status of their machines by extracting data from devices via sensors. Anomaly detection is the process of finding unexpected, abnormal, or undesirable deviations in collected data and is used to predict costly failures, system problems, and mechanical errors. Sensor technology, IoT, cloud computing, and tools like Node-RED make anomaly detection more effective and efficient. This technology can be applied in many sectors such as production, energy and transportation, providing early warning, reducing maintenance costs and increasing operational efficiency.

- **Work Package 4:** In the project, we are developing a work package aimed at assessing the digital maturity levels of small and medium-sized businesses (SMEs). This work package aims to measure the digital competencies of businesses with a survey method covering various areas such as organizational structure, customer management, product development, production management, warehouse and supply, information technologies, maintenance and quality unit. Based on the survey results, the current digital maturity levels of SMEs will be determined and areas that need improvement will be identified and digital transformation strategies will be proposed. This project aims to contribute to SMEs gaining competitive advantage in the digital world and their long-term success.

The integration of digital transformation and lean production principles increases the efficiency of SMEs, reduces their costs and ensures customer satisfaction. In this context, providing work package services to SME's helps them have efficient and flexible production processes equipped with digital technologies.
Further research could explore investigating more sophisticated machine learning models or artificial intelligence algorithms to predict and prevent machine failures, using the data collected from sensors from the perspective of advanced data analytics and predictive maintenance. Moreover, analyzing how human workers and automated systems can collaborate more efficiently in lean environments, especially in dynamic production settings by considering human-machine collaboration in Lean Manufacturing are another one. A longitudinal study on how the digital maturity of SMEs evolves over time and its impact on their competitiveness in the global market can be thought also as new subject again in this area.

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