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IMPROVING SUPPLY CHAIN PERFORMANCE THROUGH PRODUCTION AND WAREHOUSE PROCESS OPTIMIZATION: A CASE STUDY OF A MANUFACTURING COMPANY

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Abstract: This article presents a comparative analysis of supply chain management at manufacturing company X, with particular emphasis on production and warehouse processes. The paper describes implemented improvements, such as automated quality control of fuel line components, semi-automatic raw material availability verification systems, and the implementation of Kanban racking . These changes led to shorter production process times, improved quality control efficiency, and reduced operating costs. Another area of optimization was the warehouse, where the use of modular trolleys, changes to the rack layout, and product placement in accordance with the XYZ analysis allowed for increased storage capacity and faster picking. As a result, these improvements increased process efficiency and improved the functioning of the entire supply chain.
Keywords: supply chain management, process automation, quality control, warehouse logistics, production optimization

1. INTRODUCTION

A supply chain is a complex system of interconnected entities, processes, and resources that participate in the flow of raw materials, materials, information, and products from the initial supplier to the final recipient (Wiśnicki et al., 2024). One of the key areas determining an organization's competitiveness and operational efficiency is supply chain management. A properly designed and effectively managed supply chain allows not only for cost optimization but also for increased flexibility and responsiveness to customer needs and changes in the environment. The aim of this article is to conduct a comparative analysis of supply chain management at Enterprise X, focusing on streamlining production and warehousing processes, which translates into more efficient operation of the entire supply chain.

2. LITERATURE REVIEW

The concept of "supply chain" is well established in the literature and typically refers to the network of companies that bring products or services to market (Chopra & Meindl,

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2025; Jodlbauer, et al., 2023). A supply chain includes the manufacturer, suppliers, carriers, warehouses, wholesalers, retailers, other intermediaries, and even customers themselves (Mentzer et al., 2001). Every product sold in the consumer goods market, on its way from raw material to finished product, passes through a series of sequential business-to-business transactions (Viveros et al., 2021). Chopra and Meindl believe that a supply chain consists of all parties involved, directly or indirectly, in fulfilling a customer order (Chopra & Meindl, 2025). In any organization, such as a manufacturer, the supply chain encompasses all functions related to receiving and fulfilling a customer order. These functions include, but are not limited to, new product development, marketing, operations, distribution, finance, and customer service (Salachudin & Fadillah, 2024). Chen and Paulraj stated that a typical supply chain is a network of links processing materials, information, and services, with characteristics of supply, transformation, and demand (Chen & Paulraj, 2004).

There are three traditional stages in a supply chain: procurement, production, and distribution (Chopra & Meindl, 2025). Each of these stages may involve several facilities located in different locations around the world. For example, in the automotive industry, assembly plants are located in different countries than the suppliers of various components, and distribution is carried out worldwide (Choi , Guo , & Li, 2023). Mentzer and colleagues describe a supply chain as "a set of three or more entities (organizations or individuals) directly involved in the flow of products, services, finance, and/or information up and down the chain, from source to customer" (Mentzer et al., 2001; Ding, et al., 2023). According to Mentzer and others, there are three levels of supply chain complexity: "direct supply chain," "extended supply chain," and "ultimate supply chain" (Mentzer et al., 2001).

The direct supply chain consists of a central organization, its suppliers, and its customers (Chopra & Meindl, 2025). Additionally, the extended supply chain includes the suppliers of direct suppliers and the customers of direct customers (APICS, 2017). The ultimate supply chain encompasses all organizations involved in all flows of products, services, finance, and information from ultimate suppliers to ultimate customers (ASCM, 2023). The ultimate supply chain also includes functional intermediaries, such as market research firms, financial and logistics service providers (De Giovanni, 2021). A supply chain can have varying degrees of complexity depending on the number of participants and the variety of business processes, but there is always a central organization (Jodlbauer & Koren , 2023). This organization can manage the entire supply chain or just part of it. Even if the supply chain is not formally managed, it still exists as a business phenomenon (Mentzer et al., 2001). An integrated supply chain model typically includes three interconnected flows:

- material flows – covering three stages: purchase, transformation and distribution (Pekarčíková et al., 2025),
- information flows – such as electronic data exchange or internet connections (ASCM, 2023),
- financial flows – including payments to suppliers and subcontractors for goods and services and payments from customers to retailers for the final product (Rogers & Tibben-Lembke, 2001).

While physical distribution is a key part of supply chains, information and financial components are equally important (Liu, Li & Zhao, 2025). The importance of knowledge input into supply chain processes should also be emphasized (Fetais et al., 2022). For

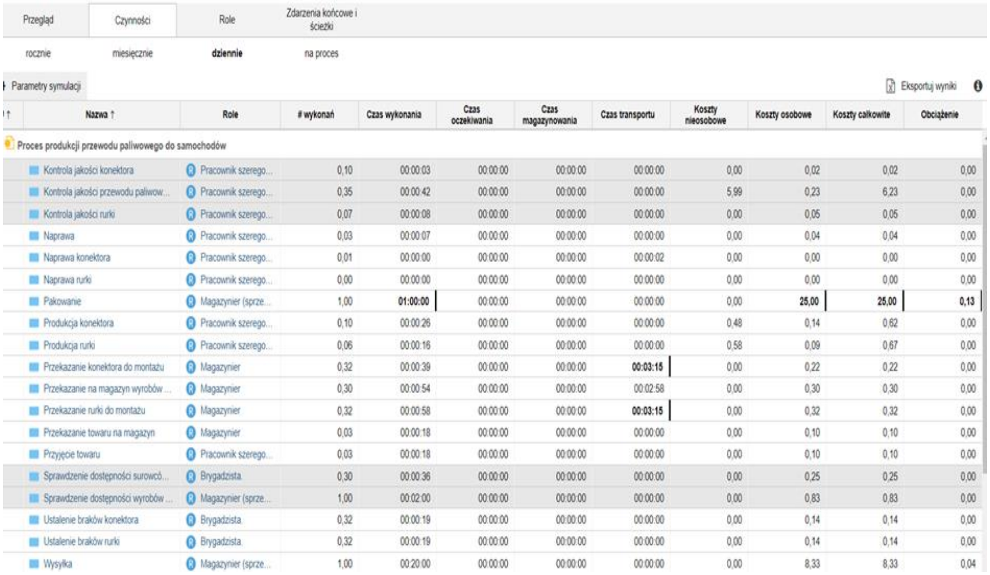
example, new product processes require close coordination between intellectual inputs (design) and physical inputs (components, prototypes, etc.) (Viveros et al., 2021).
The direction of flows in a supply chain is not limited to forward movement, from the first supplier to the final customer. Goods can also flow backward through the supply chain for various reasons, such as service or repair, remanufacturing, recycling, or disposal (Govindan, et al., 2021). The reverse supply chain plays a significant role in areas such as customer satisfaction, recycling, and environmental protection (Hassan & Osman, 2025).
Contemporary supply chain management utilizes a variety of concepts and strategies aimed at improving process efficiency, flexibility, and quality, as well as increasing customer satisfaction and reducing costs. One of the most important methods is Lean Management, which focuses on eliminating waste in all processes to deliver maximum customer value (Kot, 2017). The Lean philosophy encompasses activities such as inventory minimization, process optimization, and continuous improvement (Kaizen), which allows for increased efficiency and reduced operating costs. An example is the Toyota production system, in which key components are delivered directly to the production line, eliminating the need for warehousing.
Agile management, on the other hand, emphasizes the supply chain's ability to quickly adapt to dynamically changing market conditions. This approach allows organizations to effectively respond to changes in demand or supply disruptions (Nowakowska-Grunt, 2011).
Total Quality Management (TQM) involves the entire organization in striving to continuously improve the quality of products and services (Ingaldi & Krynke , 2015). TQM requires collaboration between all partners in the supply chain, and a key element of this philosophy is preventing errors rather than fixing them later. Implementing TQM is often supported by tools such as ISO certifications and statistical process control, which helps maintain high standards at every stage of delivery.
The Supply Chain Operations Reference Model (SCOR) is a reference model developed by APICS that allows for the analysis, design, and optimization of supply chain processes. SCOR encompasses five core processes: planning, sourcing, production, delivery, and returns management, helping organizations standardize and compare operational performance (Junior & Godinho, 2010).
Quick Concept Response (QR) focuses on rapid response to market needs. Thanks to optimized information flow and efficient logistics, companies can quickly respond to changes in demand, increasing product availability. In the apparel industry, QR allows for shorter design times and the delivery of new collections to stores.
Just-in-time (JIT) management is key to delivering raw materials and products precisely when they are needed in the production process, minimizing warehousing costs and the risk of excess inventory. This model is widely used in the automotive industry, where precisely managed deliveries enable ongoing vehicle production (Batth, 2021).
Business Process Business process reengineering (BPR) is an approach that radically redesigns business processes to achieve significant improvements in efficiency, quality, and flexibility. By analyzing existing processes, identifying bottlenecks, and implementing new solutions, companies can significantly increase their competitiveness (Kotjoprayudi , 2021).
Six Sigma methodology focuses on eliminating errors and reducing variability in processes. By utilizing statistical tools and structured steps such as DMAIC

(Define, Measure, Analyze, Improve, Control), organizations strive to achieve near-perfect quality in their processes. This is particularly important in industries requiring high precision, such as semiconductor manufacturing (Pongboonchai-Empl et al., 2024).
Finally, Efficient Consumer Response (ECR) is a collaborative strategy between supply chain partners that aims to meet customer needs while minimizing costs. By synchronizing activities such as demand forecasting and inventory optimization, companies can increase product availability and reduce operating costs (Rokhzad, 2023).
Each of these concepts brings unique tools and strategies that allow organizations to adapt their operations to a dynamically changing market and increasingly high consumer expectations. Putting them into practice can significantly increase the efficiency and competitiveness of the entire supply chain (Van den Bogaert, et al., 2022).
An effective improvement of supply chain processes depends not only on technological and organizational solutions but also on the involvement and competencies of employees (Ingaldi & Dziuba, 2016). Numerous studies indicate that employee engagement, communication skills, adaptability to change and teamwork significantly influence the success of process optimization initiatives. Soft competencies play a particularly important role in the implementation of concepts such as Lean Management, TQM and continuous improvement, where the participation of employees at every organizational level is essential.
The literature emphasizes that organizations which consciously develop human capital achieve higher sustainability of improvements and greater resistance to operational disruptions. Leadership style, organizational culture and internal communication mechanisms strongly affect employees' willingness to participate in change processes. Therefore, human resources management should be treated as an integral element of supply chain management.

3. METHODOLOGY OF RESEARCH

This study adopts a qualitative case study approach. Company X was selected due to its complex production structure, significant scale of operations and ongoing transformation of production and warehouse processes. The authors actively participated in the diagnostic phase and formulation of improvement proposals in cooperation with company management. The contemporary market in which manufacturing companies operate is constantly evolving. The dynamic pace of change and environmental pressures force companies to continually improve their processes to remain competitive. The company also decided to streamline its processes. In a daily review, the entire production process of one fuel line takes 1 hour 34 minutes 56 seconds. The plant operates a three-shift production system. However, the entire process does not occur X times during a single shift. During a single shift, 8 hours are divided into parts. During the first part of the shift, the tube production process continues, the following hours are devoted to the production of the connector. The final hours are reserved for assembling the parts into a single unit, i.e., the fuel line. However, if the data were standardized, the entire process could be repeated five times during a single shift by five employees, and 15 times during a full 24-hour period. Production plant X employs approximately 450-500 employees in this department. After calculating these results, it can be concluded that the entire process during good, with this number of employees, can give us a total of about 1,500 produced parts that will be assembled into a whole.

Figure 1 details all the activities performed in the fuel line production process. The shaded rows indicate activities that need to be streamlined to shorten their execution time. These include: connector quality inspection, fuel line quality inspection, tube quality inspection, checking raw material availability in the warehouse, and checking finished product availability.



Nazwa	Role	# wykonań	Czas wykonania	Czas oczekiwania	Czas magazynowania	Czas transportu	Koszty nieosobowe	Koszty osobowe	Koszty całkowite	Obciążenie
Kontrola jakości konektora	Pracownik szerego...	0,10	00:00:03	00:00:00	00:00:00	00:00:00	0,00	0,02	0,02	0,00
Kontrola jakości przewodu paliwow...	Pracownik szerego...	0,35	00:00:42	00:00:00	00:00:00	00:00:00	5,99	0,23	6,23	0,00
Kontrola jakości rurki	Pracownik szerego...	0,07	00:00:08	00:00:00	00:00:00	00:00:00	0,00	0,05	0,05	0,00
Naprawa	Pracownik szerego...	0,03	00:00:07	00:00:00	00:00:00	00:00:00	0,00	0,04	0,04	0,00
Naprawa konektora	Pracownik szerego...	0,01	00:00:00	00:00:00	00:00:00	00:00:02	0,00	0,00	0,00	0,00
Naprawa rurki	Pracownik szerego...	0,00	00:00:00	00:00:00	00:00:00	00:00:00	0,00	0,00	0,00	0,00
Pakowanie	Magazynier (sprze...	1,00	01:00:00	00:00:00	00:00:00	00:00:00	0,00	25,00	25,00	0,13
Produkcja konektora	Pracownik szerego...	0,10	00:00:26	00:00:00	00:00:00	00:00:00	0,48	0,14	0,62	0,00
Produkcja rurki	Pracownik szerego...	0,06	00:00:16	00:00:00	00:00:00	00:00:00	0,58	0,09	0,67	0,00
Przekazanie konektora do montażu	Magazynier	0,32	00:00:39	00:00:00	00:00:00	00:03:15	0,00	0,22	0,22	0,00
Przekazanie na magazyn wyrobów ...	Magazynier	0,30	00:00:54	00:00:00	00:00:00	00:02:58	0,00	0,30	0,30	0,00
Przekazanie rurki do montażu	Magazynier	0,32	00:00:58	00:00:00	00:00:00	00:03:15	0,00	0,32	0,32	0,00
Przekazanie towaru na magazyn	Magazynier	0,03	00:00:18	00:00:00	00:00:00	00:00:00	0,00	0,10	0,10	0,00
Przyjęcie towaru	Pracownik szerego...	0,03	00:00:18	00:00:00	00:00:00	00:00:00	0,00	0,10	0,10	0,00
Sprawdzenie dostępności surowcó...	Brygadzista	0,30	00:00:36	00:00:00	00:00:00	00:00:00	0,00	0,25	0,25	0,00
Sprawdzenie dostępności wyrobów ...	Magazynier (sprze...	1,00	00:02:00	00:00:00	00:00:00	00:00:00	0,00	0,83	0,83	0,00
Ustalenie braków konektora	Brygadzista	0,32	00:00:19	00:00:00	00:00:00	00:00:00	0,00	0,14	0,14	0,00
Ustalenie braków rurki	Brygadzista	0,32	00:00:19	00:00:00	00:00:00	00:00:00	0,00	0,14	0,14	0,00
Wysyłka	Magazynier (sprze...	1,00	00:20:00	00:00:00	00:00:00	00:00:00	0,00	8,33	8,33	0,04

Fig. 1. List of activities performed in the production process of the fuel pipe in the enterprise

Improvements included the introduction of automatic quality control for connectors, tubes, and fuel lines, as well as the introduction of semi-automatic checks for the availability of raw materials and finished products. This automation reduced the error rate previously performed by humans and shortened the process time. A comparison of the models is presented in Figure 2.

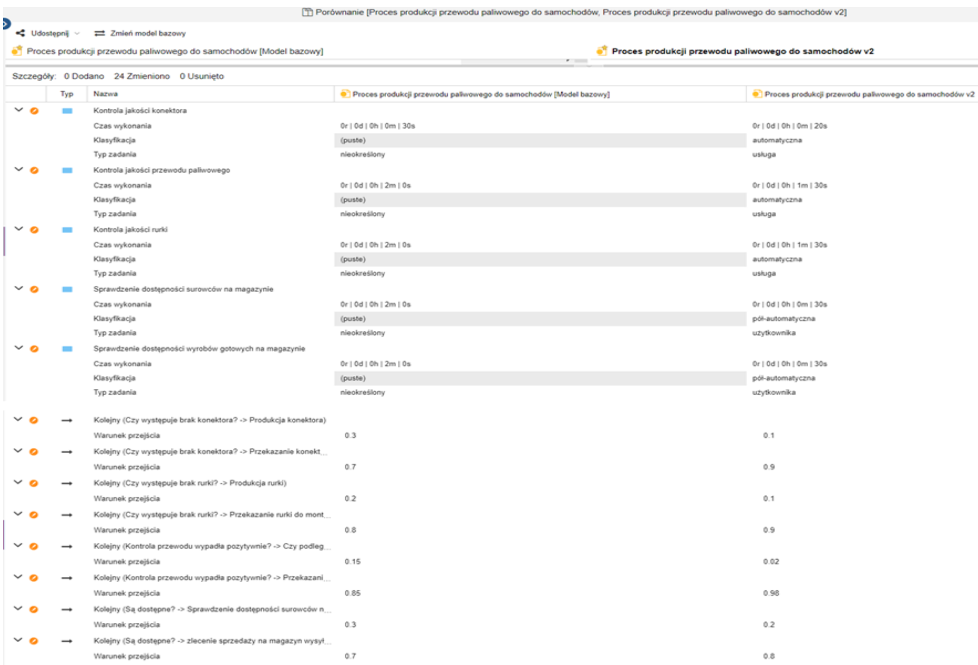


Fig. 2. Comparison of fuel line production process models

Figure 3 shows the changes that occurred after the improvements were implemented. The first column shows the error rate during the execution of the activity. The second column shows the changes over time.

Kontrola jakości konektora	Pracownik szerego...	0,10	00:00:03
Kontrola jakości przewodu paliwow...	Pracownik szerego...	0,35	00:00:42
Kontrola jakości rurki	Pracownik szerego...	0,07	00:00:08

Kontrola jakości konektora	Pracownik szerego...	0,02	00:00:00
Kontrola jakości przewodu paliwowego	Pracownik szerego...	0,21	00:00:19
Kontrola jakości rurki	Pracownik szerego...	0,02	00:00:02

Sprawdzenie dostępności surowcó...	Brygadzista.	0,30	00:00:36
Sprawdzenie dostępności wyrobów ...	Magazynier (sprze...	1,00	00:02:00

Sprawdzenie dostępności surowców na m...	Brygadzista.	0,20	00:00:06
Sprawdzenie dostępności wyrobów gotow...	Magazynier (sprze...	1,00	00:00:30

Fig. 3. Comparison of steps in the fuel line production process after improvements

By introducing automated and semi-automated tasks (using appropriate systems or devices), the time taken to complete these tasks was reduced, resulting in a total of 1 hour 28 minutes 42 seconds compared to 1 hour 34 minutes 38 seconds. This included tasks such as checking the availability of finished products and raw materials, and inspecting manufactured parts. The number of positive fuel line quality inspections also improved, as the automation of inspection tasks eliminated the human error rate. This now stands at 98% to 2%. Both personnel and non-personnel costs also decreased, resulting in a total cost of 44.41 from 52.45. The change also relates to a higher percentage of having all necessary parts, leading to immediate packaging and shipping of orders to the customer due to increased production.

Another improvement was the use of Kanban racks on the production floor. Kanban racks , also known as flow racks or gravity racks Flow is a system for storing and delivering materials based on the "pull" principle instead of " push ." This means that materials are only retrieved from the rack when they are actually needed. The volume of raw materials on the racks is adjusted to the production shift. The use of these racks also allows for the FIFO principle (first in, first out). This principle assumes that the raw materials received first are released into the flow (in this case, production). To speed up product release and avoid repacking in the warehouse, packaging units have been modified. To achieve this, the number of products packaged in a single collective package was reduced before being transported to the warehouse.

4. IMPROVEMENTS IN THE STORAGE PROCESS

One of the key areas that impacts the efficiency of an entire enterprise is the warehouse. The efficient operation of a warehouse impacts the entire production process, the supply chain, and customer service. Manufacturing company X has implemented several significant improvements at the warehouse level. Figure 4 shows the company's warehouse layout before the changes were implemented.

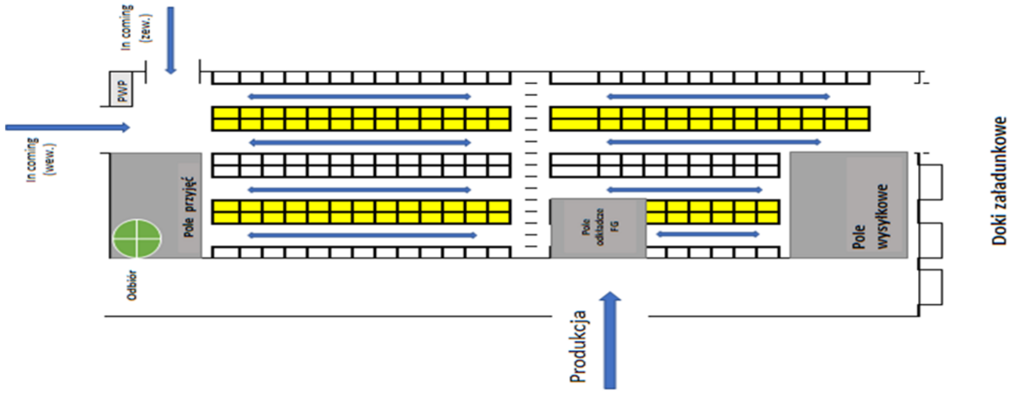


Fig. 4. Warehouse layout before improvements were introduced

Both parts of the warehouse contain eight racks each with a 3-meter-wide work aisle. The warehouse is conventionally divided into two sections. The upper section is used for receiving and storing raw materials and semi-finished products. This is where the entire process of accepting these products into the warehouse takes place. They are then placed on racks located in the upper section of the warehouse. The lower section stores finished products (finish) . Goods are transported directly from production to the FG storage area, and then to the warehouse racks in the other half of the warehouse. The racks have four levels, and the stored products are stored using Euro pallets. With this configuration, the company has approximately 1,700 pallet spaces. Electric forklifts are used to handle warehouse operations.

One of the first improvements implemented in the warehouse was the introduction of modular trolleys in the upper part of the warehouse. Using these solutions, the company can see a 20-30% increase in internal transport within the warehouse. The trolleys ensure reliable operation in two-shift operation without the need for battery replacement. They are equipped with modules that integrate various processes, such as a logistics interface, RFID technology, and path and height measurement systems. They move through the racks using a physical rail attached to the floor or an inductive rail embedded in the ground. The modular trolleys operate in narrow aisles, allowing for an increased number of racks and better utilization of available warehouse space. The use of system trolleys allowed the company to add two additional racks (marked in navy blue in Figure 5).

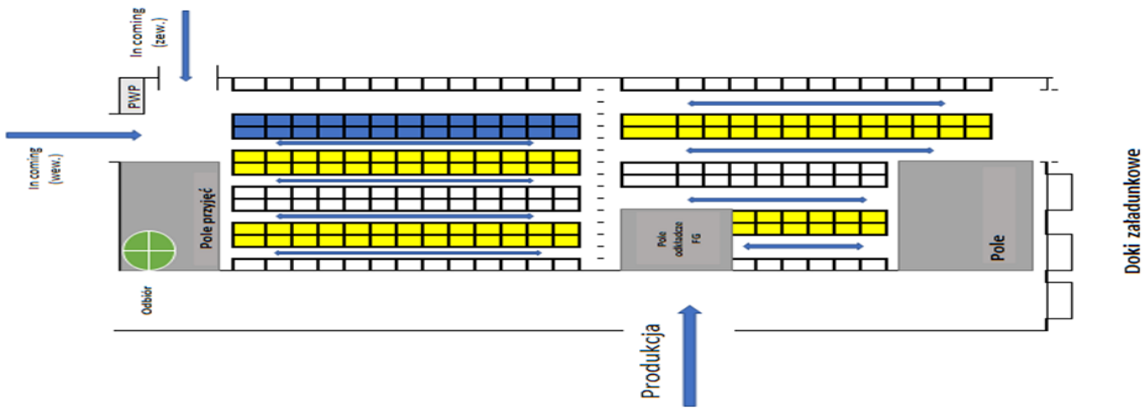


Fig. 5. Warehouse layout after the implementation of the proposed improvements.

The working aisle was reduced from 3m to 1.9m. These changes contributed to saving space in the warehouse, improving efficiency and safety. Work can also be sped up during full-container picking. The lower part of the warehouse remains unchanged. Figure 5 shows the warehouse layout after these improvements were implemented.
Product storage on four levels of racks using Euro pallets was replaced with nine levels of mesh shelves, bypassing the Euro pallets. This allowed for an increase in pallet space to approximately 3,000 pallet spaces.
Another improvement was the implementation of the XYZ method. Previously, employees had been guided by the principle of placing the lightest products on the top levels of the racks, without taking into account their picking frequency. With over 2,000 products, the TOP 300 products were selected, indicating the highest picking frequency. These (products X) were placed on levels 0 and 1. Subsequent products were placed on higher levels based on proportion.

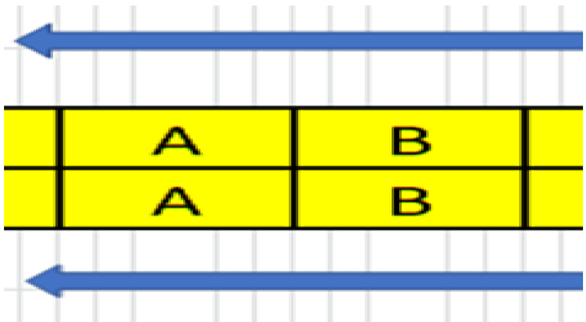


Fig. 6. Scheme of products on shelves

The products were then placed on the racks so that the same products were at the front and back of the rack. Organizing the products accelerates the work of warehouse workers. A diagram of the product arrangement on the racks is shown in Figure 6.
To improve operational efficiency, the production plant decided to implement a series of improvements at both the production and warehousing levels. These changes were aimed at increasing productivity, shortening order fulfillment times, and improving inventory management, which ultimately impacted the entire supply chain. Among the improvements implemented were automatic quality control of connectors, tubes, and fuel lines, as well as a semi-automatic system for verifying the availability of raw materials and finished products. Automation significantly reduced the number of errors previously made by employees and shortened the time required to perform these tasks using appropriate systems and equipment. Comparatively, the task completion time after implementing the improvements was 1 hour, 28 minutes, and 42 seconds, compared to the previous 1 hour, 34 minutes, and 38 seconds. Eliminating negative quality checks resulted in a 98% efficiency rate, with only 2% of negative results. Simultaneously, both personnel and non-personnel costs decreased, resulting in a reduction in total costs from 52.45 to 44.41 units. An additional effect of the implemented improvements is the increased availability of all necessary components, enabling immediate packaging and shipping of orders to customers thanks to increased production efficiency. Another important aspect was the introduction of Kanban racking in production , the FIFO principle, and the packaging of specific, smaller quantities of product into bulk packaging to avoid repacking of finished goods in the warehouse.

Table 1
Comparative analysis of the improvement process

No.	**Before the improvements are made**	**After the improvements were made**
1.	Manual quality control of the connector, tube, and fuel line	Automatic quality control of the connector, tube, and fuel line
2.	Manual system for verifying the availability of raw materials and finished products	Automatic system for verifying the availability of raw materials and finished products
3.	Fuel line production lead time: 1 hour 34 minutes and 38 seconds	Fuel line production lead time: 1 hour 28 minutes and 42 seconds
4.	Ratio of positive to negative quality controls: 85/15	Ratio of positive to negative quality controls: 98/2
5.	Total cost of 52.45 units	Total cost of 44.41 units
6.	Standard shelves in the production hall	Kanban racks on the production floor
7.	16 4-level racks, storage on Euro pallets	18 9-level racks with mesh shelves, no Euro pallets
8.	Approximately 1,700 pallet spaces	Approximately 3,000 pallet spaces
9.	Electric forklifts	Electric forklifts, system trucks
10.	Working corridor between racks: 3m	Working aisle between racks: 1.9.
11.	The agreed location of the assortment in the warehouse	Location of assortment in the warehouse based on XYZ analysis, FIFO

In the warehouse section of the plant, system trolleys were introduced, narrowing the aisle between racks from 3m to 1.9m and enabling the addition of two additional racks. The 4-level racks (storage on Euro pallets) were replaced with 9-level racks with mesh shelves, bypassing Euro pallets. Pallet space availability increased almost by half. These improvements resulted in approximately 3,000 pallet spaces, compared to the previous capacity of 1,700 pallet spaces. The use of system trolleys also speeds up the picking process (for full picking), translating into a 20-30% reduction in internal transport time. From over 2,000 products, 300 products with the highest picking frequency were selected. The most frequently picked products (so-called X products) were placed on the lowest rack levels – levels 0 and 1 – for easier access and reduced picking time. The remaining products were arranged on higher levels, according to their turnover and demand, maintaining appropriate proportions. The products were then arranged so that the same products were found on both sides of the rack – front and back. This arrangement of the assortment allows for faster and easier access to products, which directly translates into increased work efficiency for warehouse workers.

The implementation process required intensive employee involvement. Workers participated in training sessions, testing of new solutions and continuous feedback collection. Their engagement and adaptive competencies significantly influenced the pace and effectiveness of the improvements. Initial resistance to change was observed, particularly in relation to automation of quality control, but systematic communication and managerial support helped overcome these challenges.

5. CONCLUSION

Improvements in production and warehousing at Company X have contributed to increased productivity, improved product quality, and reduced operating costs. Automated quality control and systematic monitoring of raw material availability shortened process times and reduced the number of errors. Warehouse modernization, including the use of modular trolleys, reorganized racks, and product layout based on XYZ analysis, allowed for better space utilization and faster order picking. These changes improved the functioning of the entire supply chain, increasing the company's efficiency and flexibility.

The implementation process also revealed organizational challenges, including the need for employee retraining and adaptation to new technologies. These findings confirm that technological improvements must be supported by deliberate human resource management. The case demonstrates that sustainable supply chain improvement requires simultaneous development of technical systems and human competencies. Although the study is limited to a single company, the presented approach can serve as a reference framework for similar manufacturing organizations.

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