Advances in Science and Technology
Research Journal

Advances in Science and Technology Research Journal, 2025, 19(9), 442–451
https://doi.org/10.12913/22998624/207622
ISSN 2299-8624, License CC-BY 4.0

Received: 2025.06.12
Accepted: 2025.07.15
Published: 2025.08.01

Optimization of manufacturing plant layout by practical application of plant simulation

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ABSTRACT

This paper presents a detailed case study on the optimization of a manufacturing tool shop layout using Plant Simulation software. The goal was to propose a more efficient layout through a simulation model. The selected company, specializing in the production of subcomponents for the electrical engineering industry, aimed to improve production efficiency, ergonomic conditions, and spatial utilization as part of its on-going modernization strategy. The existing tool shop was divided into five zones, each with distinct equipment and layout challenges. On the basis of a thorough analysis, a new layout was proposed involving the relocation of selected machines, introduction of consistent material flow directions, and improved accessibility to critical resources. The application of Plant Simulation enabled accurate modeling and testing of different scenarios, minimizing implementation risk. The results demonstrated significant potential for space saving, time reduction, as well as preparation for future investments in newer and safer machines. This case underlines the practical advantages of integrating digital simulation tools into industrial layout planning to support operational and strategic goals.

Keywords: layout optimization, plant simulation, production efficiency, manufacturing ergonomics, digital modeling.

INTRODUCTION

The rapid advancement of industrial technologies and the emergence of concepts such as Industry 4.0 have placed increasing emphasis on the optimization of production systems [1]. Modern manufacturing environments are no longer static, they demand constant adaptation, integration of digital tools, and thoughtful layout planning to meet efficiency, cost-effectiveness, and safety standards. To remain competitive, manufacturing companies must embrace new approaches, including simulation and digital modeling, for continuous improvement [2, 3].

This paper focuses on the practical application of simulation software – specifically Plant Simulation – in optimizing the layout of a tool shop within a manufacturing company. The chosen company specializes in the production of electrical subcomponents for both domestic and international markets, where high precision and compliance with technical norms are paramount. As part of its modernization efforts, the company sought to revise its workplace layout to increase operational efficiency, accommodate new machinery, and reduce downtime. The existing layout of the tool shop was divided into five zones, each housing specific machines and operations. By analyzing space usage, machine placement, and logistical flows, the paper proposes targeted changes – relocating outdated or inefficient machines as well as reorganizing critical equipment to enhance accessibility and workflow.

This research highlighted how combining domain-specific expertise with simulation tools can drive informed decisions in industrial layout design. The result is not just an increase in productivity and improvement in ergonomics, but also a strategic alignment with the company's modernization and investment plans [4, 5].

Optimization is continuously evolving in all its fields. With new challenges and technologies, it must advance to address these problems efficiently. It is closely connected with several disciplines, such as mathematics, technology, and industrial processes. Its early traces go back to ancient mathematics, when Greek mathematician Archimedes dealt with the problem of maximizing the volume of a sphere within a cylinder [6, 7].

Industrial optimization is a dynamic process that requires constant attention and adaptation to technological progress to remain competitive and achieve the best possible results. This process focuses on improving manufacturing procedures and operations to achieve maximum efficiency and productivity. Flexibility and continuous improvement are essential to adapt to rapidly changing market conditions and innovative trends [8, 9].

Process efficiency aims to optimize individual manufacturing processes to minimize unnecessary steps as well as maximize speed and reliability. Efficient use of raw materials, energy, and labor helps minimize waste and costs. Quality and safety are key to maintaining customer trust and a safe working environment. Implementing quality management systems and safety protocols helps minimize risks and ensures high standards [10, 11].

Automation and digitization are crucial for improving processes and managing them through modern technologies like robotics, IoT, and artificial intelligence. These lead to increased accuracy, speed, and reliability of production. Currently, the most used concept is Industry 4.0, built upon the foundations of the third industrial revolution. Its main goal is communication and collaboration between humans, machines, systems, and devices. The emphasis is on network interconnection of all available machines, devices, and systems, contributing to significant automation [12, 13].

Utilizing all the advantages that the fourth industrial revolution offers, Industry 4.0 has the potential to bring a high degree of optimization into production environments. Examples include the machines that can predict failures or smart logistics that respond to sudden or unexpected production changes. Digitization of the entire workplace provides the possibility to deliver the right information to the right person at the right time [14, 15].

There are many virtual software tools for simulating production processes. Simulations are a powerful tool with several benefits that contribute significantly to improving production processes for companies and organizations. One key advantage is identifying and solving potential problems before implementing processes in the real environment. This helps prevent errors and improve overall efficiency. Owing to simulation, various aspects of production operations can be optimized [16, 17, 18]. Plant Simulation enables detailed simulation of material flow through the production process, minimizing waiting times, optimizing inventory, and increasing overall efficiency. It also allows planning and simulating stock, which is essential for supply management and warehouse optimization. Plant Simulation is a sophisticated software tool for modeling and simulating manufacturing processes in a digital environment to predict and optimize their progress. It allows the creation of highly detailed digital models of entire production lines or specific processes, which can then be simulated under various scenarios, enabling companies to better predict and analyze all production aspects [19, 20, 21].

Describing of production workplace – tool shop

The selected company places great emphasis on the quality of its products and their ability to provide safe solutions in the electrical sector. It sells its products not only on the domestic market but also abroad, supporting its sales with certificates from independent testing laboratories in various countries, including Slovakia, the Czech Republic, the United Kingdom, Ukraine, and Germany.

The selected company focuses on the production of subcomponents for the electrical engineering industry, which constitutes its main manufacturing program. These components are used in electrical devices and must meet strict technical standards, including high precision and specific technical parameters. Examples include plastic components for switches, circuit breakers, residual-current devices, and electrical installation materials for households. In addition to the electrical engineering industry, the company also manufactures components for advertising purposes and other sectors according to customer requirements. It is possible to identify two sub-workplaces here.

Tool shop for production of larger semi-finished products

This production workplace features a CNC milling machine along with a CNC lathe (Figure 1). In terms of layout, the machines are positioned diagonally across the corners of the room and rotated

Figure 1. CNC wire cut machines in the tool shop workplace

90 degrees. Along the perimeter of the room, cabinets containing the necessary tools for operating the machines are placed, along with tables used for storing finished semi-finished products or those prepared for machining. Significant disadvantages of this layout include insufficient space for handling larger objects, inefficient use of space, and time loss due to the need to transport semi-finished products from one machine to another.

Tool shop for production of more complex semi-finished products

This workplace is located directly next to the tool shop for larger semi-finished products, in a separate room. It is equipped with six chip-cutting machines for electrical discharge machining (EDM), a process in which material is removed by electro-abrasive action of an electric spark. One electrode is the workpiece, and the other is the tool, which is brought close enough for a spark to jump between them, tearing a small portion of molten metal from the surface of the workpiece. To flush away the chips, enhance the effect, provide cooling, and prevent oxidation, the entire process takes place in a liquid medium.

The whole workplace contains a larger number of machines. For more effective analysis, the workplace will be divided into several sections, each of which will be analyzed individually (Figure 2). Figure 3 shows a 3D model of the entire tool shop. The first zone is located directly at the entrance to the room, with the entrance separated from the machines by a small fence. Immediately behind this fence are four milling machines and a forklift. Behind these milling machines is a larger sheet metal forming machine, next to which are pallets for finished components. In front of the pallets is a grinding machine. Along the wall are shelves and storage areas for employees' personal belongings. Figure 4 shows and describes the first zone of the tool shop.

The second zone consists of twelve pillar drilling machines, arranged in two rows of six units each, positioned side by side. The machines are oriented back-to-back. Next to the drilling machines are a hydraulic press and a welding room, which are separated from the drills by a larger gap to ensure better access to the machines and facilitate material supply. Behind the hydraulic press is a CNC lathe with an automatic feeder. In front of both machines, there are racks for storing components. Figure 5 shows and describes the second zone of the tool shop.

The third zone consists of lathes and feeders, which are positioned side by side at an angle. Behind them are four presses. Figure 6 shows and describes the third zone of the tool shop. The fourth zone is located on the opposite side of the room. This zone contains two larger presses, a sheet metal straightening machine, and a coil of sheet metal, all positioned side by side. In front of these machines are storage boxes for finished stampings. Along the wall of the room are three sorting boxes for waste generated throughout the tool shop. Next to these sorting boxes is the exit from the hall as well as a smaller room with restrooms and

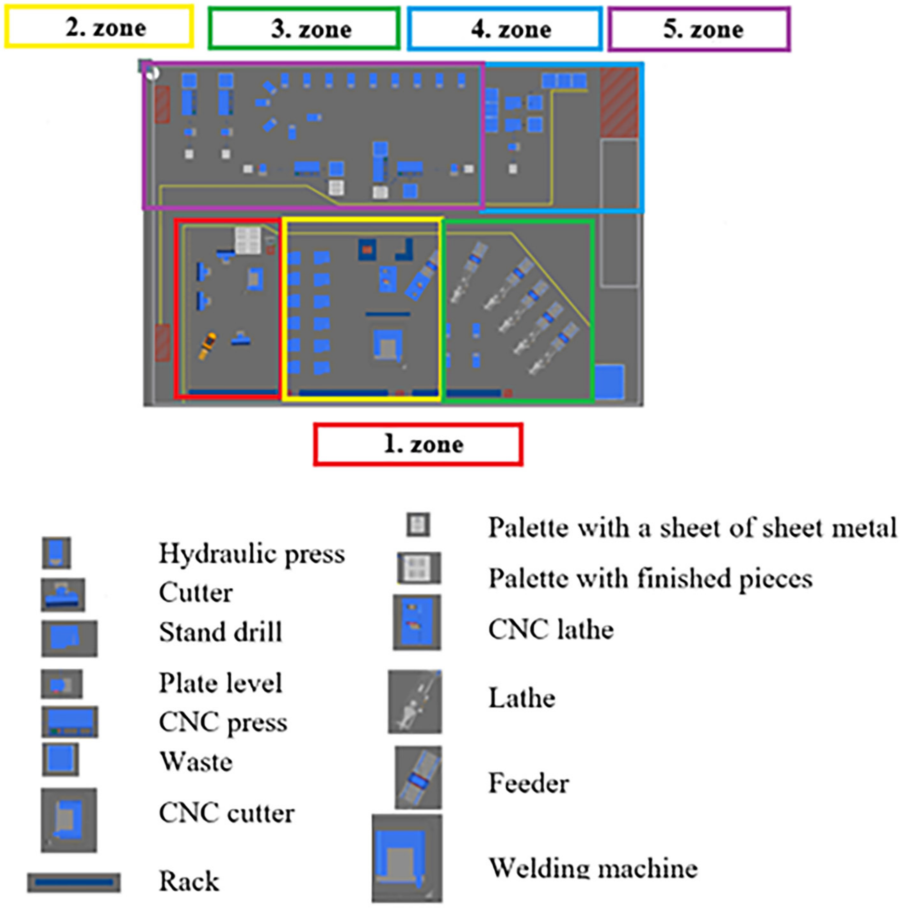

Figure 2. Schematic representation of the workplace with legend [22]

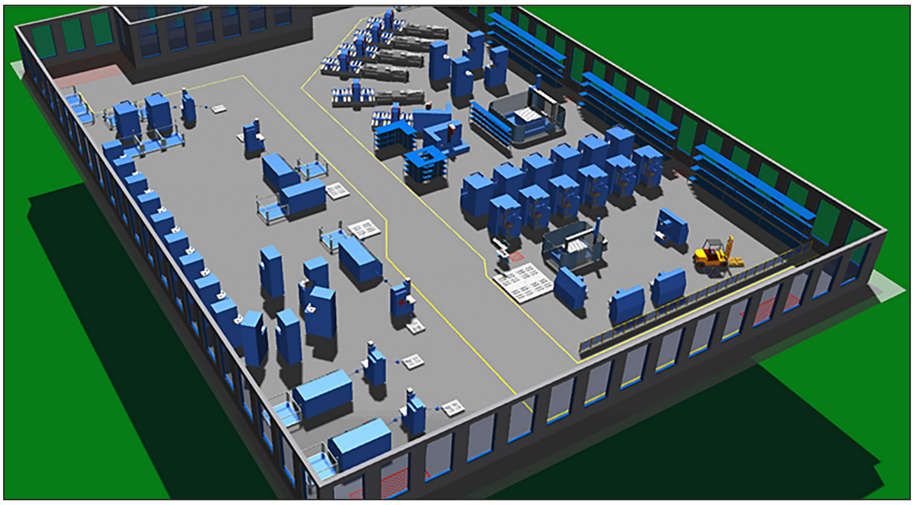

Figure 3. Tool shop 3D model

changing facilities for the workers. Figure 7 shows and describes the fourth zone of the tool shop.

The fifth and final zone of the tool shop consists of presses arranged side by side along the wall in the shape of the letter J. In front of the presses are CNC presses together with sheet metal straightening machines and coils of sheet metal. In front of them are two boxes – one for finished stampings and the other designated for waste. At the edge of the room, there are two additional similar groupings of machines. At the very end of the room, there is a storage area containing the

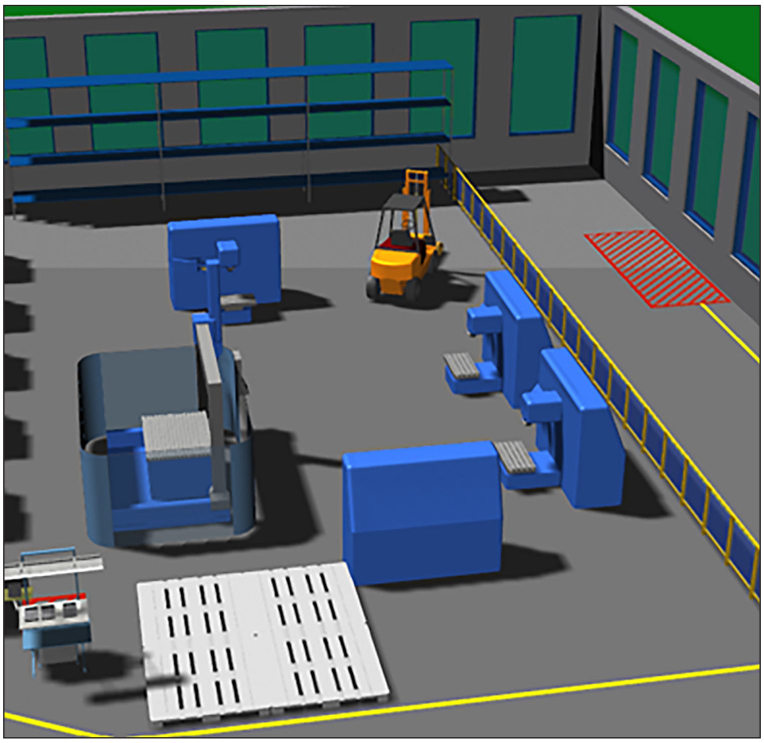

Figure 4. First zone of the tool shop

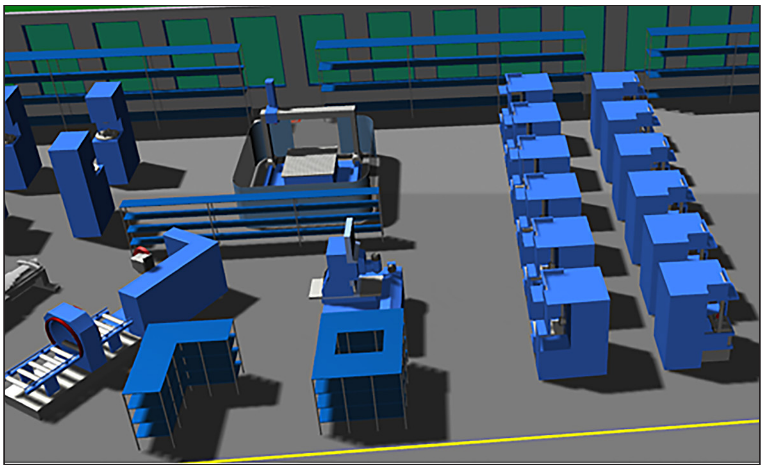

Figure 5. Second zone of the tool shop

tools required in this workshop. Figure 8 shows and describes the fifth zone of the tool shop.

The optimization of workplace layout

On the basis of the analysis of workplaces, the tool shop was selected for the design and optimization of the layout solution. As shown in Figures 3–8, the 3D model of this workplace has already been created in the Plant Simulation software. In the design of the optimized layout, factors such as the company's future investments in this workplace were taken into consideration. The company is gradually modernizing its workplaces with newer and safer machines, aimed at increasing efficiency and reducing overall production costs. The selected workplace is next in line for this modernization; therefore, the proposal emphasized the creation of free space for new machines specifically at this site.

In Zone 1, a significant amount of unused space was identified, and it is proposed that all presses previously located along the wall in Zone 5 be moved here. In front of the presses, waste

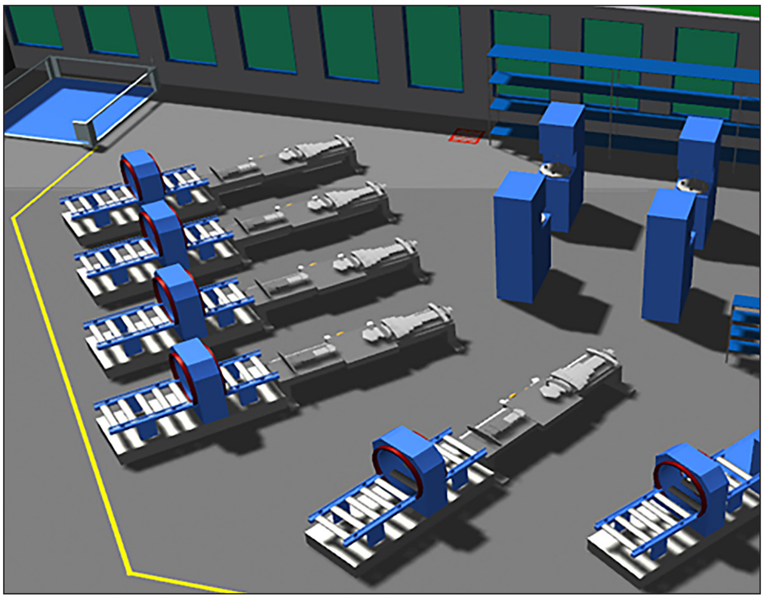

Figure 6. Third zone of the tool shop

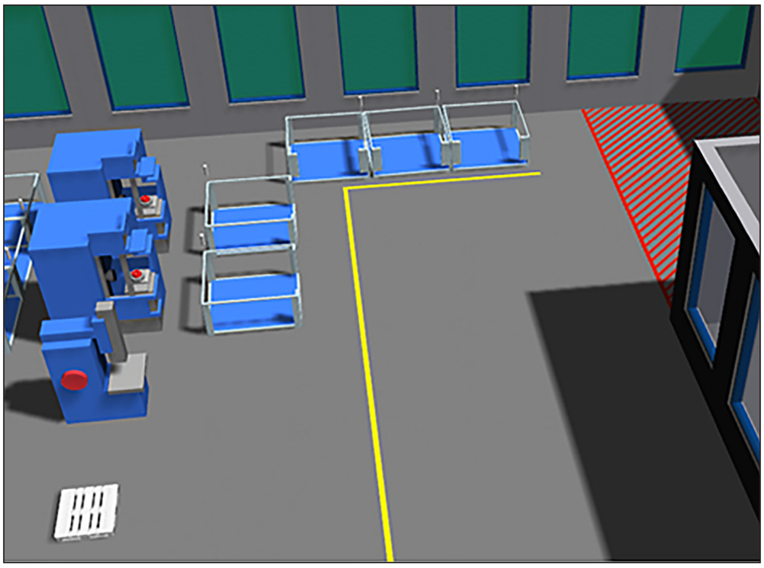

Figure 7. Fourth zone of the tool shop

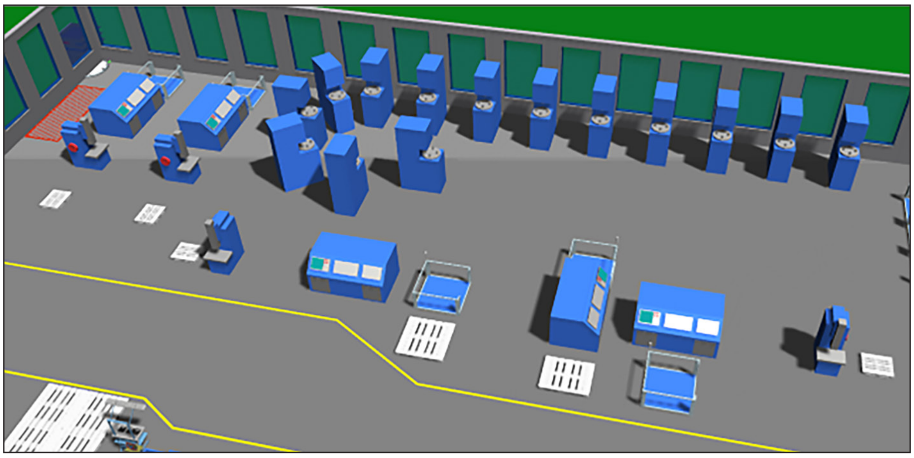

Figure 8. Fifth zone of the tool shop

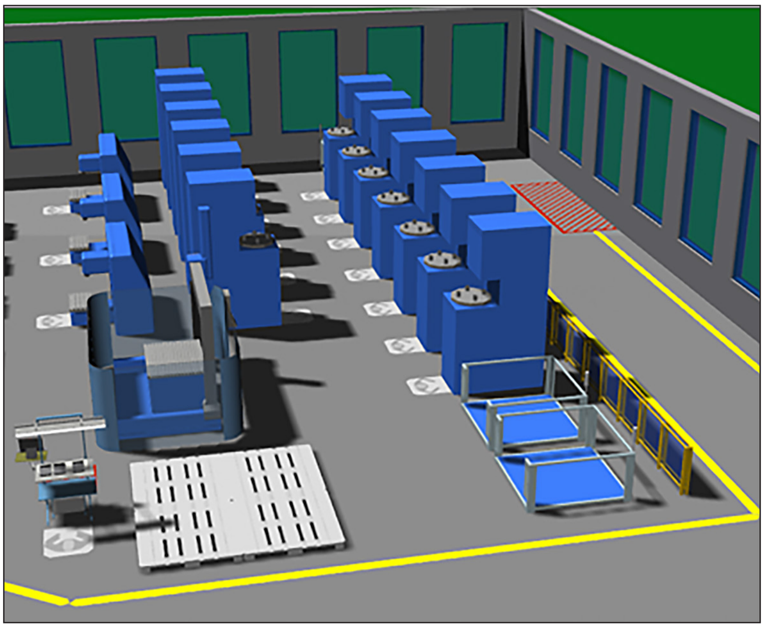

Figure 9. Optimized first zone of the tool shop

bins and containers for finished castings will be placed. The milling machines will be relocated and arranged side by side behind the presses. The larger sheet metal forming machine will remain in its original location due to its size and the complexity of moving it. Optimized first zone of the tool shop is presented in Figure 9.

The relocation of machines is proposed due to the modernization of the workplace. These machines will gradually be decommissioned and replaced with new ones. Additionally, the utilization of these machines is no longer at full capacity, and only a few of them are currently used in production. The second zone will remain unchanged. This zone contains the largest machines, and therefore their handling would be excessively demanding and costly. Relocating these machines would not result in space savings or increased production efficiency. Figure 10 shows the second zone, which has been retained in its original layout.

In the third zone, the lathes with feeders will be relocated to the fourth zone. This relocation will create space for new machines that are planned to be purchased. The presses, which

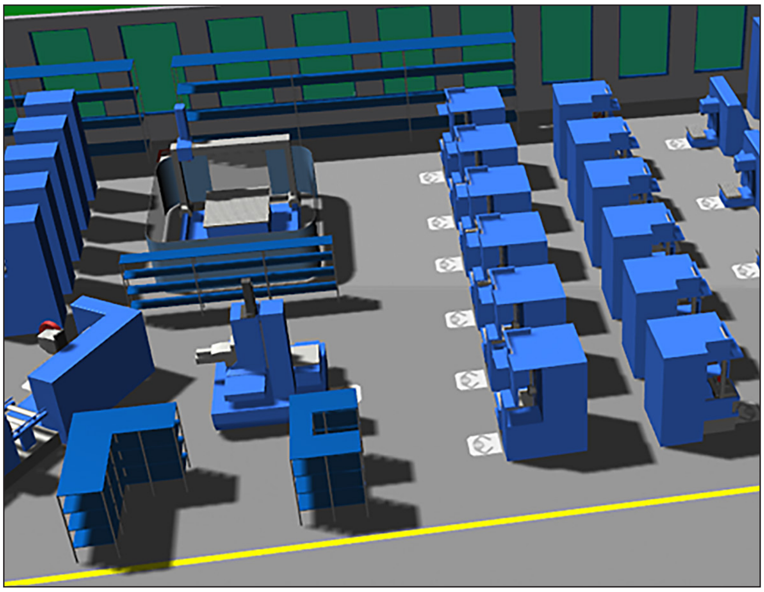

Figure 10. Second zone of the tool shop (without changes)

were previously arranged in a square configuration, will be moved closer to the second zone and aligned side by side (Figure 11).

The fourth zone will undergo minor modifications, during which two presses located at its edge will be relocated to the fifth zone. Lathes will be moved into this zone, thereby saving space in zone three, as well as a smaller area behind the lathes. This relocation will improve accessibility to the lathes and facilitate the loading of semi-finished products into the automatic feeders, since in zone three, longer semi-finished products were obstructed by the proximity of the locker and restroom areas. Additionally, these feeders will be more easily accessible by forklift in the case of larger semi-finished products, as the path in front of them was previously narrowed due to the locker and restroom spaces. Figure 12 shows the proposed optimization of the fourth zone of the tool shop.

The fifth zone has remained unchanged at the edge of the room, with two machines left in their original positions. Directly behind these machines, one CNC press will be relocated along the wall. Subsequently, two additional CNC presses, together with sheet metal straightening machines and coils of sheet metal, will be arranged in a U-shape. Behind these two presses, the previously mentioned presses from the fourth zone will be placed.

All these presses will be arranged with a consistent material flow – left to right – in order to save time when replacing empty coils with new ones and to eliminate safety risks, as this replacement is performed using a forklift. Likewise, the final stampings or waste will be placed on the same side to facilitate easier handling and removal. Figure 13 shows the proposed optimization of the fifth zone of the tool shop.

The presses from the fourth zone will be relocated here due to their maintenance requirements.

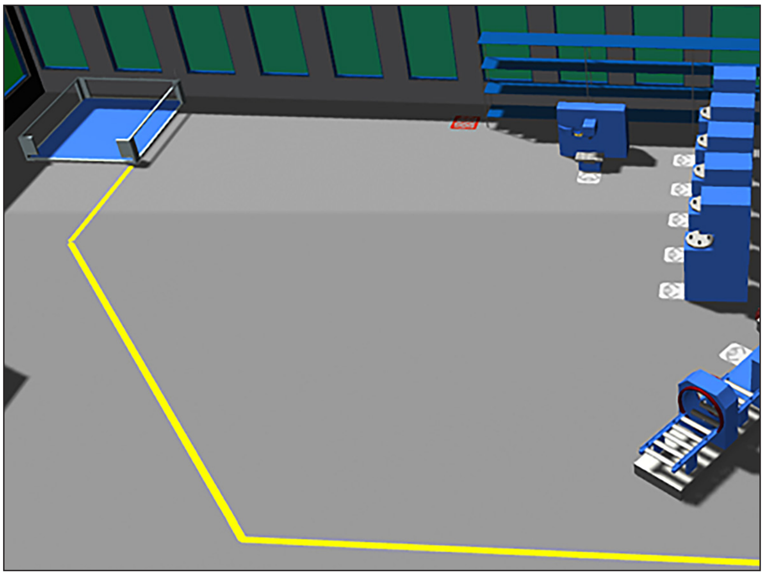

Figure 11. Optimized third zone of the tool shop

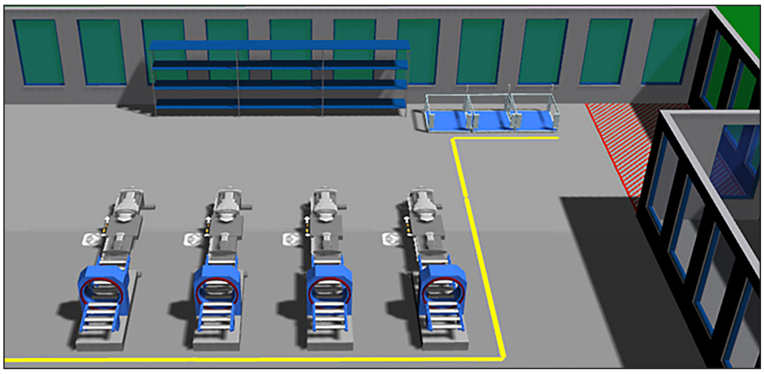

Figure 12. Optimized fourth zone of the tool shop

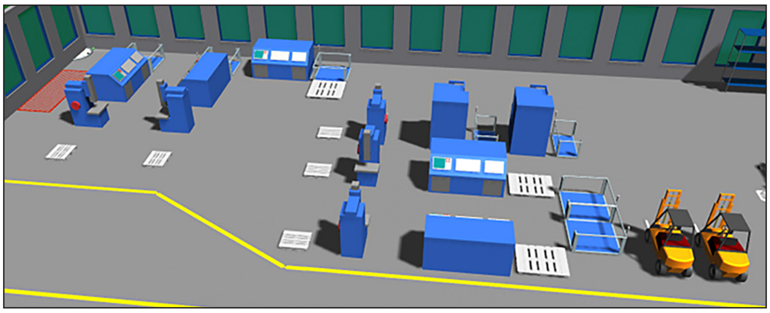

Figure 13. Optimized fifth zone of the tool shop

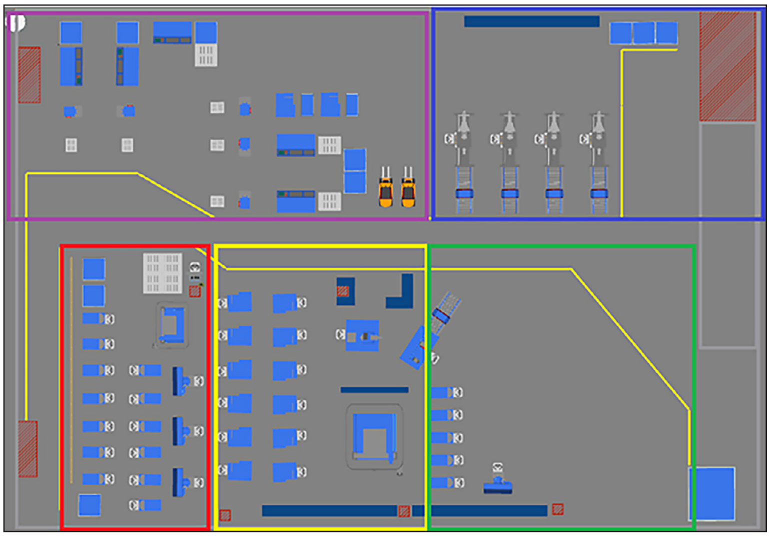

Figure 14. Schematic representation of the optimized workplace [22]

As these are older machines, they are more prone to malfunctions, and the tool storage will be located at the end of the fifth zone. This relocation will save the time that would otherwise be spent by workers moving across the entire production hall, and it will also improve the ergonomics of the workplace. In addition to space and time savings and improved ergonomics, another reason for relocating these presses is the modernization of the workplace. These presses are also planned to be replaced with newer machines over time. The schematic representation of the optimization of the entire tool shop workplace is shown in Figure 14.

CONCLUSIONS

The optimization of the tool shop layout, as presented in this study, demonstrates the tangible benefits of integrating simulation tools into industrial engineering practices. Through careful spatial analysis and strategic planning, the proposed changes addressed both existing inefficiencies and future requirements, aligning operational practices with the long-term vision of the company.

One of the key takeaways is the value of freeing up space in strategic locations to accommodate new, more efficient machines. This ensures a smooth transition toward modernized production while minimizing disruption to current processes. Moreover, the relocation of underutilized or aging equipment – particularly from the zones with spatial constraints – allows for better flow of materials, easier access for maintenance, and overall improved workplace ergonomics.

Another important finding is the impact of machine reorganization on safety and workflow optimization. Aligning machines along consistent material flow directions simplifies supply operations and reduces potential hazards, especially when forklifts are used for material handling. Lastly, this case study exemplifies how digital tools like Plant Simulation empower decision-makers to visualize, test, and implement improvements without physical disruption. It offers a replicable model for other industrial settings aiming to modernize their production layout in a cost-effective and data-driven way.

The proposal of optimization ultimately reaffirms that industrial modernization is not solely about acquiring new technologies, but about intelligently redesigning the systems in which they operate to maximize their potential.

Acknowledgements

This work has been supported by the Scientific Grant Agency of the Ministry of Education of the Slovak Republic (Project KEGA 003EU-4/2025, VEGA 1/0064/23, KEGA 003TUKE-4/2024 and VEGA 1/0383/25).

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