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المجلة العلمية لنشر البحوث
S . J . R . P

“Enhancing Manufacturing Efficiency through Industrial Engineering”

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Abstract

Production and Industrial Engineering spans a large swath of time in the development of technology and engineering. Whether you're in the manufacturing or service industries, staying competitive today requires ongoing innovation. Output waste, encompassing factors such as insufficient output volume relative to the intended target, arises as a consequence of industry-related downtime and delays. The implementation of a Lean manufacturing approach has the potential to mitigate production waste such as the one described. The industrial setting of the study is represented by the Metals and Alloys sector. The research findings indicate that delay time emerged as the predominant cause of production waste. In order to mitigate manufacturing waste, a more effective maintenance program is being formulated. Current manufacturing cycle efficiency is at 66.08%, while future manufacturing cycle efficiency is expected to be around 71.3%. This means that the suggested improvement plan has the potential to boost manufacturing cycle efficiency by 3.22 percentage points.

ملخص

يغطي الإنتاج والهندسة الصناعية مساحة كبيرة من الوقت في تطوير التكنولوجيا والهندسة. سواء كنت تعمل في مجال التصنيع أو الخدمات، فإن الحفاظ على القدرة التنافسية اليوم يتطلب ابتكارًا مستمرًا. ينشأ هدر المخرجات، الذي يشمل عوامل مثل عدم كفاية حجم الإنتاج مقارنة بالهدف المقصود، نتيجة لوقت التوقف عن العمل والتأخير المتعلق بالصناعة. إن تنفيذ نهج التصنيع الخالي من الهدر لديه القدرة على تخفيف هدر الإنتاج مثل ذلك الموصوف. يتمثل الإطار الصناعي للدراسة في قطاع المعادن والسبائك. وتشير نتائج البحث إلى أن وقت التأخير ظهر باعتباره السبب الرئيسي لمخلفات الإنتاج. ومن أجل التخفيف من مخلفات التصنيع، تتم صياغة برنامج صيانة أكثر فعالية. وتبلغ كفاءة دورة التصنيع الحالية 66.08%، بينما من المتوقع أن تصل كفاءة دورة التصنيع المستقبلية إلى حوالي 71.3%. وهذا يعني أن خطة التحسين المقترحة لديها القدرة على تعزيز كفاءة دورة التصنيع بنسبة 3.22 نقطة مئوية.

Introduction

Those businesses that wish to flourish in a more intricate economic environment and preserve their competitive edge must prioritize the pursuit of manufacturing excellence in today's intensely competitive global marketplace. This objective extends beyond ordinary production to encompass the optimization of processes, the reduction of expenses, the improvement of product quality, and the maximization of overall operational efficiency. The discipline of industrial engineering, which is devoted to accomplishing these specific goals, arises as a critical success factor for manufacturers in a variety of industries.

Utilizing scientific principles, data analysis, and systematic methodologies to enhance the design and execution of processes in manufacturing and production environments constitutes the fundamental premise of industrial engineering (Harika et al., 2021). By examining all aspects of operations, including production lines, supply chains, and more, industrial engineering seeks to identify inefficiencies, reduce bottlenecks, streamline workflows, and improve the utilization of both material and human resources. The ultimate objective is to increase productivity, reduce waste, and optimize resource allocation, all of which are essential for sustaining competitiveness and sustainability.

Industrial engineers work to increase production and efficiency in a wide range of businesses. Designing, optimizing, and leading complex systems, processes, and organizations is the focus. Industrial engineers are professionals who apply their expertise in technology to improve efficiency, cut costs, and boost productivity. The evolution of industrial engineering and its foundational ideas, as well as its current and potential future uses, will be discussed. Manufacturing and production methods advanced greatly throughout the Industrial Revolution in the 18th century, marking the beginning of industrial engineering. However, industrial engineering as a distinct field didn't emerge until the early 20th century. Often credited as the "father of scientific management," Frederick Winslow Taylor was an early proponent of using empirical research to enhance organizational performance. The techniques of contemporary industrial engineering can be traced back to Taylor's guiding ideas (Kambhampati, 2017).

The field of industrial engineering studies and applies numerous theories, methods, and tools to improve operational efficiency. Industrial engineers see businesses as complex systems, with many interrelated parts that all affect performance in some way. They can make significant efficiency benefits by studying and enhancing the system as a whole. Industrial engineers work to improve systems and procedures by removing waste, inefficiencies, and bottlenecks. To identify the best answers, they employ mathematical modeling, simulation software, and statistical analysis. To ensure that jobs, tools, and work environments are optimal for human performance and well-being, industrial engineers take human aspects into account at every stage of the design and operation of a system. This encompasses concerns like security, convenience, and efficiency.

Industrial engineers aim to enhance the efficiency and effectiveness of processes and systems by the identification and elimination of inefficiencies, bottlenecks, and waste. Mathematical models, modelling tools, and statistical analysis are employed in order to identify the most optimal solutions (Goshime et al., 2019). Industrial engineers are professionals who focus on enhancing efficiency by effectively managing both human resources and business processes. In addition, organizations develop management control systems to facilitate financial planning, cost analysis, production planning, and the logistical distribution of goods and services.

1. Research Problem

The manufacturing industry faces ongoing challenges related to efficiency, cost-effectiveness, and productivity. Inefficient processes, suboptimal resource allocation, and inadequate utilization of technology often lead to increased production costs and reduced competitiveness. The research problem addressed in this study is how to enhance manufacturing efficiency through the systematic application of Value stream mapping (VSM) which is one of lean tools.

2. Research Objectives

1. To determine the most significant obstacle in the current manufacturing processes.
2. To develop and implement innovative industrial engineering solution to optimize manufacturing processes.
3. To assess the impact of the proposed solution on manufacturing efficiency.

3. Research Significance

This research is significant because it has the potential to effect profound changes in the manufacturing sector. In the current extremely competitive global marketplace, manufacturing efficiency is of the utmost importance for the survival and profitability of businesses. This research can significantly improve manufacturing processes by identifying and implementing innovative industrial engineering solutions, resulting in decreased production costs, increased productivity, and enhanced product quality. Not only do these enhancements benefit specific manufacturing firms, but they also have broader economic and environmental consequences. By optimizing resource utilization and minimizing waste generation, the research's findings may cause job creation, economic growth, and sustainability. As a result of the study's contribution to the academic comprehension of industrial engineering principles and their application in manufacturing, the field may experience further development. In conclusion, the significance of the research extends beyond the manufacturing industry, influencing economic growth, environmental sustainability, and the advancement of industrial engineering knowledge.

4. Definition of key terms

Manufacturing Efficiency: It refers to the quantification of the degree to which resources, including labor, materials, and time, are utilized in the production of goods or services (Reisgen et al., 2020).

Industrial Engineering: Industrial engineering is a specialized field within engineering that concentrates on the enhancement of intricate systems and processes, encompassing manufacturing, with the objective of augmenting efficiency, productivity, and quality (Sackey & Bester, 2016).

Literature Review

1. Industrial engineering

Industrial engineering is a broad field of study that concentrates on enhancing the efficiency, productivity, quality, and overall performance of organizations, systems, and processes. It integrates management, mathematics, and engineering principles to develop and execute integrated solutions for a broad spectrum of industries.

1.1. History of Industrial engineering

The historical origins of industrial engineering can be attributed to the period of the Industrial Revolution, which occurred throughout the late 18th and early 19th centuries. The process of industrialization was rapidly altering the methods and systems employed in manufacturing and production throughout this era of significant change. Industrial engineering emerged as a response to the imperative for more methodical and efficient approaches to manage the newly mechanized enterprises.

One of the pivotal figures in the early history of industrial engineering was Frederick W. Taylor. Taylor is often regarded as the "father of scientific management." In the early 20th century, he introduced the concept of scientific management, which emphasized the application of scientific methods to analyze and optimize work processes. Taylor's time and motion studies sought to identify the most efficient ways for workers to perform tasks, leading to significant improvements in productivity and efficiency (Hazarika et al., 2019). Another key contributor to industrial engineering was Frank and Lillian Gilbreth. They expanded upon Taylor's work by introducing motion study techniques and developing time-saving innovations, such as the assembly line, which revolutionized manufacturing.

Industrial engineering acquired further prominence during World Wars I and II as it played a crucial role in optimizing production processes for wartime manufacturing. Contributing to the war effort, industrial engineers were instrumental in streamlining the production of armaments, equipment, and supplies.

Incorporating principles from disciplines such as human factors engineering, computer science, operations research, and quality management, industrial engineering continued to develop in the post-war period. The discipline expanded to incorporate numerous industries, including healthcare, logistics, finance, and services, in addition to manufacturing.

Presently, industrial engineering continues to be at the vanguard of efforts to enhance productivity, quality, and efficiency in intricate systems and organizations. Its history is characterized by an ongoing pursuit of innovation and optimization, adjusting to the evolving requirements of industries and societies (Baudin & Netland, 2022).

1.2. Core principles of Industrial engineering

Industrial engineering is governed by a set of fundamental principles that serve as the basis for its optimization of intricate systems, processes, and organizations. In numerous industries, these principles are crucial for attaining efficiency, productivity, and overall excellence.

- Systematic Approach

It is a fundamental principle of industrial engineering to employ a structured and methodical approach to problem-solving. Industrial engineers meticulously examine and model processes in order to acquire a thorough comprehension of their operation and potential for enhancement. This methodical strategy guarantees that solutions are founded on data, analysis, and a thorough comprehension of the system's constituent parts.

- Efficiency

The fundamental principle of industrial engineering is efficiency. The objective of industrial engineers is to maximize resource utilization while minimizing waste and lowering expenses. This involves optimizing processes, removing bottlenecks, and discovering methods to accomplish more with fewer resources. Enhancements in productivity and competitiveness are fueled by efficiency (Sackey et al., 2017).

- Quality

Ensuring high-quality and consistent output is an additional fundamental principle of industrial engineering. Industrial engineers develop and execute quality control procedures in order to minimize defects, errors, and variations. In addition to increasing customer satisfaction, quality management reduces waste and revisions, resulting in cost savings.

- Resource Optimization

Industrial engineers are adept at optimizing the allocation of time, labor, materials, and apparatus, among other resources. They strive to accomplish the desired results in an efficient manner by balancing the use of resources. Resource optimization is essential for achieving production objectives and effectively managing costs (Sackey & Bester, 2016).

- Continuous Improvement

Continuous improvement is an entrenched concept in industrial engineering. Embracing a culture of continuous improvement, industrial engineers seek to incrementally enhance processes, products, and systems. Utilizing methodologies such as Lean, Six Sigma, and Total Quality Management (TQM), inefficiencies are continuously identified and eliminated.

- Data-Driven Decision-Making

Industrial engineers make well-informed decisions by utilizing data and analysis. They gather, analyze, and interpret data in order to detect patterns, trends, and opportunities for enhancement. Decision-making that is driven by data guarantees that modifications are founded on evidence and quantifiable outcomes.

- Sustainability

Sustainability has emerged as a fundamental principle in contemporary industrial engineering. The objective of industrial engineers is to create and implement sustainable practices that minimize resource consumption, reduce environmental impact, and promote eco-friendly manufacturing processes. These practices are not only socially responsible but also consistent with long-term economic interests (Manavalan & Jayakrishna, 2019).

Collectively, these fundamental principles of industrial engineering direct the profession's pursuit of productivity, quality, and continuous improvement. In today's dynamic and swiftly changing environment, industrial engineers utilize these principles to develop and execute solutions that improve overall success, competitiveness, and performance in various industries, including healthcare, logistics, manufacturing, and services.

1.3. Applications of Industrial Engineering

Industrial engineering offers solutions to optimize processes, increase efficiency, and enhance overall performance across a broad spectrum of industries. Key implementations of industrial engineering in various industries include the following:

- Manufacturing: In the manufacturing sector, industrial engineering is of critical importance in optimizing production processes. Industrial engineers are responsible for enhancing quality control measures, decreasing waste, and optimizing workflow efficiency. To streamline manufacturing operations, they design layouts, devise production schedules, and implement automation and robotics (Dhiman & Kumar, 2019).
- Supply Chain Management: In the field of supply chain management, industrial engineers concentrate on inventory management, distribution networks, and logistics optimisation. Enhancing the flow of products from

suppliers to customers, minimizing transportation costs, and decreasing lead times are their primary objectives. Effective supply chain management is essential for cost reduction and satisfying consumer demands.

- Healthcare: Systems of healthcare have been substantially impacted by industrial engineering. Industrial engineers assist healthcare facilities and hospitals in optimizing patient flow, decreasing wait times, and improving resource allocation. They utilize data analysis to enhance hospital workflows, thereby guaranteeing timely and effective patient care.
- Quality Control: Product and service quality assurance is a fundamental industrial engineering application. Industrial engineers execute quality control procedures, perform statistical analysis to identify flaws, and devise strategies to minimize errors and variations. They strive to ensure quality standards are met and to increase customer satisfaction (Godina & Matias, 2019).
- Energy Management: In industries with high energy consumption, industrial engineers develop solutions that conserve energy. They assess patterns of energy consumption, suggest energy-efficient technologies, and devise methods for mitigating environmental impact.

1.4. Tools used in Industrial Engineering

Industrial engineers analyse, design, and optimize processes, systems, and organizations by employing a wide range of instruments and methods. These instruments enable them to increase productivity, decrease waste, improve quality, and make well-informed decisions. The following are standard instruments and procedures employed in industrial engineering:

- Value Stream Mapping (VSM)

VSM is an instrument utilized in lean manufacturing to map the entire value chain, from raw materials to the final consumer. The process is streamlined and non-value-added activities are identified (Kumar & Shankar, 2019).

- Six Sigma and DMAIC

Six Sigma is a methodology designed to decrease manufacturing process defects and variations. Within Six Sigma, DMAIC is a structured approach to problem-solving that assists in identifying enhancement opportunities and implementing solutions (Swarnakar & Vinodh, 2016).

- Kaizen and Continuous Improvement

Continuous improvement, or Kaizen, is a Japanese concept that promotes the incremental and ongoing refinement of processes, products, or services. All employees are involved in the process of identifying and implementing enhancements.

- Total Quality Management (TQM)

TQM is an all-encompassing methodology that emphasises employee participation in quality enhancement initiatives. Utilizing instruments such as quality circles and benchmarking, it promotes ongoing improvement.

2. The key challenges in manufacturing processes

The identification of the key challenges within contemporary manufacturing processes is crucial in order to facilitate enhancements in both efficiency and productivity. The manufacturing industry, being a multifaceted and ever-evolving domain, encounters a plethora of obstacles that necessitate meticulous scrutiny and evaluation.

- Supply Chain Disruptions

A significant issue faced in the industrial industry is to the susceptibility of supply chains to disruptions. Various factors, such as natural calamities, political volatility, or unanticipated material scarcities, possess the capacity to substantially impede production timetables and result in considerable delays.

- Resource Constraints

Manufacturers frequently face obstacles pertaining to the accessibility and expenditure of resources, encompassing essential components, energy sources, and proficient workforce. The impact of pricing fluctuations and resource shortages on production costs and capacity can be significant (Kannan et al., 2022).

- Complex Regulatory Compliance

Manufacturing processes are subject to a multitude of rules, encompassing a wide range of aspects such as environmental norms, safety protocols, and quality criteria. Manufacturers often face significant challenges in keeping pace with the dynamic nature of regulatory frameworks and ensuring adherence to compliance requirements.

- Workforce Skills Gap

The presence of a proficient and driven labor force is crucial for achieving success in the manufacturing industry. Manufacturers frequently encounter obstacles pertaining to a scarcity of proficient laborers, the necessity for continuous training, and the preservation of a secure and efficient work milieu.

- Quality Control and Variability

Ensuring a consistent level of product quality is of utmost importance. The management of product variability, defect minimization, and the effectiveness and efficiency of quality control operations provide significant challenges (Illés et al., 2017).

- Cost Pressures

The current global manufacturing industry is characterized by intense competition, wherein producers often encounter significant demands to decrease their production expenses. The perpetual challenge lies in achieving a delicate equilibrium between cost reduction and the preservation of quality and efficiency.

- Production Complexities

The complexity of manufacturing processes has witnessed a notable increase, characterized by the presence of several sequential steps, interdependencies, and a wide range of variables. The intricate nature of this complexity may give rise to bottlenecks, resulting in production delays and challenges in effectively controlling the entire process (Arinez et al., 2020).
The initial phase in formulating effective strategies and solutions involves the identification and comprehension of the primary issues present in contemporary manufacturing processes. In order to maintain competitiveness within a dynamic sector, manufacturers are required to adapt, innovate, and consistently enhance their operational processes.

3. Importance of enhancing manufacturing efficiency

Improving production efficiency is of utmost significance in the contemporary industrial environment characterized by intense competition and rapid evolution. The significance of this matter is supported by a number of crucial factors:

- Cost Reduction and Competitiveness

Enhanced manufacturing efficiency results in a direct decrease in production expenses. By optimizing resource allocation, minimizing waste, and refining processes, manufacturers can offer products at competitive prices. Production that is economical is crucial for obtaining a competitive edge in the global marketplace.

- Increased Productivity and Output

Productivity increases as a consequence of increased efficiency, enabling manufacturers to produce more with the same or fewer resources. This increased output capacity is essential for expanding market share and satisfying rising consumer demand (Haq et al., 2022).

- Quality Improvement

Efficient processes frequently result in improved product consistency and quality. Decreased errors and variability result in fewer defects, reduced rejection rates, and increased customer satisfaction. Maintaining product quality is crucial for the reputation of a brand and for retaining customers.

- Global Supply Chain Resilience

Increased manufacturing efficiency can contribute to a supply chain that is more resilient and agile. In addition to reducing the lead time necessary for manufacturing, efficient production processes enable manufacturers to respond more effectively to supply chain disruptions, such as those caused by natural disasters or geopolitical events (Song et al., 2022).
Enhancing manufacturing efficiency is a fundamental requirement for manufacturers who wish to maintain competitiveness, lower expenses, fulfill their environmental obligations, and adapt to the ever-changing demands of the global market. Economic expansion, technological progress, and long-term sustainability in the manufacturing sector are all possible outcomes.

4. Previous studies

According to (Salah & Sobhi, 2018) numerous organizations are currently interested in employing a lean manufacturing strategy that will allow them to compete in this market characterized by globalization. The elimination of all types of waste is the primary objective of lean production philosophy, which is adopted by both industrial and food industrial organizations. Reducing process time and identifying all types of production line defects are crucial for increasing productivity, particularly in mass production businesses. The purpose of this paper is to implement lean production tools in a food industry mass production company in order to decrease the most significant types of waste and boost the company's productivity. Collecting qualitative data on the major types of waste in the production line, analyzing those data to identify the underlying causes of the major wastes in all production line processes, and attempting to eradicate them in order to increase productivity is the primary focus of this paper. Results indicate that the implementation of certain lean tools in the organization, such as routine maintenance, correction, adjustment, and repair, with the available resources and at no additional cost has a significant impact on increasing machine availability, total productivity, and net profit.
To the study of (Gebeyehu et al., 2022) some sectors' ability to compete globally has been greatly aided by adopting lean manufacturing (LM) principles and tools. The focus of this article is on implementing lean theory, methodology, and equipment in Ethiopia's Hibret Manufacturing & Machine Building Industries (HMMBI). This study focuses primarily on lengthy manufacturing lead times since they provide a fundamental challenge for HMBI. The primary objective of this research is to shorten the manufacturing lead time by cutting back on the non-value-adding tasks connected to using a number of resources. Quantitative and qualitative approaches are employed to gather information. Value Stream Mapping and the Spaghetti Diagram are used to analyze the process time and physical space to locate

inefficiencies. Production lead time, WIP, non-value adding time (waiting time), and total distance traveled are all shown to decrease by 23.66 percent, 8.6 percent, 37.74 percent, and 61.22 percent, respectively. Ultimately, a 25.59 percent increase in process cycle efficiency is achieved. For the Hibret Manufacturing & Machine Building Industries (HMMBI) and others like it, the study's findings hold a lot of weight.

To study of (Ketan & Yasir, 2015) numerous organizations are currently interested in employing lean manufacturing principles, which should enable them to reduce manufacturing lead times and eliminate waste. This document focuses on enhancing the company's competitiveness in globalized markets and enhancing productivity through the reduction of manufacturing lead time. In order to accomplish this, the primary instrument of lean manufacturing, value stream mapping (VSM), will be utilized to identify all manufacturing process activities, including both value-added and non-value-added activities. Additionally, waste elimination will be reduced by converting a manufacturing system to pull rather than push by implementing pull system strategies such as kanban and first on first out lane (FIFO). In order to simulate the present and future state, ARENA software is utilized. In Baghdad, this activity is carried out by the state-owned electrical industry company. The application yielded results indicating that the implementation of lean principles contributed to a 33% reduction in manufacturing lead time.

According to (Lira-Aquino et al., 2021) due to its substantial contribution to GDP, footwear production is among Peru's most vital industrial sectors. In fact, competition in this market is fierce due to shoppers' insistence on ever-increasing quality standards at ever-lower rates. Therefore, businesses must consistently enhance their procedures to speed up production, enhance quality, and reduce costs. According to reports, low production processes are a major challenge for SMEs in Peru, where the national efficiency rate is estimated to be 46%. The primary issue at hand for the Lima-based micro footwear company studied in this research is subpar manufacturing procedures, which are addressed by implementing Lean Manufacturing tools including 5S, Work Standardization, Kanban, and TPM (Total Productive Maintenance). The Arena Simulation program will be used to verify this model. The outcome is a rise in productivity of between 55% and 87%. Also, there was a 68% decrease in the duration of the cycles. and orders were fulfilled 98% of the time.

Method

1. Lean Manufacturing

The principles of lean are rooted in the ideology of perpetual enhancement and prioritization of customer satisfaction. These principles can be succinctly encapsulated as follows: delineating value from the customer's standpoint, discerning the value stream and eradicating inefficiencies, facilitating the seamless and uninterrupted flow of value, instituting pull systems to prevent excessive production, and striving for perfection through the elimination of variation. Industrial engineers have the capability to effectively apply these fundamental concepts to various processes or systems, encompassing production, service, and administration domains. One potential strategy that individuals might employ is a methodical approach, such as the plan-do-check-act cycle, in order to effectively strategize, implement, evaluate, and adapt their activities as needed.

By integrating lean principles into their operations, industrial engineers can attain a multitude of benefits, including increased profitability and cost reduction, enhanced quality and customer satisfaction, heightened productivity and efficiency, improved employee engagement and morale, increased innovation and creativity, and enhanced environmental and social responsibility.

2. Value Stream Mapping (VSM)

Companies in today's fast-paced, competitive market are always looking to improve their operations by eliminating inefficiencies and maximizing productivity. Value Stream Mapping (VSM) is a powerful technique that has evolved to meet these difficulties head-on. Originally established as part of the Toyota Production System, VSM is a visual management tool and foundational principle of lean manufacturing.

Value Stream Mapping (VSM) is, at its essence, a methodical and comprehensive strategy for comprehending, evaluating, and enhancing the movement of resources, data, and operations within a given institution. It offers a lucid, graphical depiction of a comprehensive production process, delivery of services, or any activity that contributes value. Through the systematic delineation of each stage within a value stream—from the instant a customer initiates an order until the ultimate delivery of the product or service—VSM provides an all-encompassing perspective on the present condition of operations.

Waste in the form of overproduction, excess inventory, wasteful transportation, waiting periods, and defects is the primary focus of Value Stream Mapping. This helps businesses save money, work more efficiently, produce higher-quality products, and provide better service to their customers.

The purpose of this research is to apply lessons learned from lean manufacturing to hot strip mill production in the Metals and Alloys sector, with the hope of increasing output per unit of input. Information about production can be derived from an observation, such as the number of workers, their shift schedules, the quantity of raw materials, the status of work in progress, the availability of finished goods, the number of workstations, the flow rate, and the total amount of time spent on production. The information is then used to calculate the value added time, non-value added time, inventory lead time, process lead time, and production cycle efficiency. A VSM is used to analyse the current situation of six major categories of production waste: overproduction, motion waste, transportation waste, processing waste, waiting/delay waste, defect inventory, and inventory waste. The study pinpoints the most common form of trash produced during the production process. Several potential causes of production waste are examined in order to determine their combined impact. A factory-improvement plan and a VSM road map for the future are developed to reduce waste. The effectiveness of the program is measured by the manufacturing efficiency indicator.

Result and Discussion

It is possible to increase efficiency through waste reduction, quality enhancement, workflow streamlining, and performance enhancement. Industrial engineers can measure and enhance efficiency through the use of a variety of instruments and methods, including key performance indicators, benchmarking, standard work, and continuous improvement. Production processes are optimized, cycle times are decreased, waste is minimized, and overall productivity is increased. By implementing the principles of lean manufacturing, industrial engineers assist businesses in achieving substantial cost savings and enhanced competitiveness.

The figure provided in Figure 1 illustrates that the duration of value-added activities in hot strip mill manufacturing.

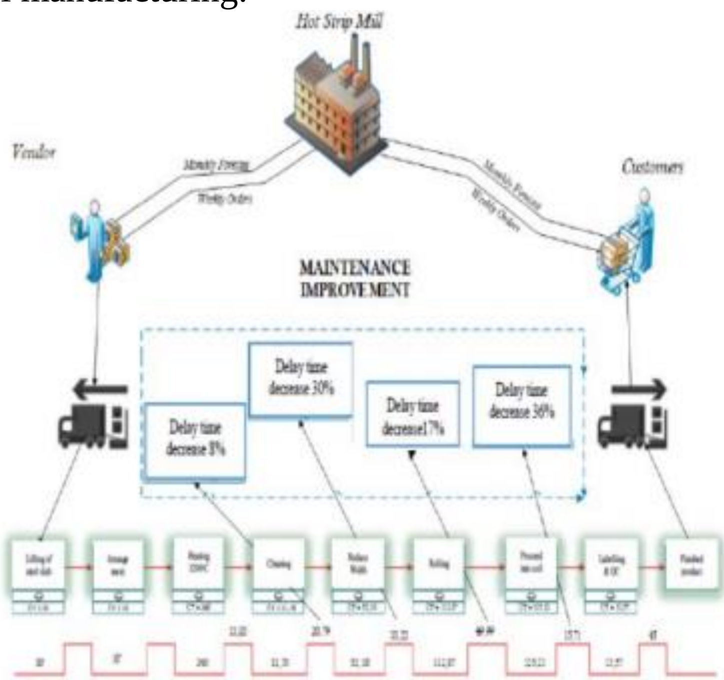

Figure (1): The current state of value stream mapping (VSM)

Value-added procedures include heating the slab, cleaning using a chemical reaction, thinning it down, rolling it out, cutting it to size, and labelling it. Meanwhile, production processes such as retrieving slabs from the warehouse and transporting them to the reheating furnace, arranging slabs before they enter the reheating furnace, transporting slabs to the water dis-caller, transporting slabs to the sizing press, transporting slabs to the roughing mill, transporting slabs to the Integrated station, transporting slabs to the labelling area, and so on, take up a total of about 270.45 seconds. Value-added operations make up only 66.08% of the total, which is below the target percentage of 70%, indicating inefficiency in the production process. In addition, production delays account for a significant amount about (30.90%) of the time spent on non-value-added tasks.

The value-added operations encompass a range of processes, namely slab heating, cleaning through chemical reaction, thinning, rolling, cutting, and labelling. The process of transporting a slab from the warehouse to the reheating furnace, arranging it for entry into the furnace, transporting it to the water dis-caller, sizing it, roughing it and finally transporting it to the station involves around 270.45 seconds of non-value-added time. The integrated production process, which encompasses travel coil to labelling, exhibits a value added activity rate of 66.08%, falling below the threshold of 70%. Conversely, the non-value added activities constitute a substantial proportion of 30.90%. The emergence of this problem can be attributed to the operational inefficiencies causing delays in the production process.

Making an examination of various aspects that can create production waste is one way to advance the manufacturing process. Here, non-value-added steps in hot strip mill manufacturing can be broken down into six groups, each of which accounts for a different kind of delay. As may be seen in Figure 2, these considerations include operation, mechanic, adjustment, computer, electrical, and instrument.

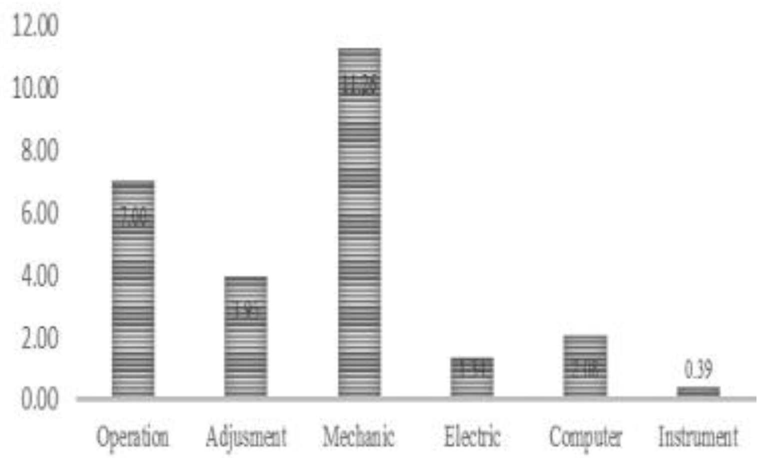

Figure (2): Delay Time

Mechanical issues account for the largest proportion of tardiness, constituting 11.26 percent of the total. In order to streamline the process of problem-solving and the identification of prospective solutions, a fishbone diagram is employed to ascertain several factors that may contribute to production delays. One such explanation could be attributed to equipment or mechanical problems. Hence, implementing a maintenance improvement program, as depicted in Table 1, presents a feasible solution for reducing waiting durations.

Table (1): Maintenance Improvement Program

No	Factors	Improvement Activity	Impact
1	Mechanic	Conduct routine checks and treatments on water discaller	Water can spray against slabs without any constraints
2	Mechanic	Replacing machine components that are past their lifetime	No damage to the machine during the production process takes place
3	Mechanic	Caring for cranes and forklifts	Slab and coil connections can run faster
4	Mechanic	Replace the roll that is already operating ineffectively	No interruptions during slab trips
5	Operation	Doing activities slab identification with care	The process of slab positioning can run faster
6	Operation	Scheduling for roll table checking once every 3 months	Slab travel process can be faster
7	Adjustment	Perform roll turn on down coiler on a regular basis every 6 months	Increases the performance of the coil rolling process
8	Adjustment	Perform roll repair on down coiler once every usage	Reduces errors during coil rolling process
9	Computer	Updating the system used by the company	No errors in production data
10	Computer	Perform repairs on the computer every 6 months	Can function properly
11	Electric	Set the slab temperature appropriately	The slab does not stick to the roll table

Figure 3 depicts the state of the manufacturing process after the implementation of the maintenance improvement program. In the future, non-value-added tasks, such as the time it takes to go from the water dis-caller to the sizing press, will be shortened from 30 minutes and 10 seconds to 27 minutes and 79 seconds. It is anticipated that the 47.72-second time it takes to travel from the size press to the roughing mill can be lowered to 33.22 seconds. Expected time savings include a reduction from 60.39 seconds to 49.99 seconds in the time it takes to get from the roughing mill to the integrated station. It is anticipated that the time it takes to get from the integrated station to the labelling process will be cut in half, from 24,36 seconds to 15,71 seconds.

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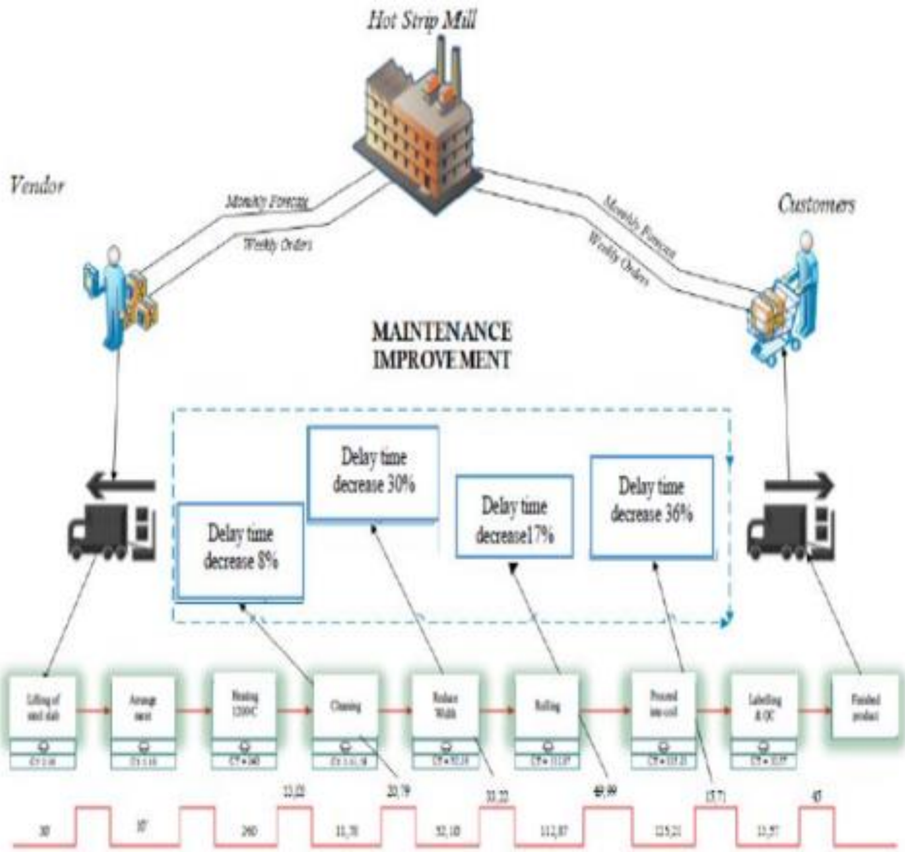

Figure (3): Future State of the value stream mapping (VSM)

The improvement in the value-added activities (from approximately 65.08% to 71.83%) and reduction in non-value-added activities (from approximately 30.90% to 26.6%) indicate that the future state of the production process flow at the hot strip mill production is more favorable compared to the existing state condition.

The categorization of value as effective is based on the criterion that a process is considered to run efficiently when the proportion of its value-added activities is at least 70%. Through the implementation of a maintenance improvement program, the industry is able to enhance the efficiency of its manufacturing cycle, hence optimizing the production process.

Conclusion

Various industries rely heavily on industrial engineering to improve their efficiency, productivity, and competitiveness. Through the application of optimisation, systems thinking, and quality management principles, industrial engineers foster innovation and continuous improvement. As we enter a new era characterized by technological advances and global challenges, industrial engineering will continue to develop in order to meet emergent demands and promote sustainable development.

Improving competitiveness and profitability, industrial engineering can help manufacturers become more efficient at their work. This proposal details a systematic approach that includes finding the source of the issue, analysing the data collected, and applying Value Stream Mapping. Production efficiencies, expenses, and product quality are all predicted to rise as a result. Production delays are the most significant source of production waste in the metals and alloys processing business, according to the study's findings. Current VSM state mapping indicates a 66.08% efficient manufacturing cycle. Maintenance improvement programmes are implemented on six different categories of production waste generators (operation, mechanic, adjustment, computer, electric, and instrument) in order to create improved production flow. In a perfect world, the manufacturing cycle's efficiency would be at around 71.3%. There has been a boost in productivity in the factory of 3.22%.

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