VISUALIZATION-BASED DESIGN AND OPTIMIZATION OF PROCESS-ORIENTED MANAGEMENT SYSTEMS

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DOI: 10.17973/MMSJ.2025_11_2025108

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This paper focuses on designing and optimizing production layouts in manufacturing enterprises, using Ehlebracht Slowakei, Ltd. as a case study. Effective spatial planning is shown to be essential for improving efficiency, productivity, and competitiveness. The Michalovce plant initially suffered from capacity limitations that restricted flexibility and hindered modernization. A systematic approach was applied—covering analysis, redesign, optimization, simulation, and evaluation. The relocation to a new hall in Kosice enabled a complete reorganization: warehouse capacity was doubled, and production was upgraded with advanced Zhafir injection moulding machines. Visualization with Twinmotion supported accurate 3D modelling and layout validation. A comparison between the digital model and the final implementation confirmed minimal deviations. The study demonstrates that integrating structured layout methodologies with digital visualization tools can significantly enhance production efficiency, transparency, and scalability, while offering practical guidance for designing flexible, future-ready manufacturing systems.

KEYWORDS

Manufacturing layout, Production capacity, Storage optimization, Visualization, Industry 4.0.

1 INTRODUCTION

The design or reorganization of production and logistics systems, as well as the expansion of manufacturing enterprises or the conceptual development of a company, represents an exceptionally important and complex process. Even the implementation of the smallest change may entail a high level of risk or expose the enterprise to considerable pressure resulting from potential failure. For this reason, every modification must be thoroughly considered and carefully planned. A comprehensive and well-prepared project can fundamentally influence the efficiency and reliability of a manufacturing enterprise. Thanks to progressive modern technologies, increasingly detailed design proposals can be realized, thereby elevating the issue of technological production design to a new level. The advantage of these technologies – such as visualization and digitalization of production facilities – lies in their extensive applicability, which facilitates companies in preparing for changes in production.

The arrangement of production systems within a manufacturing enterprise, as well as the spatial organization of the facility, is one of the fundamental and most important aspects of production management. Insufficient spatial capacities in any part of the enterprise, when aggravated, inevitably lead to increasing inefficiencies in production. By today's standards, this represents not only a challenge for employees but also a significant issue for the enterprise itself, one that must be resolved as quickly as possible.

2 LITERATURE REVIEW

The problem of optimizing production and warehouse layouts is well represented in current research, where simulation, visualization, and digitalization play a decisive role. Zuniga et al. introduced a simulation-based optimization method for facility layouts, emphasizing the importance of performance indicators in layout design and decision-making [Zuniga 2020]. Complementing this perspective, Fan et al. proposed a digital twin-based architecture for flexible manufacturing systems, which integrates real-time monitoring and visualization to support operational flexibility [Fan 2021]. In a related study, Elahi demonstrated how the improvement of plant layouts in heat treatment tooling facilities leads to more efficient flows and better utilization of space [Elahi 2021].

The integration of Industry 4.0 principles into facility design has become a central topic in manufacturing research. Mourtzis analysed the role of simulation technologies in modern manufacturing, showing their ability to predict system performance and enhance adaptability under dynamic conditions [Mourtzis 2020]. Tulli focused on logistics processes and warehouse optimization, presenting methods for improving order-picking strategies and efficiency [Tulli 2023]. Similarly, Mansur et al. applied systematic layout planning (SLP) combined with simulation to redesign production floors, proving the effectiveness of hybrid approaches for practical industrial applications [Mansur 2021].

Further research highlights the role of sustainability and lean principles in layout planning. Proenca et al. investigated logistics optimization in distribution centres using lean methodologies, demonstrating improvements in both efficiency and sustainability [Proenca 2022]. Peron et al. focused on facility layout planning for sustainable manufacturing, showing how environmental considerations can be integrated into layout design [Peron 2020]. Zuniga's and Peron's findings converge on the point that layout design must not only improve efficiency but also address long-term sustainability goals.

In the Slovak context, Vasil presented a study on the reorganization of production hall layouts, emphasizing that proper spatial planning is a key determinant of competitiveness and long-term stability in manufacturing enterprises [Vasil 2022]. Collectively, these studies establish that combining systematic methodologies, simulation, digital visualization, and sustainability-oriented approaches provides a comprehensive framework for solving layout-related challenges in modern manufacturing.

3 LAYOUT SOLUTIONS OF THE PRODUCTION PROCESS

This concept refers to the arrangement of individual machines or elements within the spaces where production is intended to take place. The layout is important in terms of work optimization, efficiency, safety, and the maximum utilization of available space.

The design of a production line is a complex process that requires a precise analysis of production requirements and the identification of optimal solutions to ensure reliable and

efficient manufacturing. In practice, this process most often begins with the analysis of the product to be manufactured on the line, based on which the appropriate production volume is determined. Subsequently, the production processes are defined in greater detail to enable the selection of the appropriate equipment necessary for production implementation.

Another, but no less important, step is the placement of equipment and the optimization of workflow, aimed at minimizing unnecessary production steps, improving, and streamlining the process. The arrangement of equipment should be such that operators have easy access to the machines while minimizing material handling between workplaces. The production flow should be designed to eliminate or at least reduce waiting times at individual stations. At the same time, in designing the layout, safety and quality must not be overlooked, which can be ensured by compliance with safety standards and the implementation of quality control checkpoints.

The production hall and the possibility of maintaining the line are also crucial aspects of the design. In addition, it is essential to prepare a cost estimate and calculate the return on investment to assess the financial effectiveness of the project. To eliminate unnecessary waste, the proposed production line should first be simulated using specialized software. Such simulation makes it possible to easily detect weaknesses in the production process and verify whether the line is properly designed in terms of layout. The results provide clear data on the volume of products the line can produce within a given timeframe.

It is also necessary to take workplace ergonomics into account to minimize the risk of accidents as close to zero as possible and to enhance employee comfort. Another factor to be considered is the optimization of the energy demands of production to achieve sustainable manufacturing.

1.1. Layout Solution of Ehlebracht Slowakei in Michalovce

The company Ehlebracht Slowakei Ltd was established on October 23, 1995, in Michalovce. The enterprise focuses on process-oriented comprehensive solutions for technical and optical plastic parts, components, and system solutions. The layout of a manufacturing enterprise can generally be classified as one of the most important factors influencing production efficiency. Through effective spatial arrangement of the production hall, a company can increase its output capacity essentially without the need for major financial investments.

However, an inefficient plant layout is not the only reason why production or material handling within production may become complicated and therefore ineffective. Other causes may include an unskilled workforce, low workplace morale, or insufficient workspace, all of which ultimately lead to inefficient and disorganized production or handling of goods and finished products.

In recent years, the Michalovce plant has faced one of the aforementioned issues—namely, a lack of workspace and storage capacity. At the beginning, when production in Michalovce was launched, the enterprise did not encounter any problems related to spatial capacities. Over time, however, the company advanced due to its solid reputation among customers, which stemmed from the high quality of its products. Consequently, the available spatial capacities in which the company operated gradually became increasingly inadequate.

For visualization purposes, the software Twinmotion 2024.1.2 was employed. Twinmotion is a computer program intended for architectural visualization, which enables designers and architects to easily and quickly create high-quality panoramas, images, product animations, and visualizations of cities, buildings, and entire landscapes.

The production hall in which the company operated in Michalovce can be divided into five main parts (Fig. 1):

1. Production section,
2. Storage section,
3. Assembly section,
4. Mold maintenance,
5. Social section.

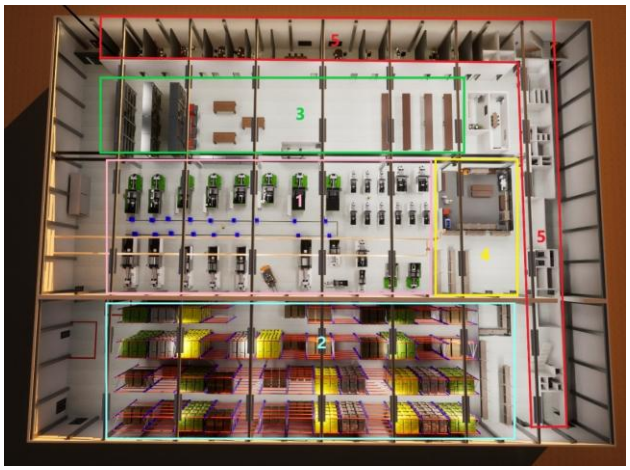

Figure 1. Division of the Production Hall into Five Sections

The primary reason that led the company's management to relocate production to a new hall was the lack of storage space and insufficient area within the production section, which made it impossible to purchase new injection moulding machines and thereby expand production capacity. For a growing manufacturing enterprise, such expansion is an essential requirement to meet customer demands and maintain competitiveness in the market.

Ehlebracht therefore planned to move production into new premises and faced a critical decision: how to utilize the new space in such a way as to achieve an efficient arrangement of production machinery and an appropriate configuration of storage areas.

To answer this question, it was necessary to analyse the existing layout, identify critical points, and subsequently take them into account in the design of the new spatial solution, with a forward-looking approach that would also consider potential future expansions of the company's key areas—namely, production and storage facilities.

4 METHODOLOGY OF CREATING THE LAYOUT OF A MANUFACTURING COMPANY

In addressing the issue of layout planning for the manufacturing company Ehlebracht Slowakei, Ltd., a systematic methodology was adopted, consisting of the following steps:

1. Problem Identification
- Mapping the current state of the enterprise in Michalovce.
- Defining critical areas (lack of storage and production capacities).
- Conducting interviews with management and responsible staff, collecting input data (hall dimensions, technologies, material flows).

2. Analysis of the Existing Layout
- Examining the spatial arrangement of the original facilities.
- Identifying barriers to the efficient operation of production and storage.
- Assessing material flow, employee movement, and space utilization.

3. Design of a New Production System

- Creating a 2D layout of the new production hall in Kosice.
- Converting the design into a 3D visualization using Twinmotion EDU 2024.
- Selecting appropriate production machinery and equipment, including new injection moulding machines.

4. Optimization of the Layout

- Iteratively modifying the arrangement of production and storage sections.
- Defining product and process flows.
- Modelling optimal storage areas, including central material distribution systems.

5. Simulation and Visualization

- Producing a 3D visualization of the real arrangement.
- Simulating material flow and product movement.
- Verifying whether the new layout improves the efficiency of production and storage operations.

6. Implementation of Changes

- Proposing modifications based on simulation results.
- Considering reserve capacity for future expansion of production and storage.
- Finalizing the layout and providing recommendations for implementation.

7. Comparison and Evaluation

- Comparing the visualization with the real arrangement after relocation to Kosice.
- Assessing differences and confirming the benefits of the new solution.

1.2. Description of the Problem of Ehlebracht Slowakei, Ltd in Michalovce

The main reasons that led Ehlebracht to relocate production to new facilities can be divided into two principal categories:

1. Storage Capacities

Manufacturers who strive to fulfil orders while simultaneously aiming to grow to gain the trust of new customers often face difficulties in delivering accepted orders within the shortest possible time frame. Consequently, increasing production capacity becomes a priority, which directly impacts storage facilities. For the enterprise, higher production volumes mean securing larger quantities of raw material—in this case, plastic granulate. Ehlebracht stored this granulate in warehouse facilities together with finished products prepared for export. With rising production volumes, the accumulation of manufactured plastic components ready for export further burdened the available storage space.

In warehouses, as well as in other storage facilities, space is one of the most valuable assets. By utilizing storage space as efficiently as possible, a company can significantly increase the amount of raw material or finished goods it can store. Moreover, effective use of space allows employees easier and more comfortable access to production materials, which in turn can lead to faster order fulfilment.

In the initial years of production in Michalovce, Ehlebracht was able to manage this issue successfully. The storage facilities provided sufficient spatial reserve. However, in recent years, the company's production grew to such an extent that the existing warehouse capacities were no longer adequate to systematically, transparently, and efficiently store both the raw production material and the manufactured plastic products.

In the storage facilities of the Ehlebracht enterprise, the shelving system was arranged in the manner illustrated in Fig. 2. It can be observed that the available space did not allow for the expansion of additional storage areas for palletized quantities.

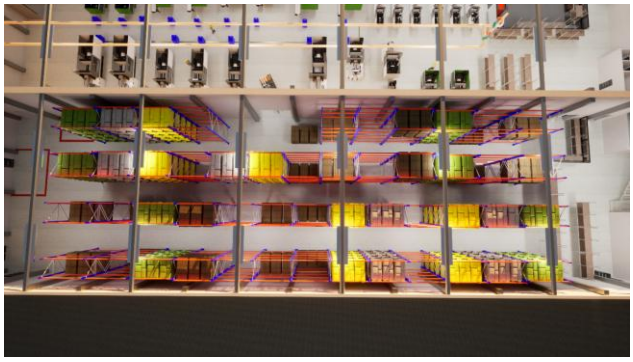

Figure 2. Arrangement of Shelves in the Storage Area of Ehlebracht in Michalovce

2. Production Capacities

Production capacity represents the maximum possible output of a manufacturing enterprise, measured in units of production over a given period. When a company has a clear understanding of its production capacities, it can improve production planning, which in turn results in more accurate delivery times of goods. Theoretically, production capacity is a numerical value that indicates how much output the enterprise can produce. Fig. 3. illustrates the production environment of the Ehlebracht company in Michalovce.

In a manufacturing enterprise, the availability of space in production is one of the most important factors influencing efficiency and the smooth operation of processes. Through rational, systematic, and efficient spatial arrangement, a company can increase its production capacity – an objective pursued by every modern manufacturing enterprise.

Effective utilization of production capacities also provides employees with more comfortable movement within the workplace. However, in recent years, Ehlebracht was no longer able to offer such comfort to its employees. While the systematic arrangement of production equipment was maintained, increasing spatial constraints led to the emergence of undesirable temporary storage areas within the production space. This situation occasionally caused frustration among production workers due to the inconvenient handling of goods.

Figure 3. Production Environment of Ehlebracht in Michalovce

The expansion of production capacity at Ehlebracht through the purchase of new injection moulding machines was essential for fulfilling newly received customer orders. However, due to insufficient production space capacities (Fig. 4), the company was unable to install the new injection moulding machines within the existing facilities. This became one of the principal decision-making factors that led the enterprise to relocate to new premises.

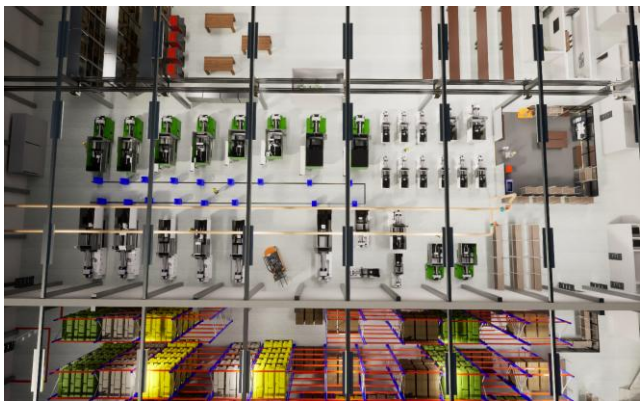

Figure 4. Layout of Production at Ehlebracht in Michalovce

5 PROPOSAL FOR IMPROVING THE LAYOUT OF THE PRODUCTION HALL

In designing a new, more efficient layout for Ehlebracht, an analysis of the existing arrangement of the production hall in Michalovce was first carried out. Subsequently, the dimensions of the new production hall, which was being constructed at a new site in Kosice, were obtained. The new layout was designed to eliminate all problems identified in the original production hall. Based on the analysis of the Michalovce facility, additional insights and suggestions were formulated with the aim of improving and rearranging the system.

The specific steps of the process in designing the new layout of Ehlebracht Slowakei, Ltd., derived from the methodology of creating manufacturing layouts, were as follows:

1. Understanding the problem of the manufacturing enterprise – Everything begins with identifying the company's needs and challenges. Before developing a new layout, it is necessary to thoroughly investigate the enterprise and identify requirements and issues. This includes discussions with responsible staff, determining the dimensions of the hall, identifying available equipment, and analysing material flows.
2. Planning the design of the production system – In this step, modelling and design work begin. Specialized software is used to create drawings in 2D or 3D. In this case, a 2D layout was created and subsequently transformed into a 3D visualization.
3. Selection of equipment – At this stage, it is necessary to identify both the equipment already available in the enterprise and the machinery intended to be procured for the new facilities. Care must be taken to ensure that the positioning of added machines and devices is as effective and efficient as possible, with the objective of achieving a layout satisfactory to the company.
4. Designing the layout arrangement – This step is part of the optimization process, during which items and equipment are repositioned until they are placed in optimal locations. Since the new layout is developed in computer software, this is essentially a "drag-and-drop" process.
5. Defining the flow – This step may be divided into three main parts: defining products, defining processes, and defining process flows. Although there is some overlap with the initial step, this phase focuses on optimizing all aspects from the perspective of spatial arrangement. It may involve changing the placement of equipment, storage, or pathways with the aim of improving the overall process.
6. Simulation – In this step, the simulation demonstrates how material moves physically along the line. The simulation is essentially a 3D video showing a "fly-through" of all production equipment and illustrating the movement of machinery and products.
7. Implementation of adjustments – In the final stage, modifications are made to improve the design. Such adjustments frequently result in increased space in production and storage areas, among others.

After completing these seven steps, the final desired layout for the enterprise was obtained.

The new layout of Ehlebracht can be divided into four main sections (Fig. 5):

1. Production section,
2. Storage section,
3. Assembly and maintenance section,
4. Social section.

Figure 5. Division of the Production Hall

1.3. Description of the New Layout of Ehlebracht in Kosice

The fundamental sections of the new layout can be described and further divided into subgroups. The core production area itself may be separated into two parts. The first part of the production environment is equipped with Zhafir injection moulding machines.

The first row of injection moulding machines consists of equipment that, in terms of operating complexity and production capabilities, belongs to the less advanced category. The second row, on the other hand, includes machines capable of producing even the most complex plastic components offered by the company. Owing to this capability, these machines represent the most advanced part of the company's equipment. These injection moulding machines are also manufactured by Zhafir (Fig. 6).

Figure 6. Production Section of Ehlebracht in Kosice

The second part of the new layout represents the storage facilities, which can be divided into three subgroups (Fig. 7). The first section of the storage area is equipped with a central distributor of production material. The second section consists of shelving units used for storing plastic granulate as well as

shelves designated for storing finished plastic components ready for export. The third section of the storage facilities is an allocated area intended to facilitate convenient handling of imported or exported materials.

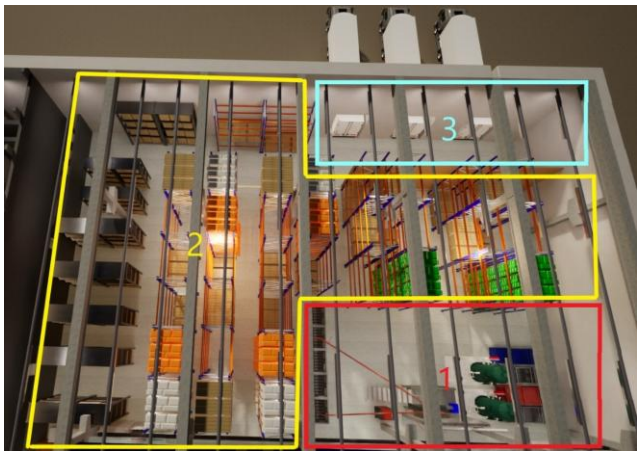

Figure 7. Division of the Storage Section of Ehlebracht in Kosice

As already mentioned, storage facilities posed significant difficulties for the company, which were reflected in overall production efficiency. This issue was so critical that Ehlebracht decided to address it decisively by substantially expanding its storage capacity.

In the Michalovce production facilities, the storage section covered an area of approximately 68 × 25 meters, which equalled about 1,700 m². This figure illustrates the extent to which Ehlebracht had expanded in recent years, since even such a large area was no longer sufficient for storing both production materials and finished products.

The new production hall built in Kosice was dimensioned in such a way as to eliminate the problems that had previously hindered the company. This objective was successfully achieved, as the design of the new layout allowed for the allocation of a storage area measuring 80 × 43 meters, which represents an expansion from 1,700 m² to 3,440 m² - effectively doubling the storage capacity.

1.4. Creation of the Visualization of the New Layout of Ehlebracht in Kosice

Three-dimensional visualizations provide versatile applications in construction, architecture, and industrial sectors. Through visualization, it was possible to illustrate a realistic representation of the manufacturing enterprise. This allowed the demonstration of the arrangement of machines, equipment, and any other components that the plant would contain, even before their actual implementation. Visualization can also replicate completed processes, including all functions, sequences, and conditions. Within the company, visualization may be employed in the following areas:

- for advertising purposes,
- to illustrate the new production arrangement,
- in sales and distribution,
- for internal presentations,
- in the development of the production process.

Throughout the equipment layout process, strict adherence to the proposed design was maintained to achieve the highest possible accuracy of visualization. Efforts were made to ensure the exact number of machines and equipment in all sections of the enterprise corresponded to the design.

The visualization of the new layout incorporated every element specified in the planned design of Ehlebracht. The visualization of the layout of Ehlebracht in Kosice is shown in Fig. 8.

Figure 8. Visualization of the Layout of Ehlebracht in Kosice

6 EVALUATION OF THE BENEFITS OF THE SOLUTION

An effective design of a new manufacturing layout is one of the fundamental key factors leading to the successful management of an enterprise. It directly influences not only the efficiency of operations but can also affect the overall functioning of the company, including processes related to production, supply, export, and other activities.

For the most accurate comparison, it was necessary to establish reference materials to serve as a basis. For this reason, a pair of visualizations was created in the Twinmotion program (Fig. 9 and Fig. 10).

Figure 9. Visualization of the Production Environment and Storage Facilities of Ehlebracht in Kosice

Based on the expressed expectations of the management of Ehlebracht, perspectives of the production environment were selected. Ultimately, this is a manufacturing enterprise; therefore, comparing the visualization of the production environment with reality is fully justified.

Figure 10. Visualization of the First and Second Sections of Ehlebracht in Kosice

After the complete relocation of the company to the new production facilities, photographs resembling the visualizations were subsequently taken, to the extent possible, to compare their similarity and thereby evaluate the quality of the visualization (Fig. 11).

Figure 11. Production Environment and Storage Section of Ehlebracht in Kosice

The differences identified between the visualization and the actual arrangement are minimal and can be observed primarily in the production area. Notably, shelving units were detected in the vicinity of the production machines, serving as storage for finished plastic components awaiting transfer to the assembly section.

The benefits of the proposed solution for Ehlebracht Slowakei, Ltd. can be summarized as follows:

- Design of a new spatial layout,
- Insights and recommendations to help Ehlebracht avoid repeating mistakes encountered in the original premises,
- Representation of the production environment in the form of a 3D visualization,
- Presentation of the new layout using visualization,
- Comparison of the projected new layout with its visualization,
- Proposal for the implementation of a new central distribution system for production material to enhance efficiency as well as overall production output.

7 CONCLUSIONS

The conducted research confirmed that effective production layout design is a decisive factor in achieving efficiency and sustainability within modern manufacturing enterprises. By relocating production to a newly built hall in Kosice and applying a systematic design methodology, Ehlebracht Slowakei, Ltd. was able to overcome the critical spatial constraints experienced in Michalovce. The redesigned layout not only addressed immediate capacity issues but also introduced flexibility to support long-term growth.

The integration of visualization technologies, particularly the use of Twinmotion software, proved essential for validating design concepts prior to implementation. The ability to model and simulate production flows, equipment placement, and storage arrangements provided the company with a high degree of certainty, minimizing risks associated with relocation and ensuring that the final arrangement closely corresponded to the proposed design. This highlights the growing importance of digital tools in industrial engineering, where simulation and visualization significantly reduce project costs and implementation errors.

Beyond the case-specific findings, the study emphasizes broader implications for manufacturing enterprises facing similar challenges. Efficient layout solutions, combined with visualization and simulation, enable companies to respond more effectively to dynamic market demands, maintain competitiveness, and align with Industry 4.0 principles. The presented approach can therefore serve as a model for other enterprises seeking to redesign or expand their production and logistics systems in a sustainable and future-proof manner.

ACKNOWLEDGMENTS

This paper was supported by the grant project KEGA 003TUKE-4/2024, KEGA 043TUKE-4/2024, and VEGA 1/0383/25, VEGA 1/0558/23 – VEGA, VEGA 1/0575/23 and KEGA 033PU-4/2023.

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