machines

MDPI

Article

Improving Material Flows in an Industrial Enterprise: A Comprehensive Case Study Analysis

Luboslav Dulina [1,2,*], Jan Zuzik [1], Beata Furmannova [1] and Sławomir Kukla [2]

[1] Department of Industrial Engineering, Faculty of Mechanical Engineering, University of Zilina, Univerzitna 8215/1, 010 26 Zilina, Slovakia; jan.zuzik@fstroj.uniza.sk (J.Z.); beata.furmannova@fstroj.uniza.sk (B.F.)
[2] Department of Industrial Engineering, Faculty of Mechanical Engineering and Computer Science, University of Bielsko-Biala, Willowa 2, 43-309 Bielsko-Biala, Poland; skukla@ubb.edu.pl
* Correspondence: luboslav.dulina@fstroj.uniza.sk or ldulina@ubb.edu.pl; Tel.: +421-041-513-2709

Abstract: The primary objective of this research endeavor was to devise an improved workplace design tailored to the demands of a digital factory environment. With the overarching aim of enhancing efficiency and productivity, a comprehensive proposal was formulated to improve layout configurations within the designated enterprise. The key focus lies in minimizing material transit across individual workstations, thereby mitigating potential bottlenecks and streamlining operations. Employing a structured workplace research framework, this study delved into material flow analysis techniques, augmented by the utilization of visTABLE software. While visTABLE served solely to visualize the work environment effectively, it played a crucial role in validating proposed solutions. Notably, the investigation yielded a discernible reduction in beam production time, marking a significant improvement of 10 min. These findings underscored the efficacy of the proposed solutions in addressing specific operational challenges faced by the company. Furthermore, this study facilitated a deeper understanding and visualization of the processes intrinsic to the digital factory environment. Elucidating workflow procedures at the workplace enabled stakeholders to identify areas for further improvement and refinement. In doing so, the research contributed to the overall efficiency and effectiveness of operations within the digital factory, paving the way for continued improvement and innovation in the field.

Keywords: industrial engineering; material flow; digital factory; layout; visTABLE; digitalization

check for updates

Citation: Dulina, L.; Zuzik, J.; Furmannova, B.; Kukla, S. Improving Material Flows in an Industrial Enterprise: A Comprehensive Case Study Analysis. *Machines* **2024**, *12*, 308. https://doi.org/10.3390/machines12050308

Academic Editor: Ou Ma

Received: 13 March 2024
Revised: 20 April 2024
Accepted: 30 April 2024
Published: 1 May 2024

1. Introduction

New industrial technology has increased noticeably in the last few years. The digital factory and its components are among them [1]. The digital factory and its instruments are now the main means of locating and resolving issues with industrial processes and systems [2,3]. In the manufacturing industry, case studies and their solutions are becoming vital resources for businesses looking to manage processes [4].

The phrase "digital factory" refers to a virtual representation of actual production [5,6]. Virtual reality takes the role of reality. It is feasible to validate conflicting scenarios and suggest the best course of action even before a solution is put into practice by using a digital factory [7].

Production and assembly technology, time analyses, processing production and assembly procedures, production system design, robotization, production layout creation, ergonomic analyses, simulation of own production, and internal logistics are all covered by the digital enterprise [8].

Research on the design of production halls, digital factories, material flows, and digital twins is bringing several significant trends and topics to light [9].

The production hall's design is primarily concerned with investigating effective spatial utilization and streamlining the facility's operations [10]. The internet of things, contemporary technology for boosting manufacturing efficiency, and the application of automation are the key trends in this field. The design of workstations with an emphasis on sustainability and ergonomics is also included in this research [11].

The digital enterprise is a prominent area of study, with research mostly concentrating on the incorporation of digital technologies throughout the organization [12]. The digital enterprise also leverages tools such as cloud computing, big data analysis, and artificial intelligence, which have yet to be fully explored [13].

The concept of a digital twin is closely associated with the digital enterprise, which is primarily concerned with the analysis, modeling, and optimization of production processes [14]. The use of improved sensors, simulation technologies, and simulations to produce more precise and efficient production operation execution is a topic of ongoing discussion in this field [15].

In terms of material flows, most of the research in this field focuses on streamlining the flow of materials to minimize warehouse space and guarantee seamless material movement throughout the production process [16]. RFID technology, real-time material tracking, and data analysis are utilized in research to enhance the tracking, management, and monitoring of material flows [17].

It can be claimed that research in these fields is connected to the ongoing transition to intelligent production systems, where innovation and the transformation of digitalization play a significant role. These elements already fit within Industry 5.0 today [18].

This research aims to suggest a process for creating a production workspace within an organization. Regarding the business, it is a privately held engineering firm based in Slovakia that manufactures cranes, crane tracks, and related goods.

Clarifying the production planning issue and describing the production system are the goals of the work's introduction. The subject of software environments and digital enterprises is then discussed. The examination of the company's current situation, which addresses the problem of workplace arrangement during beam production, forms the basis of the work. A strategy for designing the ideal office layout was suggested based on the investigation. Within the digital factory, the digitization of the workplace is aided by the software application visTABLE.

The uniqueness and innovation of this scientific article lie in its pronounced approach to designing a workplace within the context of a digital factory. The central aim of this study is to compile a proposal for improving the workplace layout in a selected company to reduce material flows between individual workstations. This study stands out notably by employing methods of material flow analysis supported by the visTABLE software, which plays a role in validating our proposed solution and effectively visualizing the work environment. The primary outcome of the research is the observed reduction in beam production time by 10 min and the formulation of proposed solutions for the company. This study contributes to visualizing processes within the digital factory, aiming to simplify and clarify workplace operations.

A primary outcome of this research endeavor manifests in the demonstrable reduction in beam production time by a noteworthy margin of 10 min, alongside the delineation of pragmatic solutions tailored to the company's specific operational context. Moreover, this study holds significant implications for enhancing operational transparency and efficiency within the digital factory landscape through its emphasis on visualizing and streamlining workplace processes.

The underlying motivation driving this research endeavor is underscored by a steadfast commitment to enhancing operational efficiency and refining manufacturing processes through innovative workplace design paradigms within the digital factory milieu. The integration of material flow analysis methodologies in tandem with advanced software not only offers novel insights but also furnishes the company with invaluable tools to fortify its competitive edge in the marketplace.

Furthermore, the proposed enhancements to the work environment and operational workflows underscore a dedication to continual improvement and adaptability amidst the ever-evolving manufacturing landscape. In this regard, the research aligns seamlessly with the prevailing trajectory of digital transformation within the industry, offering concrete solutions geared toward enhancing production operations in an era defined by technological advancement and dynamism.

2. Literature Review

The following literature review presents the variety of interests that need to be considered in this matter.

The production system is made up of production and auxiliary means (machines, tools, preparations, energy, etc.) and labor resources, which are interconnected by material and information flow and perform production operations on production objects (materials, raw materials, parts). Current production systems can be characterized by many elements (machines, warehouses, transport systems, control equipment, people), among which there are many complex deterministic and stochastic links. When designing such systems, there are strict requirements for their functional and operational capability, short project time, flexibility, simplicity and safety of operation, low investment, and operating costs [19].

The study by Mattsson et al. [20] provides a significant framework for the universal design of manual assembly workplaces, emphasizing the consideration of diverse individual needs within the context of Industry 5.0. The proposed framework encompasses areas of personalization, context, activities, outputs, methods, and standards, offering companies a structured approach for analyzing and implementing universal workplace design. This holistic approach not only contributes to the discussion on workplace design but also supports an inclusive, efficient, and resilient work environment in alignment with Industry 5.0 goals.

However, there are challenges associated with the implementation of the proposed universal design principles into existing processes and infrastructure within industrial enterprises, which may hinder their practical application and affect their effectiveness. On the other hand, an advantage of this study is that it presents a structured framework that can serve as a valuable tool for analyzing and improving material flows in industrial enterprises [20].

The study by Herwanto et al. [21] presents a pioneering approach to address the specific needs of manufacturing small- and medium-sized enterprises (SMEs). Through a meticulous review of the existing literature and a careful analysis of SME characteristics, the study proposes a tailored workplace design framework. This framework, which is designed to optimize workplace environments for safety, health, and productivity, holds significant implications for industrial enterprises seeking to improve material flows. By providing managers with actionable guidance, the framework contributes to the broader goal of enhancing operational efficiency and overall performance within industrial enterprises.

On the advantageous side, the study offers a bespoke workplace design framework specifically crafted to meet the needs of manufacturing SMEs. Emphasizing safety and health, the framework ensures that workplace environments are conducive to employee well-being while aiming to boost productivity by optimizing workplace layouts and processes.

However, there are also notable disadvantages to consider. The study's sole focus on manufacturing SMEs may limit its applicability to other industries, potentially overlooking insights relevant to broader contexts. Moreover, findings may not be directly transferable to SMEs in different geographical or industrial settings, highlighting the need for further validation through practical application to confirm the framework's efficacy [21].

A paperless checklist for confirming the procedure and production readiness for usage in the industry is covered in studies by Cosme et al. [22]. The essay discusses the benefits of the digital enterprise. The authors claim that the digital enterprise facilitates communication across workstations, as well as processing, visualization, and simulations. Additionally, the studios' digital enterprise enables the collection of production data and a set of equipment using physical sensors built into the machinery. To handle equipment information and monitoring and restart production, the study suggests a paperless checklist. The suitability of the suggested solution is assessed in an actual industrial setting by contrasting it with the current paper-based information logging method. The findings demonstrate that the paperless checklist has benefits over the existing method because it permits numerous viewings and loggings and keeps a digital record of procedure modifications for further examination. The studios were given special attention because the hall arrangement has changed in this studio. As a result, the study will assist in gathering data regarding the disruption and the hall's subsequent restart, which ought to occur as quickly and error-free as feasible [22].

The writers of studies by Lee et al. [23] concentrate on the digital twin and its simulations to guarantee the flow optimization of industrial processes. The authors of the paper stress the value of implementing a digital twin in a manufacturing organization because it guarantees that small- and medium-sized production facilities will become more intelligent and autonomous. The construction and development of digital twin models for the simulation and optimization of manufacturing process flows is the article's primary objective. In the investigations, a multi-agent simulation model was first created. Additionally, a statistical meta-modeling method for creating trials for process optimization is suggested. Thirdly, two novel graph models, the task flow graph and the automated guided vehicle movement graph, are constructed to track and monitor the performance of production workplaces in real time. Experiments are conducted to test and validate the suggested simulation-enabled digital twin approach in representing an actual manufacturing plant. The outcomes of the experiments demonstrate that the suggested approach successfully converts the production workshop, with the aid of a digital twin, into a new class of smart factories. The sequential design of experiments efficiently decreases the computing overhead of expensive simulations and, at the same time, optimally plans the autonomous guided vehicle to achieve production capacity cost-effectively. It is highly promised that this research will assist small- and medium-sized manufacturing factories in making the most of digital twins and big data technologies to obtain a competitive edge in the global market. The layout solution in this study, which took place in the setting of a digital firm, attracted attention to the studies [23].

The projection of production systems is a crucial component of this literature review because it plays a major role in resolving workplace layout issues. You can see which of the studies in this issue received attention in the lines that follow.

The goal of Baron et al.'s study [24] is to use computer software in digital factories to meet production order deadlines. The use of computer simulation tools for the production system to confirm the scheduled dates of production orders in a production company is explained in the article. The creation of a computer model of the assembly hall and the subsequent simulation of the three prohibitions' production flow was mandated by the contractual authority. The distribution of material to the assembly hall, either already created internally or acquired from vendors, marks the start of the material flow. Three computer models built within the Witness Horizon 21 environment were used for simulation tests. The trials verified that the suggested implementation timelines for two monitored orders were implausible. The production layout solution's capacity, the transport and storage system's functionality, the information flow, and the management system's performance may all be assessed using a computer simulation [24].

The article by Nyemba et al. [25] discusses several advantages and disadvantages related to improving material flows in an industrial enterprise. The study focuses on analyzing the modeling and simulation of material flow in a furniture manufacturing plant with multiple products. The outcome is the development of an efficient system that enables timely product deliveries while minimizing costs.

Among the advantages, there is a clear focus on optimizing material flows within the industrial enterprise, contributing to increased efficiency in the manufacturing process. The study provides specific insights into how to enhance product delivery systems and create additional storage space for materials, leading to increased average hourly capacity.

On the other hand, some disadvantages include the limited selection of simulation software and the absence of broader comparisons with other simulation tools. Additionally, the study may be limited to a model with only two products, which could affect its applicability to more complex industrial environments.

Nevertheless, despite these drawbacks, Nyemba et al.'s article offers valuable insights and contributes to further research in the optimization of material flows in industrial enterprises [25].

The study by Králik et al. [26] focuses on improving material flow through plant layout optimization in an existing production facility of a component manufacturing company. Their objective was to propose an optimized layout based on product portfolio analysis, capacity calculations, and optimal machine configuration. They utilized simulation-based optimization calculations to achieve this goal, resulting in a detailed layout with 3D visualization.

The study highlights the importance of appropriate machinery and equipment layout in manufacturing systems within the context of Industry 4.0. It emphasizes the direct impact of optimized layouts on minimizing material handling costs, thus enhancing overall business management. Additionally, the authors advocate for the adoption of lean production principles to further improve production efficiency by reducing waste and continuously enhancing processes.

The integration of lean production methodologies with optimized layout designs is proposed as a comprehensive approach to cost and production system optimization. The authors also note the increasing availability of software systems that facilitate the simulation of production systems, offering interactive 3D visualization and customization options. These software tools allow for the creation and optimization of layout solutions in a virtual environment, without disrupting ongoing production operations [26].

The study by Bučko et al. [27] focused on improving material flow within industrial enterprises as a means to enhance productivity, streamline production processes, and maintain competitiveness in the global market. They emphasized the importance of optimizing production layouts and workflows to eliminate inefficiencies and reduce costs. The study addressed the identification of bottlenecks in production processes and proposed methodologies for optimizing and improving the entire production process, particularly in the context of designing new production lines. By analyzing the original production processes and utilizing optimization tools, the authors developed new production designs to address identified deficiencies. The study employed graphic-analytical analysis methods, investment and economic assessments, capacity calculations, and considerations of building energy efficiency to propose optimal layouts and workflows. Additionally, the study highlighted the significance of precision manufacturing and machinery in optimizing production lines for enhanced efficiency and accuracy [27].

The study by Górnicka et al. [28] focuses on improving material flow through workstation reorganization to enhance the production process. The objective was to increase machine utilization rates within the production process. The authors conducted research using modeling and simulation techniques. It outlined a plan for optimizing workstation layout involving the grouping of workstations into functional work centers and determining the optimal arrangement using the Schmigalla method of triangles. An assessment of the arrangement was conducted by comparing simulation models before and after the reorganization. The study by Górnicka et al. contributes valuable insights into improving material flow within production processes through workstation reorganization. By utilizing modeling and simulation techniques and implementing an optimized layout plan, the authors demonstrated the potential for enhancing machine utilization rates and streamlining material flow. This research provides practical implications for optimizing production systems and improving overall efficiency in industrial settings [28].

This literature review presents a diverse range of approaches to improving material flow within production systems. The production system comprises various interconnected elements, including production and auxiliary means, labor resources, and material and information flows, all of which play crucial roles in achieving operational efficiency and competitiveness.

Studies by Mattsson et al., Herwanto et al., Cosme et al., Lee et al., Baron et al., Nyemba et al., Králik et al., and Górnicka et al. offer valuable insights into different aspects of material flow optimization. Mattsson et al. and Herwanto et al. propose frameworks for a universal workplace design tailored to diverse individual needs and optimized for safety, health, and productivity. Cosme et al. and Lee et al. emphasize the benefits of digital enterprise solutions and digital twins in enhancing communication, data collection, and process optimization. Baron et al. and Králik et al. utilize computer simulation tools and optimization techniques to improve production system performance, while Nyemba et al. and Górnicka et al. focus on the modeling and simulation of the material flow to develop efficient production systems and workstation layouts.

Although each study offers unique contributions and insights, there are challenges and limitations associated with their practical implementation and generalizability. However, collectively, these studies provide a comprehensive understanding of material flow optimization in industrial enterprises and offer valuable frameworks, methodologies, and tools for enhancing productivity, efficiency, and competitiveness.

3. Material and Methods

This chapter provides an overview of the methodology employed in designing a workplace within the framework of a digital factory, aiming to improve material flows and enhance productivity. This study utilized a combination of data collection, analysis, software simulation, and experimental validation.

The current state of material flows and workstations, as well as the subsequent proposal for their rearrangement, were determined using logistic calculations and analyses presented in the fourth chapter of the case study.

The enterprise selected for this study was chosen based on its relevance to the research objectives and cooperation feasibility. Data collection involved gathering information on the existing workplace layout, material flow patterns, and production processes through onsite observations, interviews, and document analysis.

visTABLE software was used to check the proposed solution. It helped with design and assessing different layouts by creating virtual simulations of material flows, considering factors like minimizing material handling distances.

Experiments were conducted within the actual workplace environment to validate the proposed layout improvements. Important performance metrics, including production time and worker productivity, were measured before and after implementing the solutions. Data visualization and statistical analysis were employed to interpret the results and identify trends.

This study resulted in a significant reduction in production time, demonstrating the effectiveness of the proposed layout improvements. Qualitative feedback from workers and supervisors provided valuable insights into the usability and practicality of the new layout solutions.

The configuration of a workstation layout was approached employing a systematic methodology encompassing seven pivotal stages, which are delineated as follows:

- Objective and Requirement Identification: This study began by defining layout objectives and identifying requirements crucial for understanding specific needs and goals. The first step in the process involves the identification of objectives and requirements. Here, it is crucial to define the aims of the new layout meticulously. These objectives may include minimizing material flows, increasing production efficiency, enhancing workstation ergonomics, and addressing any specific needs or constraints unique to the environment. To realize this step effectively, various methods can be employed. One method is conducting thorough interviews and discussions with key stakeholders to understand their perspectives and requirements. Additionally, utilizing observational techniques to assess current workflows and identify pain points can provide valuable insights. Moreover, employing analytical tools, such as value stream mapping or process flow diagrams, can help visualize material flows and identify areas for improvement. By employing these methods, the objectives and requirements can be clearly defined, laying a solid foundation for the subsequent steps in the layout improvement process;

- Data Collection: Data collection occurred within the manufacturing sector, in which relevant information about production processes and workflow procedures was gathered. This involves primarily collecting data on production flows, material transportation between workstations, inter-workstation intensity, and transportation costs. This segment aims to provide the groundwork for analyzing and evaluating the production process, particularly to gather information for analyzing material flow for layout redesign in this study. The second step, data collection, is essential for obtaining a thorough understanding of the current arrangement of the beam workstation. To execute this step effectively, various methods can be employed, catering to different aspects of data acquisition. Observational techniques stand out as a foundational method, wherein trained observers systematically document the layout of the beam workstation. By visually assessing the equipment arrangement, material flows, and operational processes in real time, this method offers valuable insights into the actual functioning of the workstation. In addition to observational methods, leveraging technological tools can enhance data collection efficiency. Technologies like RFID tags or sensors can automate the tracking of material movements and monitor workstation activities. These tools provide precise and detailed data, enabling a more accurate analysis of the workstation's operations. Supplementing these methods, interviews and surveys with employees working at the beam workstation offer qualitative insights. By gathering firsthand experiences and perceptions, this approach adds depth to the data collection process, providing a more holistic understanding of the workstation's functionality. By combining these diverse methods in the data collection step, a comprehensive dataset is compiled. This dataset serves as a solid foundation for informed decision-making in subsequent stages of the improvement process, ensuring that proposed changes are rooted in a thorough understanding of the current workstation arrangement;
- Analysis of the workplace: The third step is the analysis of the workspace. In this phase, the initial focus lies in understanding the cost implications of material transportation between workstations, evaluating transport performance, and assessing material flow intensity. These aspects are integral components of logistic analysis, guiding the identification of shortcomings and potential improvement opportunities within the operational framework. To execute this step effectively, a systematic examination of relevant data is imperative. Observational techniques, such as visually assessing material flows and transport processes, provide valuable insights into the current state of the workspace. Additionally, leveraging technological tools, such as RFID tags or sensors, can automate data collection, ensuring accuracy and efficiency in capturing key metrics. Following the data analysis phase, proposed changes are formulated based on the insights gleaned. These adjustments are communicated to the company for discussion and consideration, with the overarching goal of reducing transportation costs, improving material flow intensity, and enhancing transport performance. However, before implementing these proposed changes, it is crucial to validate their potential impact. This validation process involves testing the suggested adjustments using software simulations. By simulating the proposed changes in a controlled environment, their effectiveness can be assessed, taking into account feedback from the company and insights from the initial data analysis. By employing these methods in the analysis of the workplace, a comprehensive understanding of the current operational framework is achieved, paving the way for informed decision-making and impactful improvements;
- Virtual Simulation Construction: Virtual simulations were created using relevant software tools to visualize and validate proposed solutions before practical imple-

mentation. To execute this step effectively, various methods can be employed. Firstly, collaborative discussions with key stakeholders can help in finalizing the chosen layout alternative, ensuring alignment with organizational goals and objectives. Additionally, utilizing visual aids, such as 2D layout diagrams or 3D models, can provide clarity and facilitate communication during the implementation process.

- Experimentation Planning and Execution: Based on the identified objectives and criteria, a range of alternative layout schemes were developed, meticulously planned, and executed;
- Layout Implementation: After careful consideration, the most suitable layout alternative was chosen and implemented to transform the workstation. This step aimed to address the identified deficiencies and enhance the overall workspace;
- Result Evaluation and Enhancement: The outcomes of the implemented changes were comprehensively evaluated against the original layout. Areas requiring improvement were identified, prompting necessary adjustments to improve the workstation configuration.

Effective communication with the company regarding solution implementation was vital during the process. Following this systematic approach established a clear methodology for developing an efficient workstation layout. This ensured alignment with predetermined objectives and promoted an environment conducive to ongoing improvement. This study emphasizes the significance of enhancing workplace design to streamline material flows and boost manufacturing efficiency. It highlights the value of utilizing digital technologies, like simulation software, to inform decision-making and facilitate continuous improvement in the digital factory setting. Overall, this study underscores the importance of improving workplace design to optimize material flows and enhance efficiency in manufacturing operations, emphasizing the role of digital technologies in driving continuous improvement in the digital factory environment.

4. Case Study

The main objective of this study is to propose an improvement of the workplace layout and production flow in the company concerning Industry 4.0 in the digital factory environment.

The sub-objectives of the case study include:

- To examine the company from the manufacturing sector and to examine the scope of activities and services provided by the company;
- To analyze the current state of the selected company in which the case study is carried out in the field of production systems design and the level of digitization.

A production process is a set of activities of people, means of production, and physical processes that requires one or more types of input and forms an output that has value for the customer. These are activities by which the material is transformed into a product or an order into customer service [29,30].

To ensure the effective functioning of the production system, this case study researched specific elements of the production process, especially the company's flow production and layout. The aim was to streamline the conversion of inputs into valuable outputs for the customer. Given that customers typically have limited visibility into the realization of these outputs, their primary concern lies in the product or service [31,32].

4.1. Unveiling the Examined Company: In-Depth Company Description

The company, located in Slovakia, was established in 1994 as a limited liability company specializing in engineering production. It currently employs 27 individuals and is classified as a small business. The company is involved in the production of cranes and crane tracks. It then assembles the cranes and puts them into operation with all the obligations of the supplier.

The organization's staff is highly experienced and capable of meeting client needs. They have access to manufacturing facilities, assembly vehicles, and measuring tools, along with compliance with STN standards. The business holds necessary licenses and certifications, including ISO 9001 for its quality management system. This system ensures that the production, assembly, and repair of lifting and electrical equipment adhere to established standards and regulations.

4.2. Subject of the Company's Activity

Because the company specializes in producing and assembling cranes and crane tracks, specific activities include the following:

- Production, assembly, repair, and maintenance of lifting equipment;
- Production, assembly, repair, and maintenance of electrical equipment;
- Designing dedicated electrical equipment;
- Production, installation, and repair of electrical machines and devices;
- Production, assembly, and repair of consumer electronics;
- Installation and repair of measuring and control equipment;
- Electrical installation;
- Intermediary, retail, and wholesale trading;
- Business consulting and technical consulting;
- Welding services;
- Advertising;
- Education and training in labor protection, focusing on load binders.

The company adheres to relevant standards in crane production and assembly.

4.3. Unveiling the Product Portfolio: A Glimpse into the Company's Offerings

The company offers a wide range of products, including:

- Crane technology;
- Engineering production for construction, food, and advertising industries;
- Production of electrical switchboards.

In crane technology, they manufacture various types of cranes and related equipment, such as crane cabins and maintenance services.

For the construction industry, they produce beams, brackets, bridges, steps, and ladders, among other items.

In the food industry, the company specializes in engineering products made of stainless steel, tailored to customer needs.

They also provide engineering products for advertising, such as billboard structures.

Additionally, the company produces and installs electrical switchboards, including meter switchboards and custom switchboards.

The diverse product range influences workspace design, requiring specific processes and environments. For example, crane assembly may need dedicated areas, while switchboard production requires clean spaces. Understanding these needs allows for effective workspace design and innovation to optimize workflows.

Figure 1 shows an example of a special welding technique produced by the company.

Figure 1. Special crane technology produced in the company.

4.4. Evaluating the Current Work Environment: A Comprehensive Review

This section established a study of the workplace as it exists currently, which includes gathering, processing, and analyzing the relevant data. The information and analytical findings will be used to identify inefficiencies and opportunities for enhancing the chosen work environments, and they will also serve as the foundation for recommendations for potential solutions.

4.4.1. Analysis of the Company Areas

In this design phase, there is a detailed mapping of all in-house areas that are available for the next design stage. A business that has enough areas at its disposal may not be successful unless it can use these areas efficiently and purposefully.

The procedure for analyzing the surfaces was established through the following steps:

- Mapping of spaces (video sequences, photo documentation);
- Measurement of areas: directly in the plant (manual method or digital method) or using drawing documentation;
- Drawing construction and energy restrictions into the existing drawing documentation according to the actual state;
- Correction of drawing documentation due to its out-of-dates.

Figure 2 illustrates the layout of the production hall, offering a comprehensive overview of its spatial organization. Positioned on the left side is the production preparation area, housing requisite materials and machinery crucial for the manufacturing process. Notably, a bandsaw facilitates rod division, while a crane with a hoist groove supports material handling operations. Adjacent to this, sheets are cut using scissors. Moving toward the central section unveils the main production area, featuring prominent equipment, such as a bandsaw, roller conveyor, drills, and a grinder. Cranes are strategically positioned throughout the facility to optimize material handling efficiency. Finally, toward the right segment of the image, a sheet metal bender is observed, providing a holistic depiction of the production hall's layout.

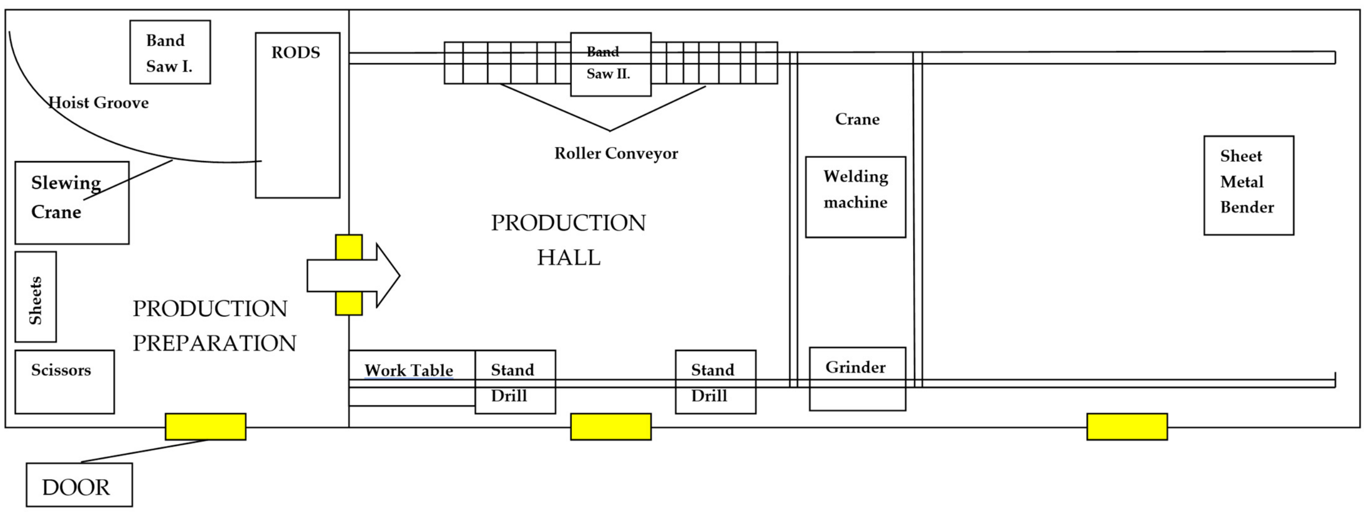


Figure 2. Workplace layout in the company.

The analysis of business areas was carried out directly in production. The sizes of individual areas were manually measured and processed in Table 1. The areas were divided into production, storage, auxiliary, and transport areas. Table 1 shows individual surfaces.

It can be seen in Table 1 that the total measuring area is 723 m^2. Production areas occupy 546 m^2, storage areas occupy 19 m^2, auxiliary areas occupy 30 m^2, and transport roads occupy 128 m^2.

Table 1 also shows the percentage of individual areas. It is clear from Table 1 that the production areas occupy 75% of the total areas of the enterprise. Transport communication occupies 18% of the total areas of the enterprise, auxiliary areas occupy 4% of the total areas of the enterprise, and only 3% of the total areas are occupied by warehouse areas. From the area ratio in %, the company uses its areas as production areas as much as possible.

Table 1. Overview of the analysis of areas in the company.

Area	Surface (m^2)	Note	Company Areas (%)
Production areas	546	The area of the production hall	75%
Warehouse areas	19	Sheet metal and rods	18%
Auxiliary surfaces	30	Unpacking, waste sorting	4%
Transport communications	128	Traffic roads	3%

4.4.2. Analysis of the Production Process

The crux of resolving the spatial configuration of the production process hinges upon the interplay between production layout and material handling. Whether it entails revamping an existing production layout or devising a new one, the overarching objective remains the economical and efficient movement of materials. Consequently, an inherent correlation exists between production layout and material handling, with any comprehensive analysis of material movement inexorably tied to the production layout. Subsequently, the forthcoming section will delve into the analysis of the beam manufacturing process, as depicted in Figure 3.

Figure 3. Representation of the analyzed beam.

In the beginning, basic data collection was carried out. The input data represented a simplified technological procedure, the duration of individual operations, predecessors of operations, and the number of workers on individual technological operations. This information is divided into two tables for better clarity and visibility.

Table 2 describes the operation number, operation description, number of workers, and duration time. Operation 1 requires one worker and takes four hours to complete.

Operation 2 requires one worker and takes four hours to complete. Operation 3 requires a single worker and takes three hours to complete. It takes two hours and two workers to complete operation 4. Operation 5 takes four hours to complete and requires one person. Operation 6 takes eight hours and needs one person. It takes 30 min and two people to complete operations 7 and 10. Operation 8 takes one hour and needs one person. One worker is needed for operation 9, which takes two and a half hours to complete.

Table 2. Duration and number of workers in the technological procedure of beam production.

Operation Number	Description of the Operation	Number of Workers (pcs)	Duration Time (h)
1	Dividing the material (beam) to the required size.	1.0	4.0
2	Sheet metal cutting—contact plates.	1.0	4.0
3	Drilling holes for sheet metal.	1.0	3.0
4	Grinding of material (beam).	2.0	2.0
5	Firing the ends of the beam to accommodate the main cross member.	1.0	4.0
6	Welding of contact plates to the beam.	1.0	8.0
7	Checking the dimensions of the beam.	2.0	0.3
8	Dividing the square (rail) to the required size.	1.0	1.0
9	Welding the square to the beam.	1.0	2.3
10	Check dimensions.	2.0	0.3

4.4.3. Analysis of the Production Process

In the case of detailed design, it is advantageous to use a production progress table instead of a classic diagram of the production process because it represents a more detailed record of individual activities with the product in the process of its processing (operation number, type of operation, description, duration, distance). The analysis of the production process is a good starting point for the analysis of the production process from the point of view of the creation of added value. The production progress table can be seen in the Table 3.

Table 3 presents an analysis of the production process and material flow, complementing the main operations outlined in Table 2. This table provides insights into intermediate operations, their respective durations, and the distances covered. Additionally, a graphical representation of the material flow is depicted in red colour, delineating the nature of operations, as illustrated in the lower section of Table 3.

It can be seen in Table 3 that during operation 1, in which the material enters the production hall, 30 m are traveled, and the duration of this operation is 20 min. Operation 4 takes 10 min, the distance traveled is 10 m, and this operation involves moving the beam to the workplace. During operation 6, there is a transfer to the welding workplace, the duration of this operation is 3 min, and the distance covered is 4 m. In operation 8, in which sheet metal is supplied to the workplace, the duration is 3 min and the distance traveled is 1.5 m. During operation 10, the sheet metal is moved to the drill, the time for this operation is 10 min, and the distance traveled is 16 m. During operation 12, the contact plates are fed to the beam, the duration of this operation is 5 min, and the distance covered is 5 m. Operation 15 takes 3 min, the distance traveled is 3 m, and this operation involves moving the square to the first saw. During operation 17, the square is fed to the beam, the duration is 10 min, and the distance traveled is 19 m. The other operations that are described in Table 4 were specified in more detail in Tables 2 and 3.

Table 3. Production progress table—analysis of production and material flow.

Analysis of the Production Process Product: Beam						
Oper.	**Time (min.)**	**Distance (m)**	**Description of the Operation**	**Type of Operation**		
				Operation	**Transportation**	**Control**
1	20	30	Entry of material into the production hall.	○	⇨	□
2	240		Dividing the material (beam) to the required size.	○	⇨	□
3	30		Checking the dimensions of the beam	○	⇨	□
4	10	10	Moving the beam to the workplace.	○	⇨	□
5	120		Beam grinding.	○	⇨	□
6	3	4	Transfer to the welding workplace.	○	⇨	□
7	240		Firing the ends of the beam to accommodate the main cross member.	○	⇨	□
8	3	1.5	Supply of sheet metal to the workplace.	○	⇨	□
9	240		Cutting sheet metal to the required size.	○	⇨	□
10	10	16	Moving the sheet to the drill.	○	⇨	□
11	180		Drilling holes for sheet metal.	○	⇨	□
12	5	5	Supply of contact plates to the beam.	○	⇨	□
13	480		Welding of contact plates to the beam.	○	⇨	□
14	30		Checking the dimensions of the beam.	○	⇨	□
15	3	3	Moving the square to the first saw.	○	⇨	□
16	60		Dividing the square to the required size.	○	⇨	□
17	10	19	Supply of the square to the beam.	○	⇨	□
18	150		Welding the square to the beam.	○	⇨	□
19	30		Check dimensions.	○	⇨	□

Table 4. Intensity of material flows between workplaces—current state.

		Receiver									
		1	2	3	4	5	6	7	8	9	Σ
Sender	1					20,000					20,000
	2						400				400
	3				1500						1500
	4									1200	1200
	5								19,000		19,000
	6							300			300
	7									240	240
	8									19,000	19,000
	9										-
	Σ	-	-	-	1500	20,000	400	300	19,000	20,440	61,640

4.4.4. Analysis of the Intensity of Material Flows

This section presents a table detailing traffic relations among individual workplaces. This tool facilitates the assessment of material flow intensity between workplaces, aiming to improve spatial proximity where material flow is highest. The table is structured into squares, each representing the volume of material transported between specific workplaces. Vertically, workplaces sending relevant materials are listed, while horizontally, those receiving the materials are identified. Table 4 provides data on material relations between individual workplaces, quantified in kilograms per month.

In Table 4, for a closer understanding, the individual numbers represent workplaces in the production section during the production of the beam. Number 1 represents the profile warehouse, number 2 represents the sheet metal warehouse, number 3 represents the bar warehouse, number 4 represents the first saw, number 5 represents the second saw, number 6 represents the cutting workplace, number 7 represents the drilling workplace, number 8 represents the grinding workplace, and number 9 represents the welding workplace.

It is also evident from Table 4 that 20,000 kg of material is moved from the saw II profile warehouse. From the sheet metal warehouse to the cutting area, 400 kg of material is moved. The bar warehouse ships 1500 kg of material to sawmill I. From sawmill I, 1200 kg of material is moved to the welding workspace. A total of 19,000 kilograms of material is brought to the grinding facility from sawmill II. From the cutting workspace to the drilling workspace, 300 kg of material is moved. From the drilling site to the welding site, 240 kg of material is moved. From the grinding area to the welding area, 19,000 kg of material is moved. This is the transport of material in one month.

In conclusion, sawmill I processes 1500 kg of material every month. In workplace saw II, 20,000 kg of material passes through each month. Every month, 400 kg of material goes through the cutting workspace. Every month, 300 kg of material goes through the drilling site. Every month, 19,000 kg of material goes through the grinding area. Every month, 20,440 kg of material goes through the welding workspace. It follows that the welding workplace will see the highest monthly volume of material flow through it, a total of 20,440 kg.

In Table 5, it is possible to see a table of distances between individual workplaces for the current state. Between the profile warehouse and bandsaw II is a distance of 30 m. There is a distance of 1.5 m between the sheet metal warehouse and the cutting area. There is a distance of 3 m between the bar warehouse and bandsaw I. There is a distance of 19 m between bandsaw I and the welding workplace. Between bandsaw II and the grinding workplace is a distance of 10 m. There is a distance of 16 m between the cutting and drilling workplaces. The distance between drilling and grinding is 5 m. The distance between grinding and welding is 4 m.

Table 5. Distance between workplaces in meters—current state.

		Receiver								
		1	2	3	4	5	6	7	8	9
Sender	1					30.0				
	2						1.5			
	3				3.0					
	4									19.0
	5								10.0	
	6							16.0		
	7									5.0
	8									4.0
	9									

In Table 6, it is possible to see the transport performance between workplaces in meters. The following mathematical formula is required to calculate the transport performance:

$$P = i*d \tag{1}$$

Table 6. Transport performance between workplaces—current state.

		Receiver									
		1	2	3	4	5	6	7	8	9	Σ
Sender	1					60,000					60,000
	2						600				600
	3				4500						4500
	4									22,800	22,800
	5								19,000		19,000
	6							4800			4800
	7									1200	1200
	8									76,000	76,000
	9										-
	Σ	-	-	-	4500	60,000	600	4800	19,000	100,000	899,900

In the mathematical formula, P represents transmission performance (piece*m/month), i represents intensity (piece/month), and d represents the distance between workplaces (m).

It follows from Table 6 that the transport performance between the profile warehouse and bandsaw II is 60,000. The transport capacity between the sheet metal warehouse and cutting is 600. The transport capacity between the bar warehouse and bandsaw I is 4500. The transport capacity between bandsaw I and welding is 22,800. The transport capacity between bandsaw II and grinding is 19,000. The transportation capacity between cutting and drilling is 4800. The transportation capacity between drilling and welding is 1200. The transportation capacity between grinding and welding is 76,000. The total transportation capacity is 899,900 pieces*m/month.

In Table 7, it is possible to see the cost of transporting one piece of product. The product cost of one piece of product is EUR 1.5 per meter, which is internal data provided by the company. The following mathematical formula expresses the calculation of transport costs:

$$N = i*n \tag{2}$$

Table 7. The cost of transporting one piece of beam—current state.

		Receiver									
		1	2	3	4	5	6	7	8	9	Σ
Sender	1					EUR 900,000					EUR 900,000
	2						EUR 900				EUR 900
	3				EUR 6750						EUR 6750
	4									EUR 34,200	EUR 34,200
	5								EUR 285,000		EUR 285,000
	6							EUR 7200			EUR 7200
	7									EUR 1800	EUR 1800
	8									EUR 114,000	EUR 114,000
	9										-
	Σ	-	-	-	EUR 6750	EUR 900,000	EUR 900	EUR 7200	EUR 285,000	EUR 150,000	EUR 1349,850

In the mathematical formula, N represents total transport costs (EUR/month), i represents intensity (piece/month), and n represents transport costs of one piece (EUR/piece).

The cost of transportation between the profile warehouse and bandsaw I is EUR 900,000. The cost of transportation between the sheet metal warehouse and cutting is EUR 900. The cost of transportation between the bar warehouse and bandsaw I is EUR 6750. The cost of transportation between bandsaw I and welding is EUR 34,200. Transportation costs between bandsaw II and grinding is EUR 285,000. The cost of transportation between cutting and drilling is EUR 7200. The cost of transportation between drilling and welding is EUR 1800. The cost of transportation between grinding and welding is EUR 114,000. The total cost of the original layout of the workplaces came to EUR 1,349,850.

5. Proposal Using a Digital Factory

This section of the study includes a workspace design for a digital factory. It will specifically deal with creating the workspace in the visTABLE software's digital factory environment. The visTABLE tool serves as a supporting application for the static design of production systems. It will entail designing a workspace layout based on an assessment of the existing situation.

The research was carried out using facilities within the Faculty of Mechanical Engineering of the University of Žilina in Žilina at the Department of Industrial Engineering, specifically, visTABLE software with version 3.0.107, 2020.3.531.0. The license information is visTABLE Touch Education.

Developing an Effective Workplace Layout

Depending on the production concept, the workspace layout can be created automatically, or you can design your layout by adding your workspace components as needed. As previously indicated, the layout was designed using the visTABLE application.

The visTABLE tool serves as a supporting application for the static design of production systems. The software contains applications that facilitate the designer's work and decision-making when designing the layout of the workplace and the entire production layout. The following activities are primarily supported in the visTABLE application:

- Interactive layout design in the project team;
- Creating material flow analyses;
- Flexible adaptation of production to commercial and innovative changes;
- Team elaboration of detailed designs of spatial structures;
- Checking and observing minimum distances;
- Evaluation of the layout solution.

The present state of each machine's layout was likewise analyzed in visTABLE. It is depicted in Figure 4 below.

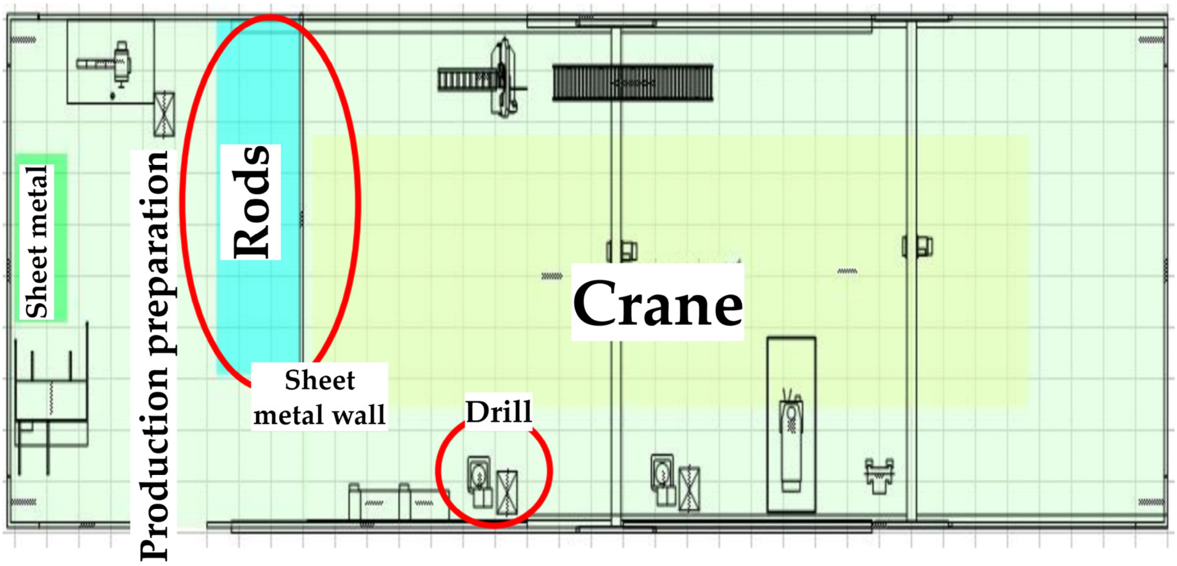


Figure 4. Workplace layout of the current state created in visTABLE.

The visTABLE environment's current situation in the workplace is depicted in Figure 4. The sole distinction between this arrangement and that in Figure 2 is that this layout was made in a digital setting. The red circles mark the space for the rods, the sheet metal wall and the drill as seen in Figure 4.

In Figure 5, it is possible to see the methodology for designing a new layout arrangement of a beam workstation using visTABLE touch software with inclusive validation.

The first step is the identification of objectives and requirements. In this step, it is necessary to define the objectives of the new layout, such as minimizing material flows, increasing production efficiency, improving workstation ergonomics, and establishing requirements for the new layout based on the specific needs and constraints of the environment.

The second step is data collection. In this step, it is necessary to gather data on the current arrangement of the beam workstation, including equipment layout, material flows, and operations.

The third step is the analysis of the workspace. In the analysis of the workplace, the initial step involves conducting a thorough examination of relevant data. This process aims to identify any shortcomings within the current operational framework and to pinpoint potential opportunities for improvement. Key areas of focus during this stage include assessing transportation costs, material flow intensity, and the performance of transport between workstations.

Following the data analysis phase, the next step is to propose changes based on the insights gained. These proposed adjustments are communicated to the company for discussion and consideration. The overarching objective is to suggest measures that will effectively reduce transportation costs, improve material flow intensity, and enhance transport performance within the workplace.

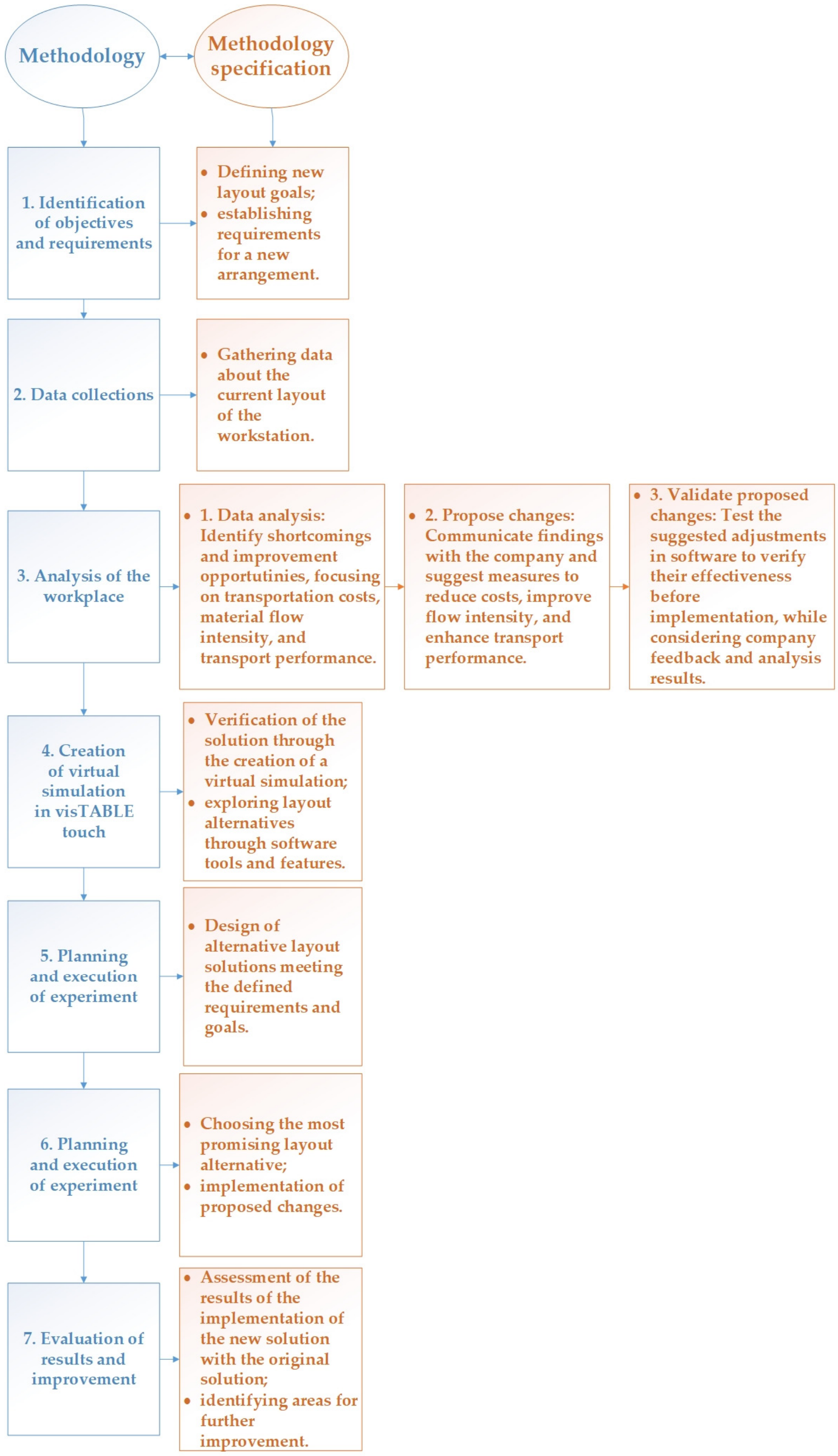


Figure 5. Methodology for designing a new layout arrangement of a beam workstation using visTABLE touch software with version 3.0.107, 2020.3.531.0.

However, before these proposed changes are implemented, it is essential to validate their potential impact. This validation process involves testing the suggested adjustments using software simulations. By doing so, the effectiveness of the proposed changes can be assessed in a controlled environment, taking into account feedback from the company, as well as insights gleaned from the initial data analysis.

In step 4, the creation of a virtual simulation in visTABLE touch is required. The step is ensured by utilizing the visTABLE touch software to create a virtual simulation of the current workstation layout. Explore various alternative layout arrangements using the tools and functionalities of the software.

Step 5 involves planning and executing validation procedures. This step ensures the creation of multiple alternative layout arrangements, meeting predefined objectives and requirements through virtual simulation. It entails planning the validation process, which includes defining measurable performance indicators and conducting assessments before implementing the new layout.

In the sixth step, the implementation of the new layout will be performed. It is necessary to select the most promising layout alternative based on the results of the simulation and validation. Implement the proposed changes in the actual beam workstation environment.

In the last step, an evaluation of results and improvement is carried out. This step consists of assessing the outcomes of implementing the new layout through measurements and comparisons with the original data. Identify any areas for further improvement.

This methodology aims to ensure a systematic and validated approach to designing a new layout arrangement for the beam workstation using the visTABLE touch software.

The basic design of the new workplace layout is shown in Figure 6.

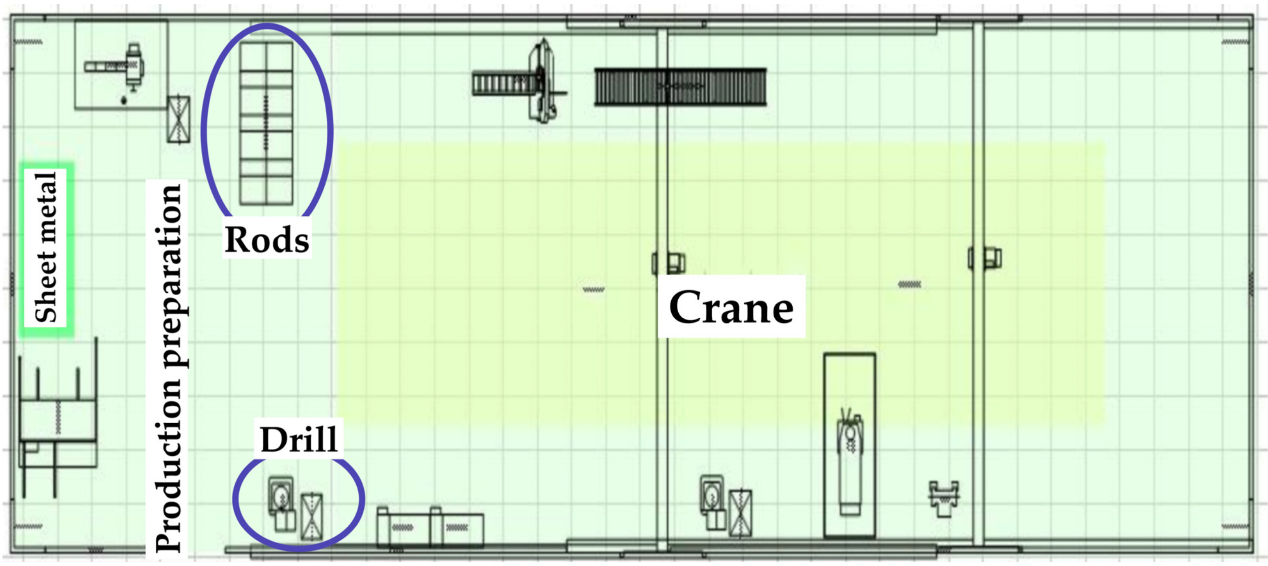


Figure 6. Workplace layout of the design state created in visTABLE.

In this proposed arrangement, it is recommended to remove the sheet metal wall to increase surface area and improve material flow efficiency between the production preparation area and the production hall. It is important to maintain the core region of the production hall for welding surfaces; thus, no changes are suggested in this area. Another proposed improvement involves relocating the standing drill closer to the shears and sheets to reduce transportation time. Stacking bars in a stacker is advised for safety reasons and to optimize storage space. Additionally, implementing workplace standards is recommended to enhance worker safety, reduce handling time, and improve tool accessibility.

The application of the targeted factory in visTABLE is explained to clarify the methodological approach. The data input into visTABLE include parameters related to the factory layout, such as workstation arrangement, material flow paths, and distances within the facility. The decision-making process for the improved approach is not solely based on human experience but follows a systematic methodological framework.

Logistic analyses conducted in preceding chapters played a crucial role in informing the approach to workspace improvement. These analyses aimed to reduce transportation costs, enhance transport performance, and improve material flow intensity. These factors were key considerations in workspace enhancement and were communicated to the company stakeholders through mutual human interaction and communication channels.

Therefore, the application of the targeted factory in visTABLE was guided by a systematic methodological approach informed by logistic analyses and collaborative communication with company stakeholders.

6. Results and Discussion

This section provides an overview of the results obtained from the comparison between the current state and the proposed design, along with an evaluation of the benefits and outcomes of the suggested solution.

The primary aim of this study was to recommend an improved layout for the beam manufacturing workstation through an in-depth analysis of the existing conditions.

In this study, logistic analyses conducted in previous chapters played a significant role. These analyses aimed to reduce the cost of transporting materials between workstations, enhance transport performance, and improve material flow intensity. Workplaces showing high or unsatisfactory values in the analysis were targeted for improvement through collaborative communication with the company. These factors were crucial in enhancing the workplace and were communicated with the company stakeholders through mutual human interaction. Additionally, the methodology outlined in Figure 5 was utilized in the process.

Figure 7 depicts the newly configured workstation layout generated using the visTABLE application. Additionally, subsequent images present detailed three-dimensional renderings of specific design proposals.

(**a**) (**b**)

Figure 7. (**a**) The state before the removal of the sheet metal wall from the production hall (current state, (**b**) The state after the removal of the sheet metal wall from the production hall (design state).

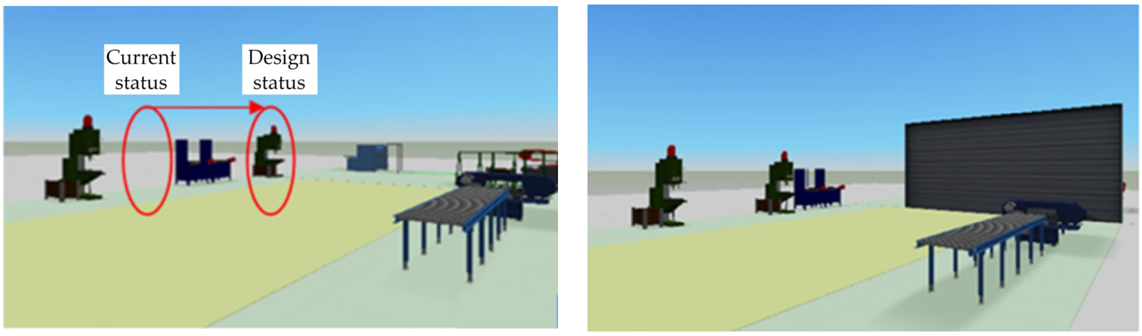
Figure 7 illustrates a virtual simulation depicting the removal of a sheet metal wall within the production hall. The first image portrays the state before the removal of the sheet metal wall, while the subsequent image illustrates the post-removal scenario, in which the sheet metal wall dividing the production preparation area from the main production hall has been eliminated. This alteration was deemed necessary to improve material handling processes and maximize space utilization within the facility.

The comparison between the before and after states offers valuable insights into the potential improvements achieved through the proposed layout changes. These visual representations serve to underscore the efficacy of the suggested solution in addressing identified inefficiencies and enhancing overall workflow efficiency within the beam manufacturing environment.

Further discussion and analysis delve into the specific advantages and drawbacks of the proposed layout alterations, considering factors such as improved material flow, enhanced worker safety, and increased productivity. Additionally, potential challenges or limitations associated with the implementation of the new layout are addressed, along with recommendations for mitigating these issues to ensure successful adoption and integration into the existing operational framework.

In addition to the layout modifications mentioned previously, another key aspect of the proposal involved relocating the stand drill to a position closer to the sheet metal cutting workplace. This strategic adjustment aimed to streamline the material flow process by establishing a more direct pathway from the scissors to the stand drill, thereby reducing handling time and improving material flow efficiency.

Figure 8a depicts the existing state, wherein the stand drill is situated at its original location, while Figure 8b illustrates the proposed design state, showcasing the relocated stand drill positioned in closer proximity to the sheet metal cutting area. This reconfiguration not only minimizes the distance traveled by materials between processing stages but also facilitates a more seamless transition between the cutting and drilling operations.



(**a**) (**b**)

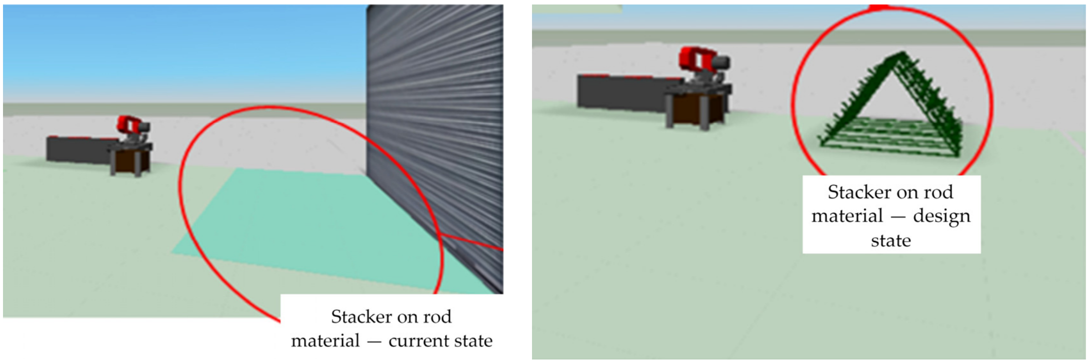
Figure 8. (**a**) The current state of the stand drill; (**b**) the design state of the stand drill.

The implementation of this relocation strategy is anticipated to yield several potential benefits, including enhanced operational efficiency, reduced production lead times, and improved overall productivity. By consolidating related processes within proximity, the proposed layout modification promotes a more cohesive and integrated workflow, thereby fostering a conducive environment for improved manufacturing operations.

Moreover, the discussion surrounding this proposed change would delve into the broader implications and ramifications of the relocation, considering factors such as potential cost implications, ergonomic considerations, and the impact on worker morale and satisfaction. By evaluating these aspects comprehensively, the feasibility and effectiveness of the proposed relocation can be thoroughly assessed, enabling informed decision-making and ensuring alignment with the overarching goals of the workplace improvement initiative.

Overall, the relocation of the stand drill represents a strategic intervention aimed at enhancing the efficiency and effectiveness of material handling processes within the manufacturing environment. Through careful planning and the consideration of various factors, this proposed modification has the potential to contribute significantly to the attainment of operational excellence and sustainable business success.

In anticipation of the production phase, a decision was made to introduce a new stacker for rods to address the issue of their unorganized storage on the floor. The previous storage arrangement was deemed inadequate in terms of both handling efficiency and safety considerations. Figure 9 provides a visual representation of the newly implemented stacker positioned atop the rod materials, illustrating the improved storage solution. The introduction of the stacker serves to alleviate concerns associated with the haphazard storage of rods on the floor, which not only posed logistical challenges during material handling but also raised safety hazards within the production environment. By consolidating the storage of rods onto the stacker, space utilization is improved, and the risk of workplace accidents stemming from tripping hazards and obstruction of walkways is mitigated.



(**a**) (**b**)

Figure 9. (**a**) Placement of stacker on rod material—current state; (**b**) placement of stacker on rod material—design state.

The decision to implement the new stacker aligns with the overarching objective of enhancing operational efficiency and safety standards within the manufacturing facility. Through the adoption of this improved storage solution, the accessibility and organization of rod materials are significantly enhanced, facilitating smoother material handling processes and minimizing the likelihood of workplace incidents.

Furthermore, the discussion surrounding this initiative would delve into the anticipated benefits and potential drawbacks associated with the introduction of the stacker. Considerations such as the investment cost, impact on workflow dynamics, and employee training requirements would be evaluated to ensure a comprehensive understanding of the implications of this decision.

Overall, the introduction of the stacker for rod storage represents a proactive measure aimed at improving resource utilization and promoting a safer working environment. By addressing the shortcomings of the previous storage arrangement, this strategic intervention contributes to the achievement of broader operational objectives and underscores the organization's commitment to continuous improvement and employee welfare.

Table 8, which calculates the differences between the existing and the proposed condition, provides a comparison of the current situation and the suggested solution.

Based on the comparison of the current (C) and design (D) variants, it was found that the company can reduce the production of the beam from 1864 min to 1854 min. Therefore, the beam production time would be reduced by 10 min. Time reduction is possible in the following operations: moving the sheet to the drill, the supply of contact plates to the beam, and the supply of the square to the beam. The main benefit of the work is the shortening of the material flow by 15 m from the original 88.5 m to 73.5 m.

Process visualization ensures the simplification and transparency of workplace processes and is used to prevent people from making unnecessary mistakes. This will also improve communication in the workplace. Other recommendations for the company are as follows:

- Color marking of assembly components;
- Signs for storing tools;
- Markers for storing materials;
- Pictorial assembly or production procedures;
- Think about the introduction of robots in the workplace in the future and pay attention to the development of the relationship between the employee and the robot.

Table 9 presents a comprehensive summary of the pivotal metrics scrutinized within the scope of this case study. Notably, the distance traversed in the material flow pathway exhibited a discernible reduction, decreasing from the initial 88.5 m to a more efficient

73.5 m. This reduction of 15 m represents a substantial improvement, quantified as a percentage decrease of 16.95%. Similarly, the production time underwent improvement, dwindling from 1864 min to 1854 min, reflecting a marginal but significant decrease of 10 min, equivalent to a 0.54% reduction.

Table 8. Comparison of the current (C) and design solution (D).

Oper.	Duration (min.)		Distance (m)		Description of the Operation
	C	D	C	D	
1	20	20	30	30	Entry of material into the production hall.
2	240	240			Dividing the material (beam) to the required size.
3	30	30			Checking the dimensions of the beam.
4	10	10	10	10	Moving the beam to the workplace.
5	120	120			Beam grinding.
6	3	3	4	4	Transfer to the welding workplace.
7	240	240			Firing the ends of the beam to accommodate the main cross member.
8	3	3	1.5	1.5	Supply of sheet metal to the workplace.
9	240	240			Cutting sheet metal to the required size.
10	10	4	16	8	Moving the sheet to the drill.
11	180	180			Drilling holes for sheet metal.
12	5	4	5	4	Supply of contact plates to the beam.
13	480	480			Welding of contact plates to the beam.
14	30	30			Checking the dimensions of the beam.
15	3	3	3	3	Moving the square to the first saw.
16	60	60			Dividing the square to the required size.
17	10	7	19	13	Supply of the square to the beam.
18	150	150			Welding the square to the beam.
19	30	30			Check dimensions.

Table 9. Summary of key indicators.

Indicator	Current Solution	Design Solution	Difference	% Difference
Distance (m)	88.5	73.5	15	16.95
Duration (min.)	1864	1854	10	0.54
Transport performance (pcs/m)	899,900	890,060	9840	1.09
Transport costs per piece (EUR)	1,349,850	1,335,090	14,760	1.09

Furthermore, the transport capacity underwent meticulous evaluation, with the original solution boasting a capacity of 899,900 pcs/m, which contrasted with the proposed solution's capacity of 890,060 pcs/m. This difference, amounting to 9840 pcs*m, translates to a percentage disparity of 1.09%, signifying a notable enhancement in transport efficiency facilitated by the proposed layout adjustments.

An additional noteworthy parameter scrutinized was the transport cost per piece, which incurred a reduction from 1,349,850 in the current state to 1,335,090 in the proposed design state. This difference of 14,760 units, when expressed as a percentage, also equates to a 1.09% decrease, underlining the financial benefits associated with the proposed layout modifications.

In the methodology employed, visTABLE served as an invaluable supplementary tool for the static design of production systems, providing a visual representation of the layout and facilitating the digitization of the workspace. Building upon this foundation, a strategic proposal was formulated, with a specific focus on relocating the stand drill to enhance operational efficiency. Additionally, recommendations were made to improve the material flow by streamlining the components required for beam production. Furthermore, the suggestion to remove the sheet metal wall emerged as an additional measure to not only reduce material flow but also augment the effectiveness of material handling processes, thereby contributing to overall operational efficacy.

The overarching recommendation for the company encompasses the implementation of comprehensive workplace standards tailored to mitigate handling times and bolster workplace safety measures. Considering evolving technological landscapes, the consideration of integrating robotics into the work environment emerges as a strategic imperative for future endeavors. However, such integration necessitates a nuanced understanding of the dynamic interplay between human workers and robotic entities, emphasizing the importance of human-robot collaboration frameworks and ethical considerations.

7. Conclusions

The principal aim of this study was to determine an enhanced workplace layout for a company situated in the Slovak Republic. A thorough analysis of the company's existing operational framework was undertaken to develop a feasible solution, which underwent rigorous evaluation. Specifically, the investigations focused on the complexities of the beam manufacturing process, dynamics of material flow, and overall arrangement of facilities within the company's premises.

The primary findings of this investigation are as follows:

- Reduction in Production Time: The comparison between the current (C) and design (D) variants revealed a notable reduction in beam production time from 1864 min to 1854 min, representing a decrease of 10 min. This reduction was primarily attributed to improvements in key operational processes, such as the movement of sheets to the drill, supply of contact plates to the beam, and supply of squares to the beam. Additionally, the proposed solution led to a substantial reduction in material flow distance, decreasing from the original 88.5 m to 73.5 m, thereby enhancing overall workflow efficiency.

Of particular concern was the welding process, which was identified as a critical aspect of the work environment due to its spatial demands within the production area and its stationary nature. Addressing the challenges posed by this aspect necessitated a strategic approach to preserve its integral role within the operations.

- Enhanced Operational Efficiency and Safety: The envisioned and executed solutions offer a multitude of advantages poised to improve operational efficiency and enhance overall organizational performance. Foremost among these benefits is the envisaged reduction in material flow, facilitating streamlined logistics and minimizing resource wastage. Concurrently, a decrease in production time is anticipated, attributable to the improvement of workflow processes and the adoption of lean manufacturing principles. Heightened workplace safety emerges as another salient advantage, as the implementation of standardized protocols and ergonomic designs mitigates occupational hazards and minimizes the risk of workplace accidents.

A detailed comparison between the existing configuration and the proposed solution is presented in Table 8, delineating the disparities between the two scenarios. Through a meticulous analysis, it was determined that the implementation of the proposed design variant could potentially yield significant improvements in operational efficiency.

- Tangible Improvements and Cost Reduction: Moreover, the proposed interventions are anticipated to yield tangible improvements in work productivity, as improved workflows and enhanced resource utilization foster a conducive environment for task completion and project delivery. Importantly, the consequential decrease in costs associated with waiting times for individual components underscores the economic viability of the recommended measures, offering potential cost savings and bolstering the company's competitive edge in the marketplace.

In sum, the integration of workplace standards and the contemplation of robotics integration represent strategic imperatives for the company's sustainable growth and operational resilience. By proactively addressing inefficiencies and prioritizing safety and productivity enhancements, the company can position itself for long-term success and adaptability in an increasingly competitive business landscape.

This study of a workplace environment yields valuable insights into the fields of management, engineering, logistics, and business process improvement. The analysis and evaluation of existing work processes enable the identification of key factors influencing efficiency and productivity. The findings of such studies provide crucial information on integrating modern technologies, such as robotics, and implementing lean manufacturing principles. These insights are then applicable in practice to enhance work processes and increase competitiveness within industrial sectors, including logistics. Moreover, they serve as a source of innovation and scholarly knowledge, contributing to pushing the boundaries of scientific research and laying the groundwork for further academic and research activities in the fields of management, engineering, logistics, and business process improvement.

Author Contributions: Conceptualization, J.Z. and B.F.; methodology, L.D and S.K.; software, B.F.; validation, J.Z., L.D. and B.F.; formal analysis, J.Z. and S.K.; investigation, B.F.; resources, B.F.; data curation, J.Z.; writing—original draft preparation, J.Z.; writing—review and editing, L.D.; visualization, B.F. and S.K.; supervision, L.D.; project administration, J.Z.; funding acquisition, L.D. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the Slovak Research and Development Agency under contract No. APVV-19-0305.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Bestvinova, V.; Praj, F.; Cambal, M. Identification of sustainability risks and their quantification in the conditions of small and medium-sized industrial enterprises. *MM Sci. J.* **2022**, *2022*, 6086–6090. [CrossRef]
2. Pekarcíková, M.; Trebuna, P.; Kliment, M.; Král, S.; Dic, M. Modelling and Simulation the Value Stream Mapping–Case Study. *Manag. Prod. Eng. Rev.* **2021**, *12*, 107–114. [CrossRef]
3. Pekarcíková, M.; Trebuna, P.; Kliment, M.; Trojan, J.; Kopec, J.; Dic, M.; Kronová, J. Case Study: Testing the Overall Efficiency of Equipment in the Production Process in TX Plant Simulation Software. *Manag. Prod. Eng. Rev.* **2023**, *14*, 34–42. [CrossRef]
4. Plinta, D.; Radwan, K. Implementation of Technological Innovation in a Manufacturing Company. *Appl. Sci.* **2023**, *13*, 6068. [CrossRef]
5. Vavrík, V.; Gregor, M.; Grznár, P.; Mozol, S.; Schickerle, M.; Ďurica, L.; Marschall, M.; Bielik, T. Design of Manufacturing Lines Using the Reconfigurability Principle. *Mathematics* **2020**, *8*, 1227. [CrossRef]
6. Więcek, D.; Więcek, D.; Kuric, I. Cost Estimation Methods of Machine Elements at the Design Stage in Unit and Small Lot Production Conditions. *Manag. Syst. Prod. Eng.* **2019**, *27*, 12–17. [CrossRef]
7. Pekarčíková, M.; Trebuňa, P.; Markovič, J. Case Study of Modelling the Logistics Chain in Manufacturing. *Procedia Eng.* **2014**, *96*, 355–361. [CrossRef]
8. Grznár, P.; Burganová, N.; Mozol, S.; Mozolová, L. A Comprehensive Digital Model Approach for Adaptive Manufacturing Systems. *Appl. Sci.* **2023**, *13*, 10706. [CrossRef]
9. Gregor, M.; Grznár, P.; Gregor, M.; Mozolová, L.; Mozol, Š. Simulation meta-model of assembly line with conwip control. *Int. J. Ind. Eng. Theory Appl. Pract.* **2023**, *30*, 1594–1615. [CrossRef]
10. Chromjakova, F. Production Planning Process Based on the Work Psychology of a Collaborative Workplace with Humans and Robots. *Machines* **2023**, *11*, 160. [CrossRef]
11. Stankalla, R.; Koval, O.; Chromjakova, F. A review of critical success factors for the successful implementation of Lean Six Sigma and Six Sigma in manufacturing small and medium sized enterprises. *Qual. Eng.* **2018**, *30*, 453–468. [CrossRef]

12. Mozolova, L.; Grznar, P.; Mozol, S.; Krajcovic, M. Streamlining utilisation of the assembly line using computer simulation. *Acta Logist.* **2023**, *10*, 165–173. [CrossRef]
13. Mesarosova, J.; Martinovicova, K.; Fidlerova, H.; Chovanova, H.H.; Babcanova, D.; Samakova, J. Improving the level of predictive maintenance maturity matrix in industrial enterprise. *Acta Logist.* **2022**, *9*, 183–193. [CrossRef]
14. Kubisova, E.; Grajzova, L.; Cambal, M.; Babcanova, D. Implementation of elements of the Industry 4.0 concept and its impact on employees in line with Human Resource Management in industrial organisations in Slovakia. In Proceedings of the 2022 20th International Conference on Emerging eLearning Technologies and Applications (ICETA), Stary Smokovec, Slovakia, 20–21 October 2022; pp. 352–357.
15. Micieta, B.; Staszewska, J.; Kovalsky, M.; Krajcovic, M.; Binasova, V.; Papanek, L.; Antoniuk, I. Innovative System for Scheduling Production Using a Combination of Parametric Simulation Models. *Sustainability* **2021**, *13*, 9518. [CrossRef]
16. Van Luu, T.; Chromjaková, F.; Nguyen, H.Q. A model of industry 4.0 and a circular economy for green logistics and a sustainable supply chain. *Bus. Strat. Dev.* **2023**, *6*, 897–920. [CrossRef]
17. Chromjakova, F.; Trentesaux, D.; Kwarteng, M.A. Human and Cobot Cooperation Ethics: The Process Management Concept of the Production Workplace. *J. Compet.* **2021**, *13*, 21–38. [CrossRef]
18. Kliment, M.; Trebuna, P.; Pekarcikova, M.; Straka, M.; Trojan, J.; Duda, R. Production Efficiency Evaluation and Products' Quality Improvement Using Simulation. *Int. J. Simul. Model.* **2020**, *19*, 470–481. [CrossRef]
19. Bucková, M.; Krajcovic, M.; Jerman, B. Impact of digital factory tools on designing of warehouses. *J. Appl. Eng. Sci.* **2017**, *15*, 173–180. [CrossRef]
20. Mattsson, S.; Kurdve, M.; Almström, P.; Skagert, K. Framework for universal design of digital support and workplace design in industry. *Int. J. Manuf. Res.* **2023**, *18*, 392–414. [CrossRef]
21. Herwanto, D.; Suzianti, A. Development of workplace design framework for manufacturing small and medium-sized enterprises in Indonesia. *J. Ind. Eng. Manag.* **2023**, *16*, 535–568. [CrossRef]
22. Cosme, J.; Pinto, T.; Ribeiro, A.; Filipe, V.; Amorim, E.; Pinto, R. Paperless Checklist for Process Validation and Production Readiness: An Industrial Use Case. In Proceedings of the 19th International Conference on Web Information Systems and Technologies, Rome, Italy, 15–17 November 2023; pp. 95–103.
23. Lee, H.; Yang, H. Digital Twin Simulation and Optimization of Manufacturing Process Flows. In Proceedings of the ASME 2023 18th International Manufacturing Science and Engineering Conference, New Brunswick, NJ, USA, 12–16 June 2023.
24. Baron, P.; Kočiško, M.; Hlavatá, S. Verification of term fulfillment of production orders with computer simulation tools. *AIP Conf. Proc.* **2023**, *2976*, 030005.
25. Nyemba, W.R.; Mbohwa, C. Modelling, Simulation and Optimization of the Materials Flow of a Multi-product Assembling Plant. *Procedia Manuf.* **2017**, *8*, 59–66. [CrossRef]
26. Králik, M.; Jerz, V.; Paštéka, M. Optimization of the Machine and Device Layout Solution in a Specific Company Production. In Proceedings of the 19th International Symposium for Production Research, ISPR 2019, Vienna, Austria, 28–30 August 2019.
27. Bučko, M.; Krejčí, L.; Hlavatý, I.; Lorenčík, J. Design and Optimization of Production Line Layout Using Material Flows. *Machines* **2024**, *12*, 189. [CrossRef]
28. Górnicka, D.; Burduk, A. Improvement of production processes with the use of simulation models. *Adv. Intell. Syst. Comput.* **2018**, *657*, 265–274. [CrossRef] [PubMed]
29. Plura, J.; Vykydal, D.; Tošenovský, F.; Klaput, P. Graphical Tools for Increasing the Effectiveness of Gage Repeatability and Reproducibility Analysis. *Processes* **2022**, *11*, 1. [CrossRef]
30. Rakyta, M.; Bubenik, P.; Binasova, V.; Micieta, B.; Staffenova, K. Advanced Logistics Strategy of a Company to Create Sustainable Development in the Industrial Area. *Sustainability* **2022**, *14*, 12659. [CrossRef]
31. Lorincová, S.; Čambál, M.; Miklošík, A.; Balážová, Z.; Babel'ová, Z.G.; Hitka, M. Sustainability in Business Process Management as an Important Strategic Challenge in Human Resource Management. *Sustainability* **2020**, *12*, 5941. [CrossRef]
32. Szabó, P.; Mĺkva, M.; Marková, P.; Samáková, J.; Janík, S. Change of Competences in the Context of Industry 4.0 Implementation. *Appl. Sci.* **2023**, *13*, 8547. [CrossRef]