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Evaluating the efficiency of layout solutions through the utilization of simulation software

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Abstract: The main goal of this article is to identify the relationship between designing a layout and developing an efficient material flow for a new production facility. The article begins with a brief overview of process development and optimization in industrial and logistical environments. It then highlights the significant impact that an effective layout and material flow can have on overall production efficiency. The following sections offer a detailed review of existing literature and theoretical models that support the connection between facility layout design and material flow effectiveness. The article stresses the importance of incorporating modern technologies and methods during the planning phase to boost productivity and minimize waste. In the practical section, the article thoroughly examines the development of the layout solution and provides an in-depth analysis of the material flow, focusing on a specific product. This includes a detailed evaluation of various layout designs and their effects on material handling, storage, and transportation within the facility. The proposed layout and material flow were validated using TX Plant Simulation software, which generated statistical reports and outputs. This software allowed for the modeling and simulation of different scenarios, offering insights into potential bottlenecks and areas for improvement. The simulation results are discussed in detail, highlighting key findings and their implications for the production facility.

1 Introduction

In today's industrial and logistical environments, optimizing and refining processes is increasingly essential for organizations seeking to gain a competitive advantage and achieve long-term success in the 21st century. A critical aspect influencing the effectiveness of these processes is the strategic design of layouts and the flow of materials.

The arrangement of equipment and workstations goes beyond mere spatial organization; it serves as a strategic component that affects various dimensions of business operations. By carefully designing and efficiently managing layouts and material flows, organizations can achieve key objectives such as improving worker productivity, maximizing space and resource use, minimizing waste and inefficiencies, shortening delivery times, and enhancing overall competitiveness [1-3].

Scientific research in layout and material flow is increasingly focused on creating methodologies and technologies that help organizations meet these goals. The integration of advanced technological equipment, automation, and data analysis is crucial for both the design and management of these layouts [4,5].

Furthermore, the incorporation of simulation tools and software, such as TX Plant Simulation, enables the detailed modeling and analysis of potential layout configurations and material flow scenarios before implementation. This predictive approach allows organizations to foresee and mitigate potential issues, ensuring a smoother transition from design to operational phases. By leveraging these technologies, companies can create more resilient and flexible production systems capable of adapting to changing market demands and operational challenges [6].

Additionally, interdisciplinary collaboration among industrial engineers, operations managers, and IT specialists is becoming increasingly important. This collaborative approach ensures that all aspects of layout and material flow design are comprehensively addressed, combining technical expertise with practical insights from daily operations. The result is a more holistic and effective strategy for enhancing overall production efficiency [7].

2 Literature review

In logistics, adaptability refers to the ability of a material flow system to respond to changing conditions through flexibility. Both processes and systems must be capable of evolving and adapting. Achieving these goals depends on the adoption of new technologies that can meet these challenges. In the near future, verifying product functionality within a virtual environment will become a critical standard [8,9]. Growing global competition and increasing customer expectations are driving the need to enhance business processes. Recently, the concept of "lean management" has gained significant attention. This management approach, originating from the Japanese company Toyota, has spread worldwide due to its capacity to respond quickly and flexibly to customer demands. The growing number of case studies highlights its expanding application across various sectors [10-12].

Lean thinking embodies the philosophy and practices of the Toyota Production System (TPS). Within TPS, any resource that does not add value from the customer's perspective is eliminated. The processes are designed to operate using fewer materials, requiring less investment, reducing inventory, minimizing space usage, and involving fewer employees [13-15].

When aiming to improve processes, many companies struggle with the absence of an individual who has a comprehensive understanding of the entire material and information flow, along with all related product processes. A common method to address this gap, while also identifying areas for improvement and proposing company-wide solutions, is value stream mapping. The distinction between process innovation and process improvement is often unclear. Innovations typically involve more radical changes that significantly alter the process [16-18]. On the other hand, improvement focuses on the ongoing efforts of individuals involved in processes, aiming to enhance their performance. Improving the entire process chain as an integrated system of activities centers around value stream mapping, which is the main subject of the following case study [19,20].

3 Methodology

3.1 Workplace spatial arrangement

The layout, or spatial arrangement, of the workplace plays a crucial role in determining the overall efficiency of a company. It involves organizing production departments, workstations, tools, machines, and other essential equipment, with a focus on optimizing the movement of work [10]. The most critical aspect of this arrangement is the strategic and effective placement of production equipment to ensure that employees have the best possible conditions for performing their tasks efficiently. A well-designed layout impacts the entire production flow, influencing production costs, particularly those associated with material handling and transportation. Finding the optimal workplace layout is complex and challenging, but it is vital for enhancing production efficiency [21-24].

Poor allocation and arrangement of production facilities lead to inefficient logistics, longer material flows, increased transport times, and a greater need for intermediate storage (buffers) for materials, semi-finished goods, and finished products [23-25]. These issues collectively drive-up production costs. Efficient allocation and layout aim to integrate capacity, material, economic, safety, and technological factors while minimizing subjective decision-making in the placement and configuration of workspaces and production facilities. Addressing these challenges requires a project-oriented approach grounded in key logistics principles such as systems thinking, algorithmic planning, coordination, and global optimization [22].

3.2 Layout of the new production hall

The new production hall being developed in the industrial zone of the Kosice district Nad Jazerom will have approximate dimensions of 90 meters by 60 meters. Unlike the existing production facility on South Avenue, the entire production process in this new hall will be carried out on a single floor, where all products will be manufactured. The layout design of the new production hall is illustrated in Figure 1.

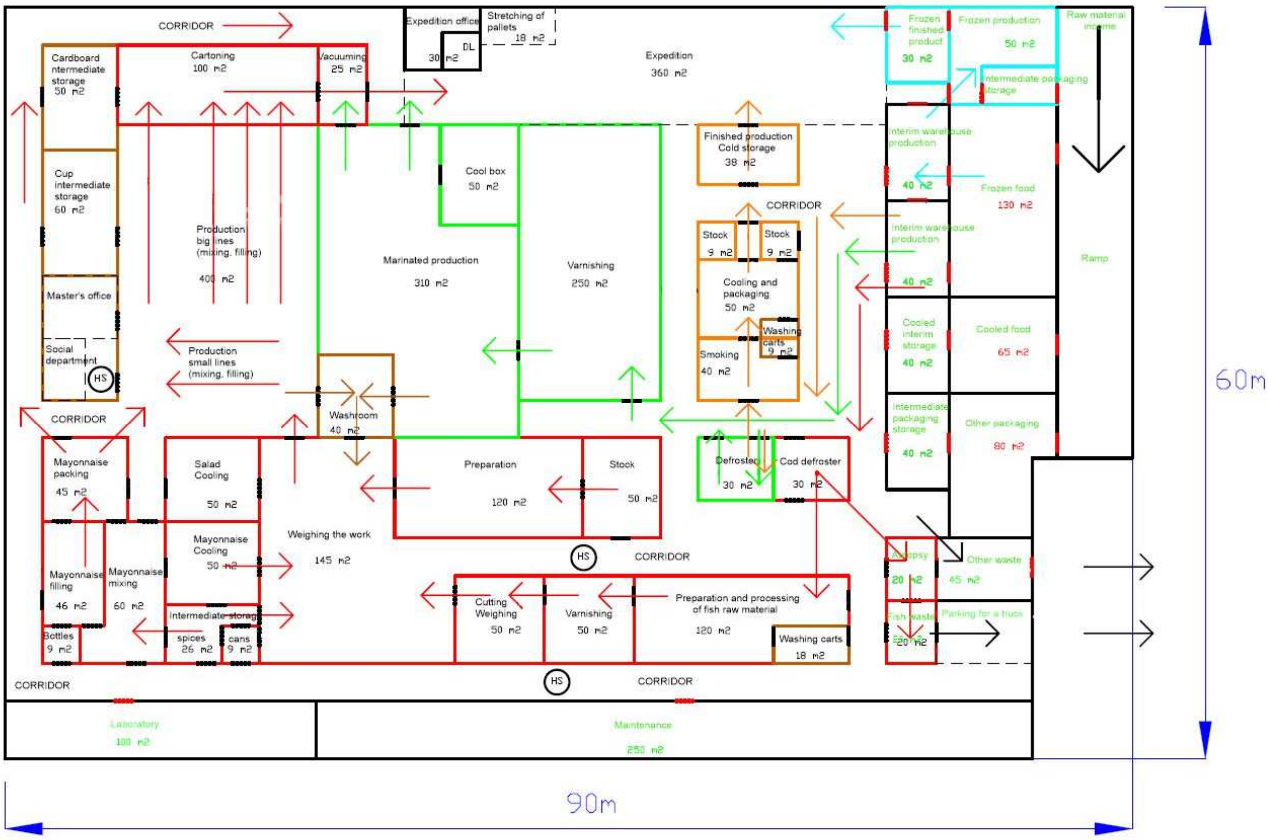

Figure 1 Layout and material flow in the new production facility

The picture (Figure 1) also shows the material flow of each production. Each color of the arrows represents a different material flow.

---> **Frozen production** ---> **Smoked production** ---> **Production of fish products**
---> **Marinated production** ---> **Garbage** ---> **Containers**

3.3 Material flow for a specific fish product

The material flow for producing a specific fish product begins with the receipt of frozen fish raw material in the warehouse, where it must first be removed from its transport packaging. The required amount for daily consumption is then moved to the intermediate storage. The initial step in the process is thawing the fish. Once the appropriate time has passed, the thawed fish is taken out of its packaging, and its quality is checked during unpacking. The inspected raw material is then transferred to the next production stage, which involves cooking. After cooking for the designated time, the fish is ready to be cooled. Following the cooking and cooling stages, the fish is marinated. Once marination is complete, the fish is ground and weighed. Meanwhile, sterilized vegetables and other necessary ingredients are prepared and weighed. These ingredients are then combined with mayonnaise. The mixture, precisely weighed and prepared, is then processed in a new fully automated line designed for fish product production. This line handles jar filling, packaging, cartoning, and stacking of the cartons onto pallets, with conveyors aiding the process. Finally, the prepared pallet is wrapped in stretch film and made ready for dispatch to the logistics distribution warehouse.

Figure 2 and Figure 3 illustrate the material flow for producing this specific fish product, with red arrows indicating the product flow and black arrows showing the waste flow. Figure 2 specifically depicts the material flow for the preparation of the fish raw material.

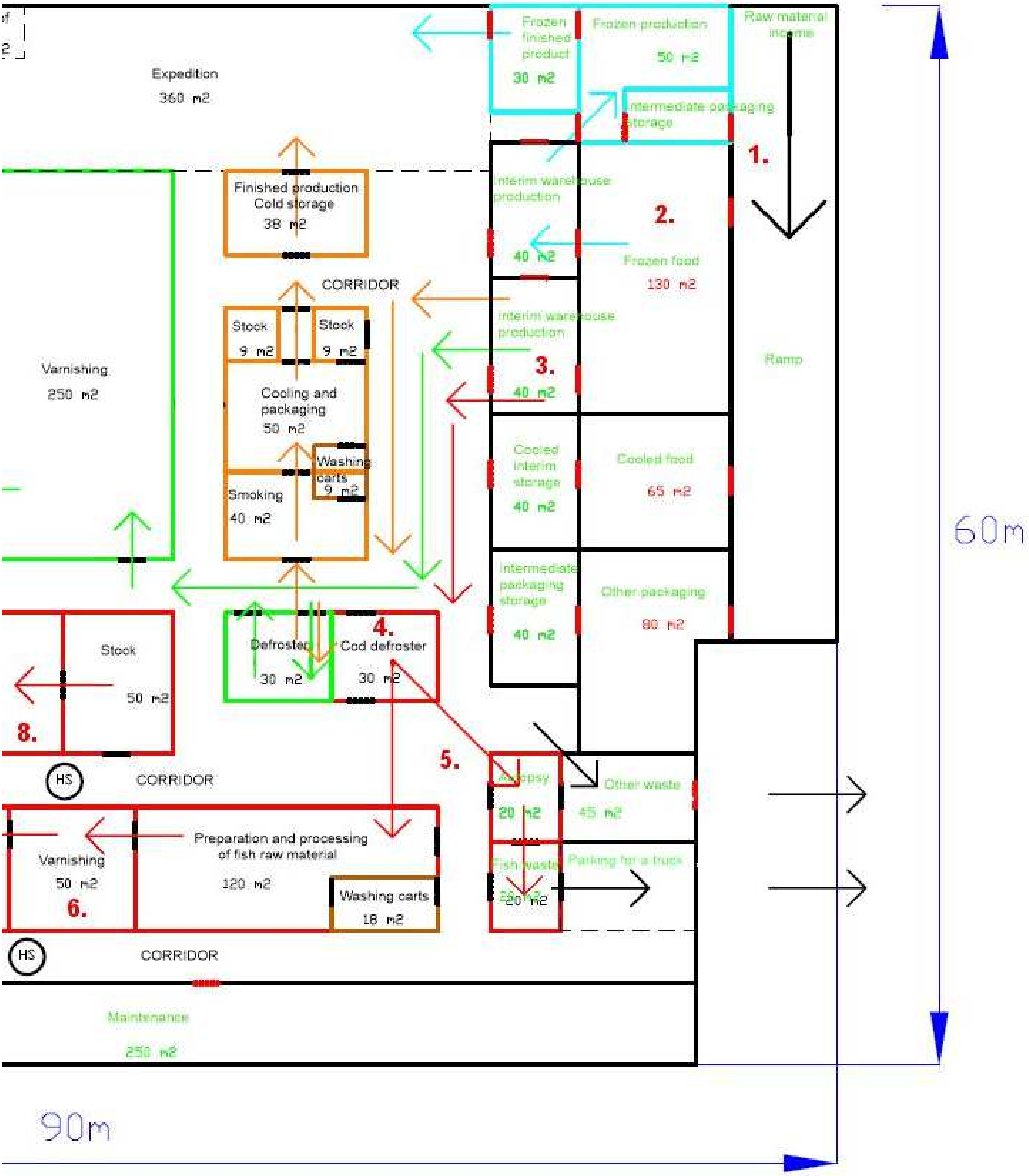

Figure 2 Material flow for producing a specific fish product – 1

Figure 3 illustrates the material flow for weighing, product manufacturing, packaging, cartoning, and the final step of shipment.

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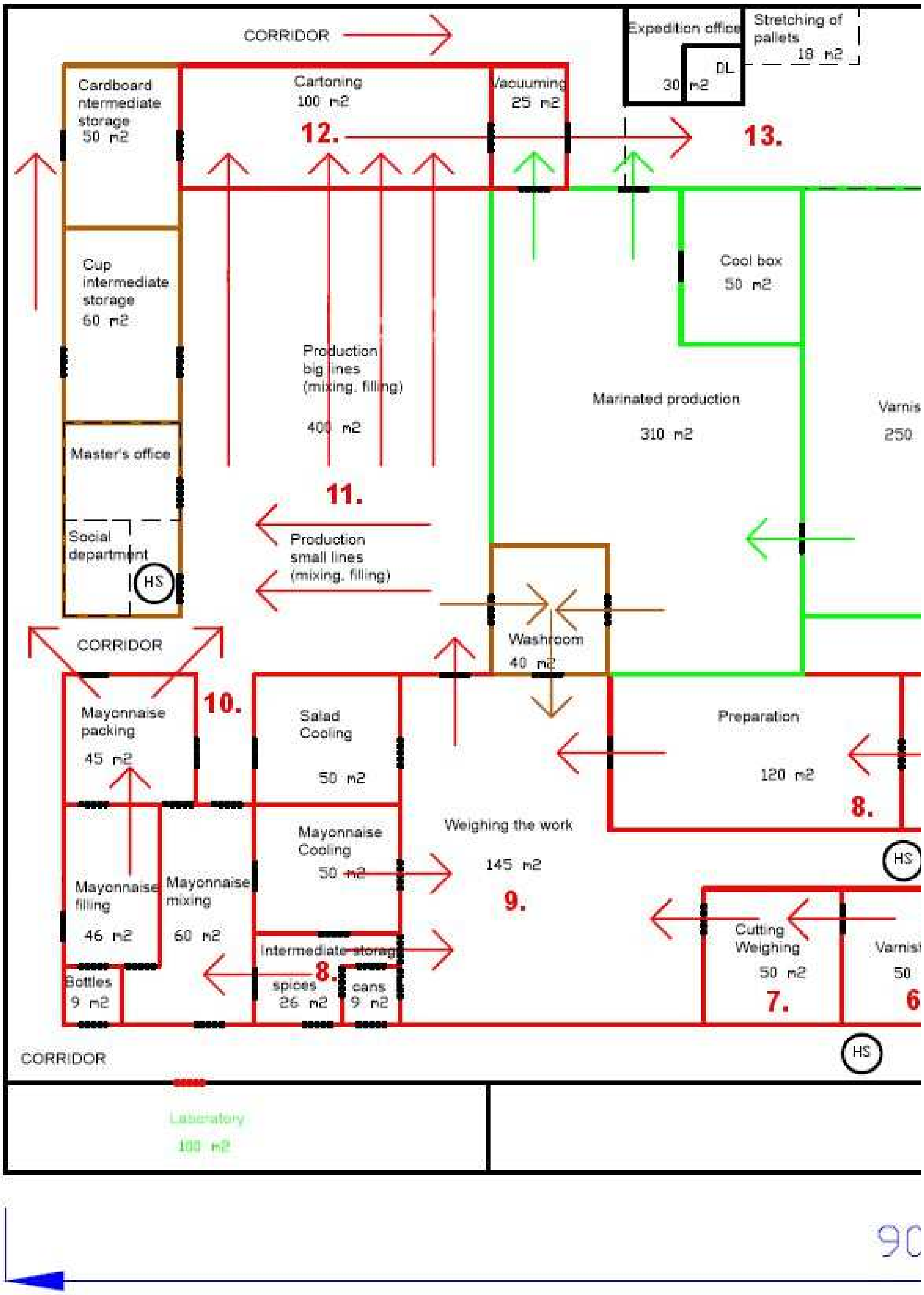

Figure 3 Material flow for producing a specific fish product – 2

The legend:
1. Intake of fish raw material,
2. Store of frozen raw materials,
3. Interim warehouse production,
4. Defrosting,
5. Preparation and processing of fish raw materials (dissection, cooking, cooling),
6. Painting,
7. Cutting and weighing,
8. Preparation of vegetables and ingredients,
9. Weighing,
10. Adding mayonnaise,
11. Production of cod or fish salads (mixing, filling),
12. Cartooning,
13. Shipping of packed pallets with the finished product.

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3.4 Predictive production simulation

Using the Tecnomatix Plant Simulation software, we will simulate the predictive production of Treskoslovak Cod in mayonnaise and Paris salad. Using the 3D function in TX Plant Simulation, perimeter walls, and partitions will be modeled according to the layout so that we can better imagine how the newly emerging production plant RYBA Košice will look like. The duration of the simulation will be set to 8 hours, exactly as one work shift will last. Based on this simulation, we will find out the estimated number of pallets of Treslovakian cod in mayonnaise and Paris salad that could be produced in 8 hours.

3.4.1 Predictive simulation of the production process of Treskoslovak Cod

The simulation of the production process for Treslovakian Cod in mayonnaise excludes certain time intervals, as the entire production process spans roughly three days. However, a more precise estimate for the duration of the full production process for Treslovakian Cod in mayonnaise is about 48 hours.

The simulation begins with the receipt of the fish raw material and its unpacking from the transport packaging, but the processing time for this step is set to zero in the simulation. Similarly, the time required for moving the material to the warehouse and then transferring the fish to the daily intermediate storage is not considered. Additionally, the time needed for thawing the frozen fish raw material is also excluded. Although the thawing process is expected to take around 8 hours, it is still under refinement, with the goal of reducing it to less than 8 hours.

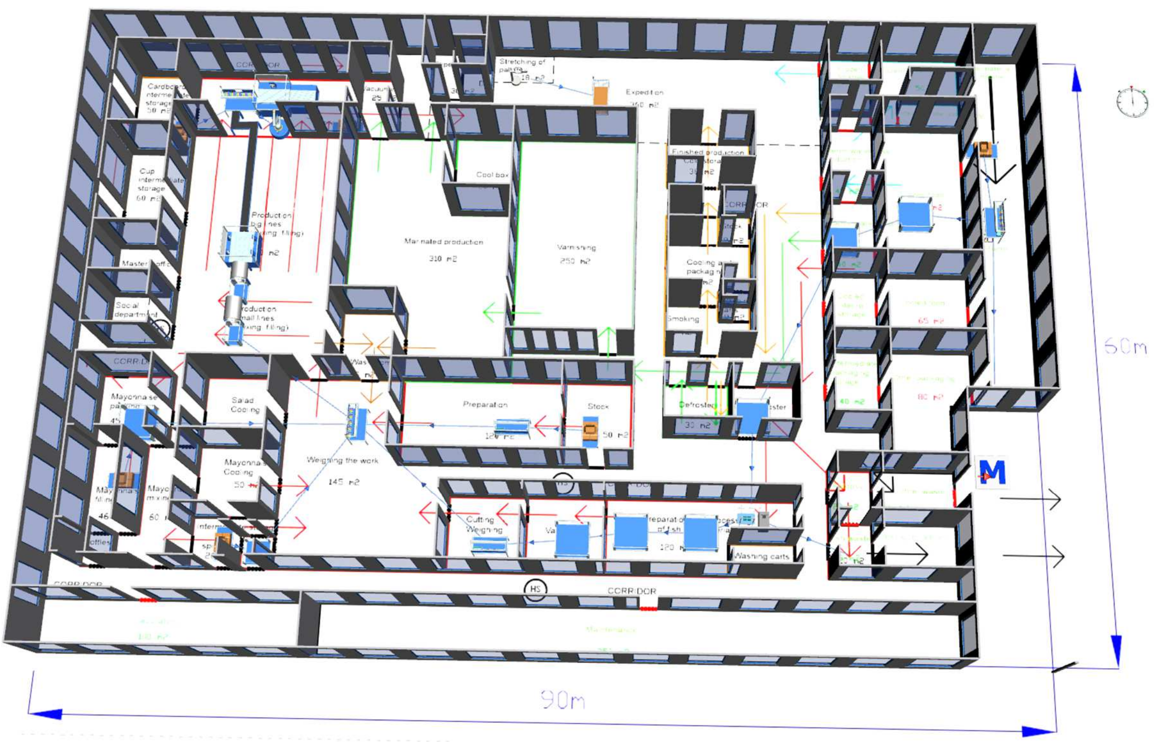

Figure 4 3D model of the production process of Treskoslovak Cod

After thawing, the fish raw material is unpacked and subjected to a quality check, although the time for these steps is not included in the simulation. Following the unpacking and inspection, the fish is cooked and cooled, but these durations are also set to zero in the simulation. The cooking process is expected to take up to an hour and a half, and the cooling process the same. Once the fish is cooked and cooled, it proceeds to the marination stage. The marination process, which actually takes 12 hours, is also set to zero in the simulation. The next step is grinding the fish, marking the first process where time is accounted for in the simulation. While the fish is being ground, the necessary ingredients and additional raw materials for producing Treslovakian Cod are prepared and weighed. The weighed mixture is then transferred to a new fully automated line that handles bag folding, mixing, filling, labeling, foreign object inspection, packing, cartoning, and palletizing. Once the pallet is full, it is wrapped in stretch film, making it ready for shipment.

For a clearer understanding of the Treslovakian Cod production process and a visualization of the production hall, a 3D model created using TX Plant Simulation software is shown in Figure 4. If only Treslovakian Cod in mayonnaise is produced during a given shift, approximately 11 pallets can be completed.

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3.4.2 Predictive simulation of the Paris salad production process

The simulation of the Paris salad production process does not account for the time spent receiving the raw materials. These materials will be delivered to the warehouse and unpacked from the transport packaging continuously, rather than on the day the salad is produced.

Once the raw materials are received in the warehouse, with the time set to zero, the production process begins with the preparation of salami, marking the first stage where time is included in the simulation. The salami must first be unwrapped, then sliced to the required dimensions. The sliced salami is then marinated for 2 hours. During this time, the vegetables and other necessary ingredients for the Paris salad are prepared.

When the salami is painted, all the ingredients are weighed. The mixture weighed in this way will be moved to the new fully automatic line. On this line, mixing, transfer of the mixed mixture to the container, filling into jars, labeling, inspection of foreign objects, cartoning and finally storage on a pallet will take place. A pallet filled in this way according to the required parameters is just wrapped with stretch film and is ready for dispatch.

For a better visualization of the Paris salad production process, we can see a 3D model from the TX Plant Simulation software in Figure 5.

Figure 5 3D model of the Paris salad production process

Based on the predictive simulation of the production process of the Paris salad, which would be produced during the entire 8-hour work shift, approximately 5 pallets could be produced and packed.

4 Results and discussion

4.1 Evaluation of the current and emerging layout

A key advantage of the layout design for the new RYBA Kosice production facility is that the entire production process will be conducted on a single floor. Currently, production is spread across two floors, creating bottlenecks and inefficiencies as part of the process begins on one floor and is completed on the second floor.

Another big advantage will be that the plant being prepared for construction will be completely new. We will be able to implement new fully automatic lines, conveyors, and other new technological devices. Based on the dimensions of the new technological equipment, and predictive simulations, we can create a perfect layout solution for the operation, where partitions and the location of machines will be designed exactly so that production is as efficient as possible and no bottlenecks arise during the production process.

4.2 Evaluation of predictive manufacturing

Initially, the results of the production process for Treskoslovak Cod in mayonnaise will be assessed. In both scenarios, the simulation duration is set to 8 hours. Also, placing packed cartons with products on the pallet is the same as in the simulation, with which the results will be compared.

Figure 6 shows the outcome of the predictive production for Treskoslovak Cod in mayonnaise at the new RYBA Kosice production facility.

.Models.Predictive_production

Simulation time:8:00:00.0000

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Finished_product	Pallete_of_product	1:22:06.7918	11	1	47.94%	52.06%	0.00%	0.04%	

Cumulated Statistics of the Parts which the Drain Deleted

Figure 6 The result of the predictive production of Treskoslovak Cod

Based on the results, it is apparent that the new production hall could produce 11 pallets of Treskoslovak Cod in mayonnaise, which is an increase of 5 pallets compared to the current output. However, this simulation result is merely predictive and may vary slightly from actual outcomes. The simulation used estimated times for some production tasks, and actual production might be influenced by technical issues or other unforeseen factors. The purpose of the simulation was to evaluate the potential production capacity of the new line, acknowledging that multiple types of Cod will be produced in each shift, not just one. Additionally, it is noted that 47.94% of the total time is spent on production processes, while 52.06% is dedicated to transportation. These results suggest that the proposed layout may not be optimal, prompting further investigation to achieve the most efficient configuration.

Next, the results of the Paris salad production process will be analyzed. In this case as well, the simulation duration is set to 8 hours, and the storage of packed cartons on the pallet remains consistent.

Figure 7 displays the results of the predictive production of Paris salad at the new RYBA Kosice production facility.

.Models.Predictive_productio_of_Paris_salad

Simulation time:8:00:00.0000

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Expedition	Paris_salad	2:59:17.9403	5	1	46.38%	53.62%	0.00%	0.02%	

Cumulated Statistics of the Parts which the Drain Deleted

Figure 7 The result of the predictive production of the Paris salad

The simulation results indicate that roughly 5 pallets of Paris salad could be produced and packed in a single work shift at the new production hall, which represents an increase of 2 pallets compared to current production levels. However, it is important to note that this simulation for Paris Salad production is only a predictive estimate. Some of the times that were used in the simulation are given only as an estimate, how long they will last in reality is not yet known exactly. Therefore, we can conclude that the result of the predictive simulation is not accurate and will differ from reality. It is also important to remind again, as with the cod production process, that during one shift, not only Paris salad is produced, but also other types of delicatessen salads. The simulation was conducted to assess the potential capacity of the new deli salad production line.

5 Conclusions

The advancement and streamlining of processes within industrial and logistical contexts are increasingly recognized as crucial factors for organizations striving to attain a competitive edge and long-term success in the 21st century. Maximizing efficiency in new operations largely depends on an effective layout design and streamlined material flow. These essential factors can be effectively achieved through the use of industrial engineering techniques.

The analysis of statistical data from the Tecnomatix Plant Simulation software shows that the production process in the production hall will be more efficient, to a large extent the specific places that arose during production will be eliminated. The simulation results provide a clear indication of the potential improvements in workflow and productivity, demonstrating the tangible benefits of an optimized layout and material flow.

In conclusion, it is very important to remember that it is not yet possible to say exactly how much production will be more efficient, since the predictions were predictive due to missing some data and times, which in the simulation were given only as approximate estimates after discussion. This inherent uncertainty highlights the need for continuous monitoring and adjustment as actual data becomes available during real-world operations.

Our forthcoming research endeavors will focus on further enhancing both layout and material flow. All modifications will undergo systematic verification through simulation experiments to ensure their efficacy and feasibility. We will persist in employing industrial engineering methods throughout these adjustments, continuously seeking to refine and improve our processes. By doing so, we aim to develop a robust framework that can adapt to evolving production requirements and technological advancements, ultimately contributing to sustained operational excellence and competitive advantage.

Moreover, future studies will consider integrating more advanced predictive analytics and real-time data collection to refine simulation accuracy. This will allow for more precise adjustments and provide deeper insights into the dynamic nature of production environments. Our commitment to leveraging cutting-edge technologies and methodologies will remain steadfast as we strive to optimize our production processes further.

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