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Mapping Forging Industry Manufacturing Optimization Approaches to Port Operations

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1. ABSTRACT: The layout facility problem has been broadly studied in manufacturing as a key factor for optimizing material flow and managing the supply of material for machines. Due to the complexity of the problem, simulations are usually applied in order to analyse the performance of the proposed layout solutions and predict their efficacy. As material routing presents the main issue when observing the production line supply there are apparent similarities with port operations. In this paper we explore the option to use the simulation approach of layout optimization in manufacturing to port operations.

Keywords: *Layout optimization, Manufacturing, Port operations.*

2. INTRODUCTION

Container ports are one of the busiest logistics hubs today. Thousands of containers flow through it every day. They can be empty or full. Filled with perishable or dangerous cargo. However, they can be filled with cargo that does not require any special treatment. But handling them all has one thing in common: they take up space and consume time. This causes costs and other impacts both on the environment and on the development of the company itself. Here the question arises, are there already developed methods for resource optimization in other branches of industry and are they transferable to the maritime sector?

For a case we present optimization in a forging process and explore how to map the optimization method to provide an impact on the overall efficiency and performance of a port. A port is a complex system that involves the movement of goods, ships, and people, and it is essential that all aspects of the operation are optimized in order to minimize delays and maximize efficiency.

One of the main ways in which optimization in a forging process can impact a port is by improving the flow of goods and cargo. In a forging factory, the layout and organization of the factory is crucial in ensuring that raw materials are received, processed, and shipped out in an efficient manner. Similarly, in a port, the flow of cargo is critical to the overall performance of the port. By optimizing the flow of goods, ports can reduce delays and increase productivity.

While performance of proper production strategy has been recognized by (Acquaah, 2008) and (Khan, 2012), a vital part of manufacturing depends on proper layout. Regarding the material flow and utilization, the Facility Layout Problem has been broadly studied (A. Drira, 2007). Layouts can be measured for their efficiency (Raman, 2009), which can provide a valuable tool for planning and analysis.

Efficiency improvement has been studied by Peña-Graf et al. (2006) in which they explore the energy requirements in the iron foundry industry, where they simulate energy requirements based on production planning. With the advances of Industry 4.0, discrete event simulations have been recognised as valuable in steel industry (Gajšek et al., 2019). Jung et al. (2022) provide a discrete event simulation approach using real-time data which is implemented as a digital twin. While simulations have been widely used in manufacturing it has also been applied in port operations such as analysing developing Ro-Ro terminal development (Muravev et al., 2016).

Another way in which optimization in a forging process can inspire optimization in a port is through the use of advanced technologies and automation. Forging factories often use automated equipment, such as robotic arms, to improve efficiency and reduce errors. Similarly, ports can also use automation and advanced technologies to optimize the movement of goods and cargo. Automated cranes and other equipment can help to reduce labour costs, improve safety, and increase the overall efficiency of the port.

In addition, optimization in a forging process can also inspire improvements in the management and coordination of the port. In a forging factory, efficient communication and coordination is necessary to ensure that materials are received and processed in a timely manner. Similarly, in a port, effective communication and coordination is necessary to ensure that ships are loaded and unloaded efficiently, and that cargo is transported to its destination in a timely manner. By optimizing communication and coordination, ports can reduce delays and improve overall performance.

Finally, optimization in a forging process can also inspire improvements in the training and development of port employees. In a forging factory, regular training and professional development opportunities help to ensure that employees are up-to-date with the latest techniques and technologies, and are able to perform their jobs to the best of their abilities. Similarly, in a port, training and development opportunities can help employees to improve their skills and knowledge, and to perform their jobs more efficiently.

In conclusion, optimization in a forging process can have a significant impact on the overall efficiency and performance of a port. By improving the flow of goods, using advanced technologies and automation, optimizing communication and coordination, and investing in employee training and development, ports can reduce delays and increase productivity, just like a forging process. The experience and knowledge gained through optimizing a forging process can be used and adapted to optimize a port's operation.

On the following pages, we will present layout optimization in the company with the help of analyses and computer models. The aim of the optimization is to address a large increase in orders. Due to small-scale production, automatization is difficult and therefore layout optimization presents the only feasible approach to achieve the increased demand.

Market demands have forced the company to increase production lines, but many opportunities for improvement lie in the already existing process. With minor changes, they could raise productivity by a few percent, and they also plan to add new additional machines into their process. In this paper, we will present these minor changes and use a computer model to check how much all these investments would mean for the company.

3. METHODOLOGY

First of all, with the help of observation, we got a better picture of how the company's processes take place. Once we had a better understanding of the processes, we measured the time of one cycle for each process separately. Due to the large number of different end products, we analysed how much the average worker makes on each machine separately.

The obtained data were analysed for each production line separately in a period of 6 months. After the analysis, we made a simulation model and analysed the solutions. The role of the simulation was to evaluate available alternatives to support major strategic decisions that may involve a large financial budget.

In general, with the help of simulations, we can constantly search for a more efficient process. with their help, we can increase or decrease production volume, introduce flow improvements, shorter delivery times and better customer response times. (Miltenburg, 2008).

We will proceed with the creation of the simulation following the steps listed in the list below. The steps follow each other as listed:

1. Identification of the processes involved.
2. Network analysis and identification of material and other flows.
3. Creation of a draft simulation model.
4. Data acquisition and analysis.
5. Creation of a simulation model.

6. Running a simulation

7. Running the simulation under different conditions and for different time periods.

8. Analysis of results and development of improvement proposals.

3.1.Material flow and network identification

The material flow is conditioned by the products themselves that the company manufactures and by the production layout. Analysis of the current floor plan, which is presented in figure number 1, we found that the company has a relatively well-designed floor plan for its needs, which can be used as the basis of our model. We will be able to easily eliminate the deficiencies identified in the available space for storing material in the process and storing empty containers with simulation results.

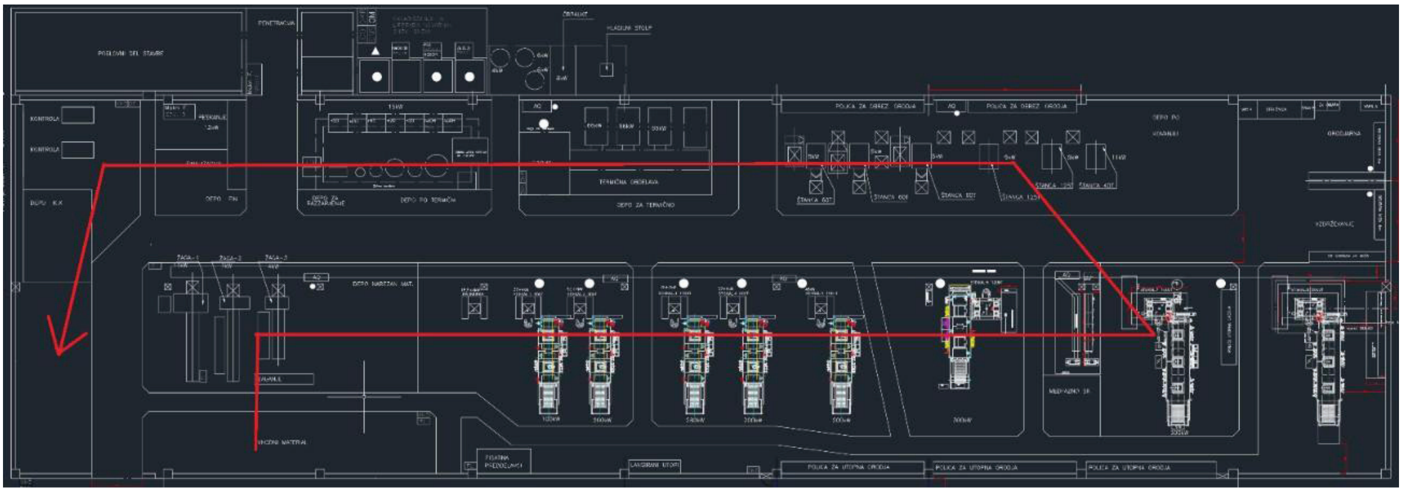

Figure 1: Current layout and material flow direction

In Figure 1, we can see that the material from the incoming warehouse to the of the finished goods warehouse travels in a "U"-shape, which in theory is a suitable shape for this type of production. The following figure (Figure 2) shows the material flow and intermediate buffer zones.

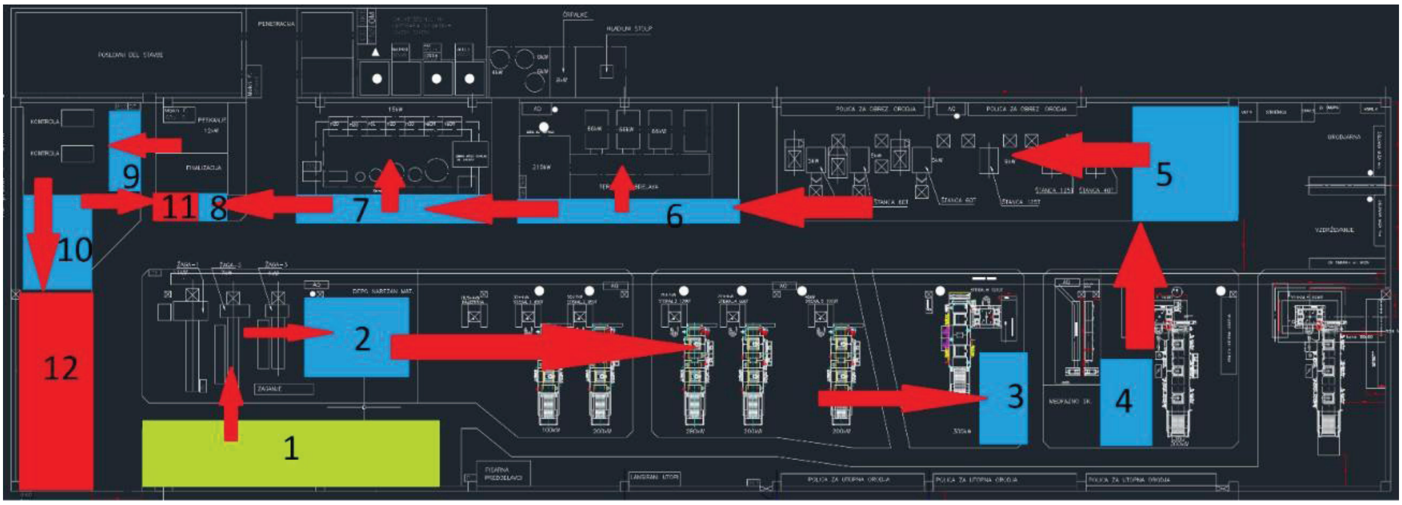

Figure 2: Material flow and buffer zones

The input material warehouse (No. 1) is marked green, from which the route continues to the first process, which consists of production on three machines. After the first process is completed, the material is stored in blue metal boxes, which continue to serve as a transport unit. All buffer zones are marked in blue.

After the first stage, the boxes can be transferred to a small warehouse located between process no. 1 and process no. 2, or they can be brought to two interphase warehouses in the second process (marked with numbers 3 and 4).

From here, according to the pull system, the material goes through another process, after which the items are moved to interphase warehouse no. 5. From warehouse 5, again according to the pull system, the items are transferred to the next process, after which they are moved to warehouse no. 6, which is located before the next operation in production. The same procedure is followed for the next operation, after which the articles change boxes and continue their journey to the penultimate operation (No. 8). In the next step, the items are moved to depot no. 9 or 10, from where the final control takes the products again according to the pull system, inspects them and packs them. If the items meet the standards, they are moved to the warehouse of inspected, finished products (No. 12), otherwise they are returned to the previous operation (No. 11), where the process is repeated.

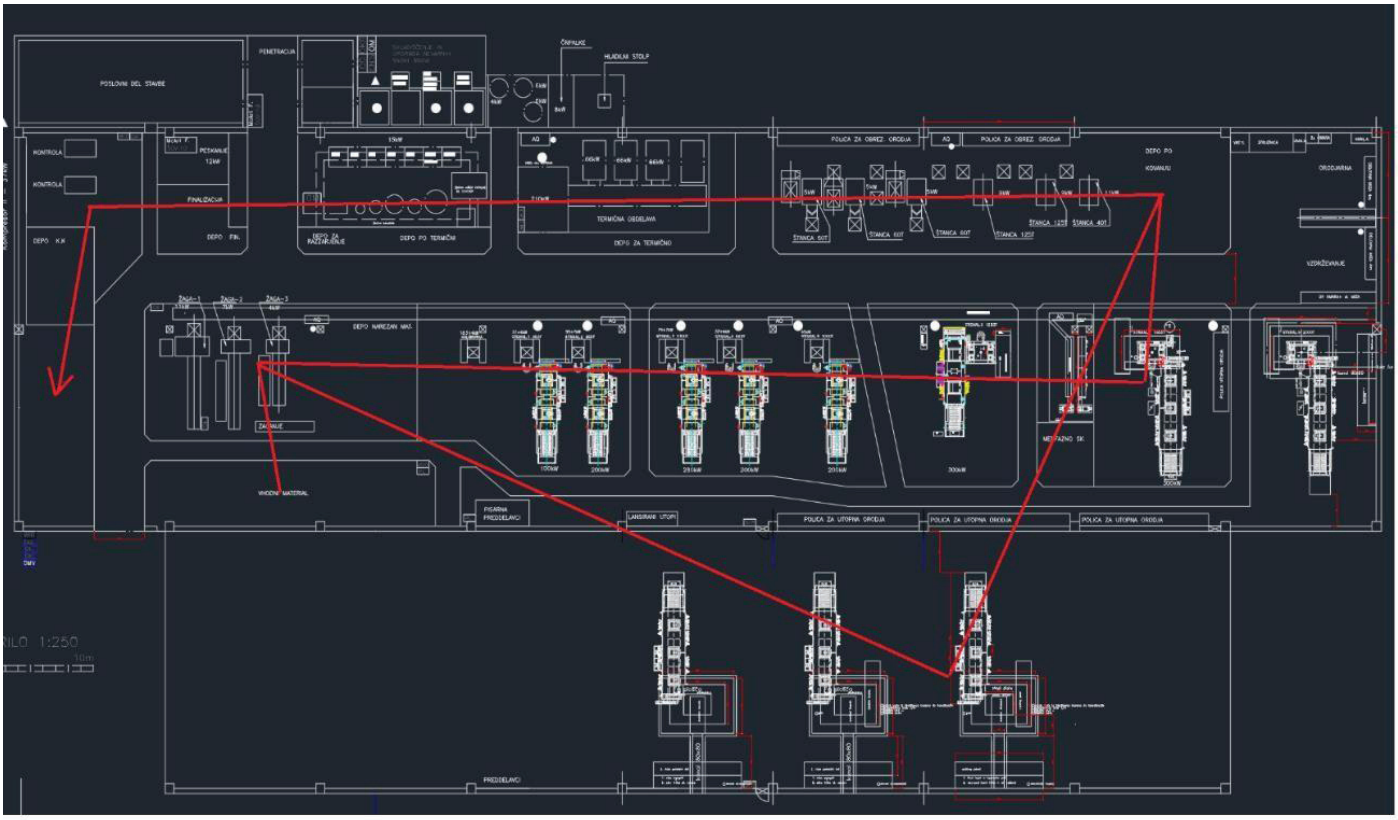

Figure 3: Proposed layout prior to simulation analysis

The future expansion of the hall needs a detailed analysis, since any deviation from the current floor plan change can be the key to the good or bad flow of the process. The original plan for the expansion of the production process is presented in Figure 3. This plan was made without detailed analysis and served only as a vague proposal to increase capacity. However, we can immediately notice the deviation from the previous flow of material, because with such a layout, we would make a lot of unnecessary movements, and on top of that, we would significantly increase the transport routes.

One would also have a lot of unused space and additional intermediate storage. It is for this reason that we later made a more detailed analysis of what layout of work machines would be the best.

3.2.Data acquisition

We obtained the data from the company's ERP system, where production is continuously recorded. We analysed the data for each machine separately where possible. For each machine or production line, we obtained monthly quantities based on how many pieces were made, and divided them by the number of working days in the month. In this way, we obtained data on the average quantity of produced pieces per machine per day for a period of six months. The average quantities per day were later divided by 1440, which represents the number of minutes in the day, giving us an exact figure of how many pieces are made per minute.

3.3.Model and simulation

This part will present the simulation model and the results obtained by observing various processes in the forging process and analysing the data obtained for each operation in the last six months. In the research itself, we made two models for simulation, where one is basic, for data comparison, and in the second model we added 3 machines, one each for the second, fourth and fifth processes. The data are presented below. The basic simulation ran for one month, and it showed that we make an average of 0.77 packets of finished goods per hour at the final production process.

Figure 4 shows all machines and their processing times. We also found that the machines in the third operation have a very small percentage of operation, but in practice they solve this by redistributing workers to other jobs, so that the efficiency is as good as possible.

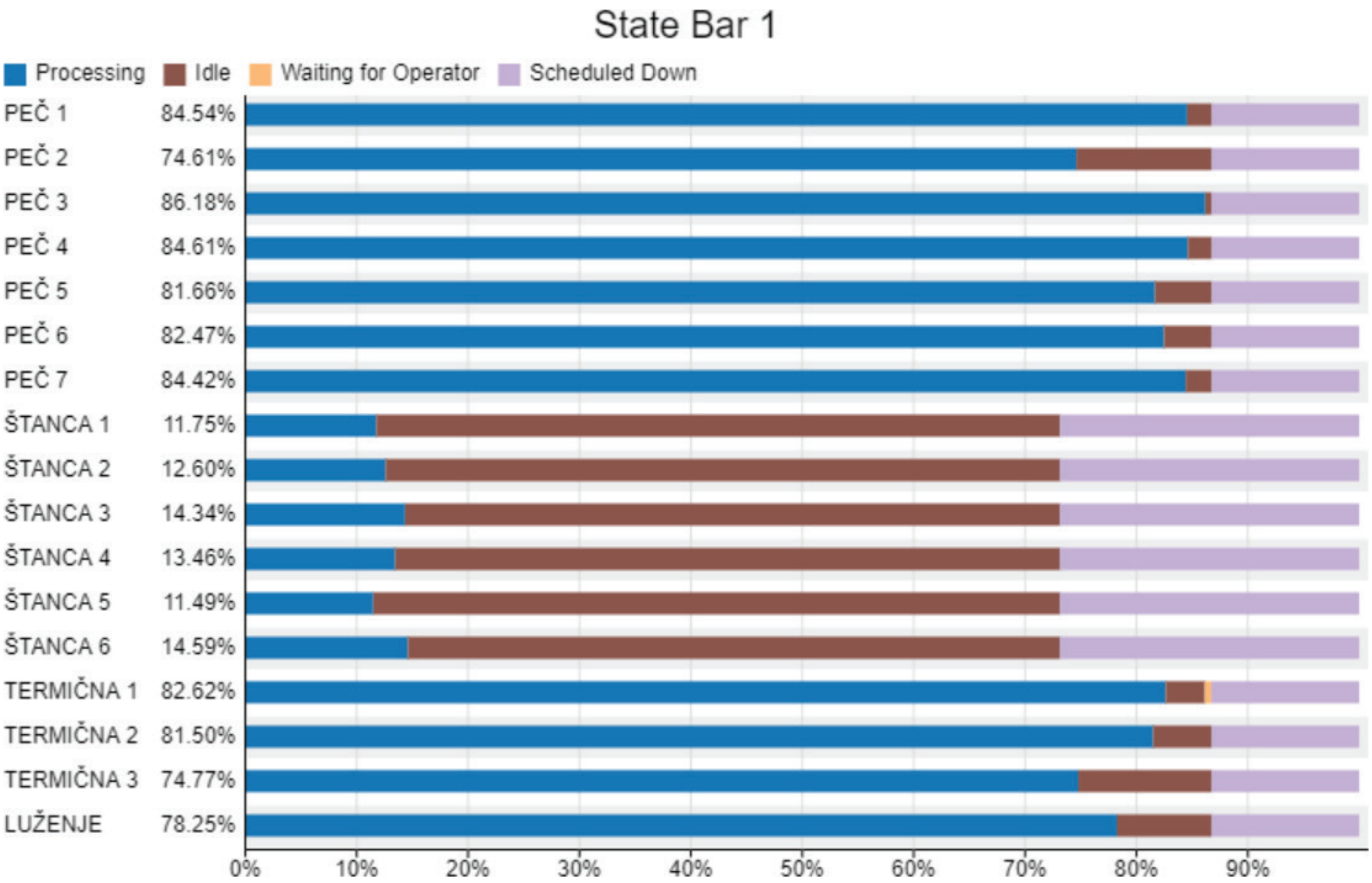

Figure 4: Utilization of production lines

Later, we added 3 machines to our model, in different operations, which we found to be bottlenecks. We found that the number of packages made every hour rises considerably. It is necessary to assume that in our simulation one package represents 400 pieces of a certain item. We did this because even in reality, items are transported in metal boxes, and the average amount of items in this box is around 400. Also, these boxes help us with the transport itself.

The number of packets made every hour rose from 0.77 to 0.95, which represents 380 pieces or 123.38%. This slightly more than 23% translates into a production of around 50,000 pieces every month.

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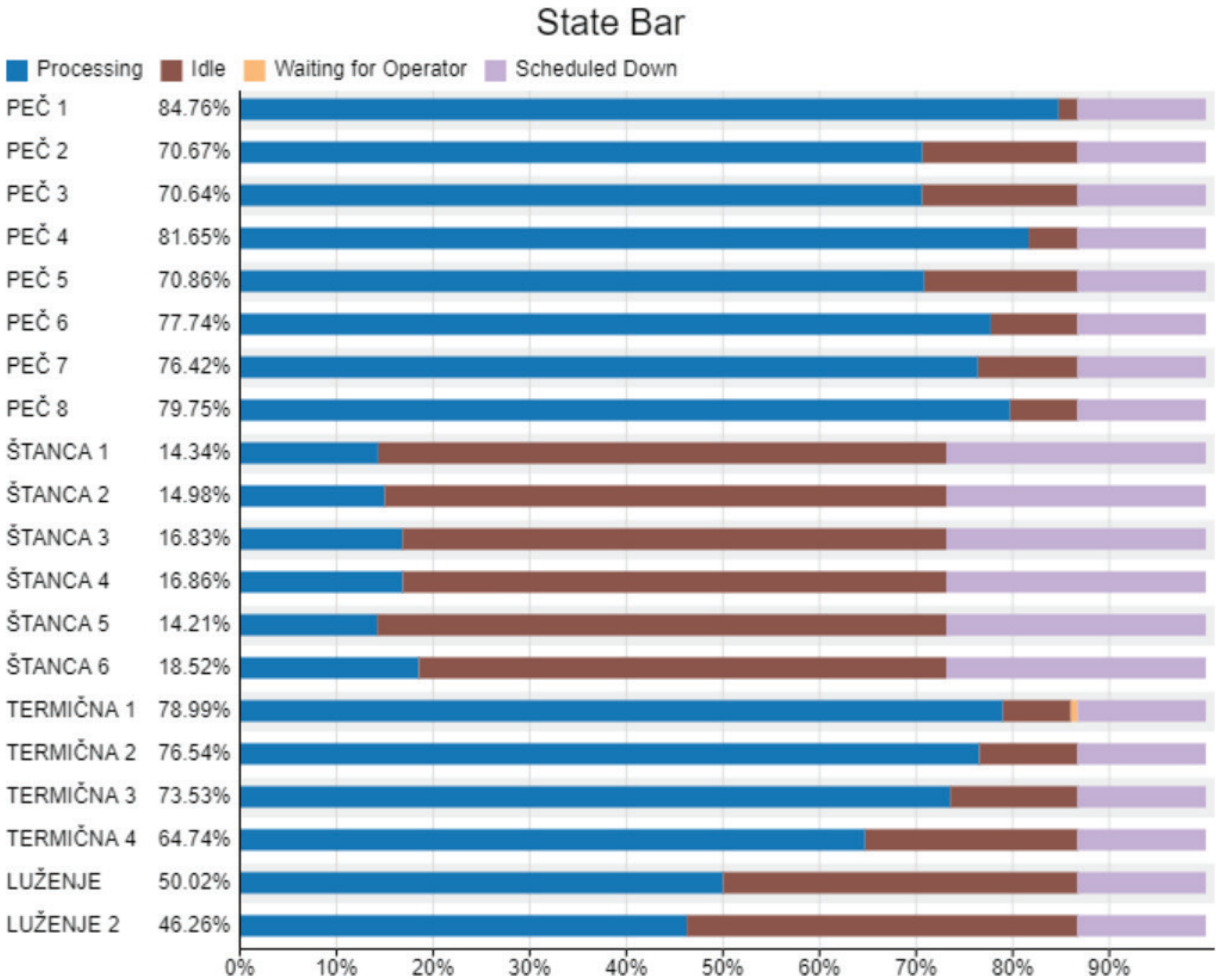

Figure 5: Production line optimization of the optimized layout

4. RESULTS

With the help of data analysis, we came to the conclusion that despite the good flow of material, the current process has a number of shortcomings, above all it has too many interphase warehouses, which consequently lead to excessive transport routes and double handling of the material. We also noticed quite a few problems when planning the new production facility.

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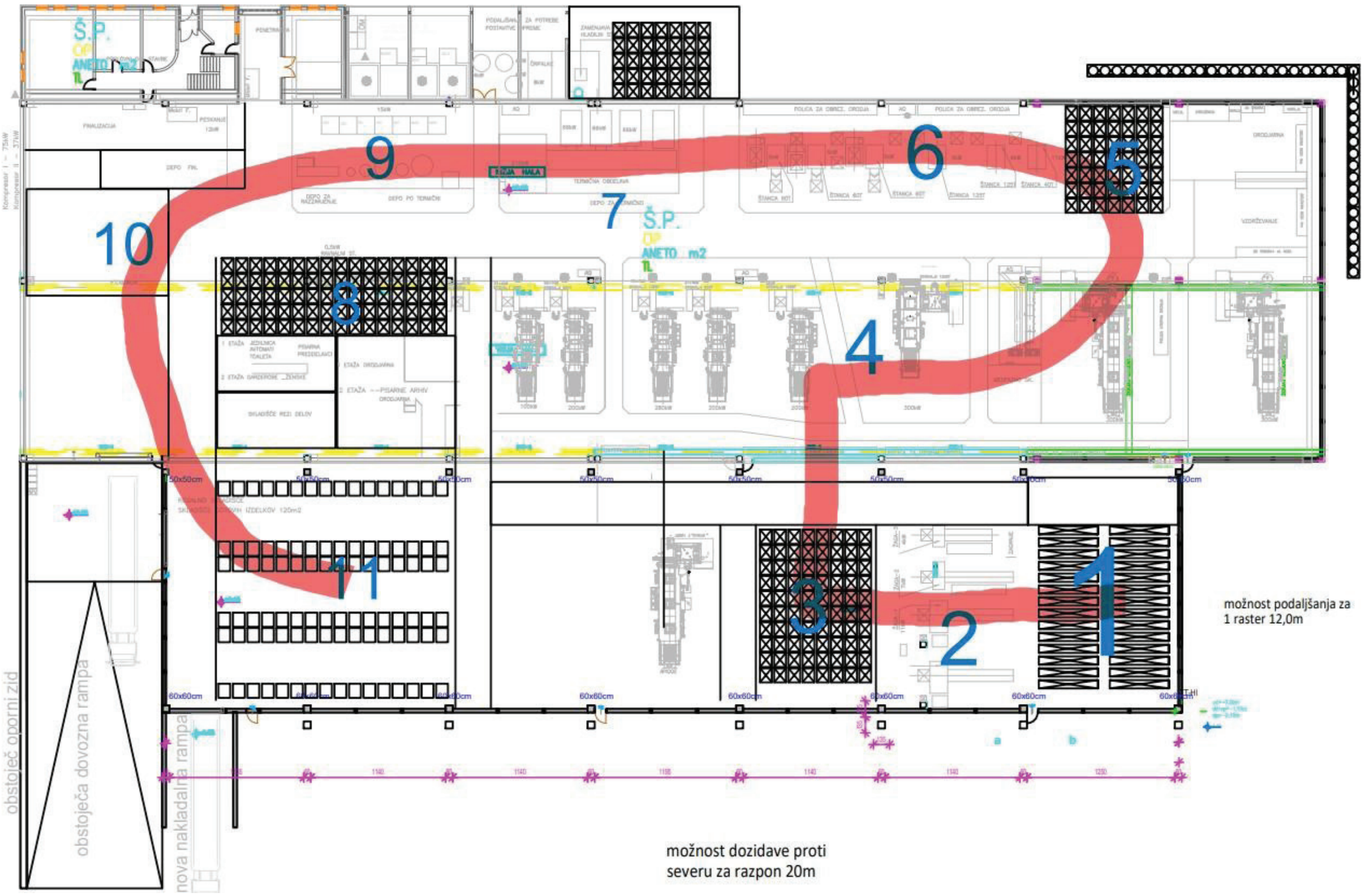

Figure 6: Proposed layout changed backed up by simulation results

The initial plan would have increased the material flow path, created additional congestion on the transport routes, and caused a deviation from the previously well-designed material flow. There would also be an increase in intermediate warehouses, in which the material sits for a considerable time and does not gain value. For this reason, with the help of analysis and simulation, we came up with a new layout of jobs. In Figure 6, we can see our proposed floor plan of the job layout. The warehouse of incoming material is moved to a new building (No. 1), where unloading will take place from the right, north side. We move the original operation (no. 2) to a new facility, because in this way they will be closer to the incoming material, and at the same time they will be able to easily stock all the lines of the second process, which are marked with the number 4 in the picture from the interphase warehouse (no. 3). From there, the crates will be moved to the intermediate warehouse (No. 5), from where the process will be the same until the last operation.

5. CONCLUSION

With the help of computer model analyses, we improved the floor plan of the distribution of tasks, which was proposed by the company, and achieved greater efficiency of the material flow through the production process. We also identified where bottlenecks occur and proposed some solutions to solve them in the future. The detailed analysis allowed us a better overview of the process itself and helped to identify places where losses occur. The model is built for production in a forging company, but is nevertheless useful for optimizing the handling of containers at the terminal. With its help, we can analyze and optimize the flow of containers through the port. This is particularly useful in cases where the development of ports is limited by space. In this way, we can save a lot of space and still increase throughput.

While port operations logistics may differ from forging processes, the main similarity presents the storage problem. While the presented case addresses the manufacturing on the production lines, it is important to observe what happens at the storage buffer zones, which can reveal bottlenecks in the production. This approach can be mapped to analyse the efficiency of other port operations that rely on any type storage and storage time. From the material flow point view port operations and forging, or basically any manufacturing industry has similar processes and which can be addressed using material flow modelling and simulation. As such cargo handling could be analysed in the same manner as production lines in manufacturing, while storage capabilities behave in a similar fashion.

Where simulation provide an actual insight into processes further advances can include machine learning approaches and real-time data capture, which can be implemented using a digital twin. As direct mapping a singular approach to another area may be difficult the idea is to focus on the basic processes and those basic characteristics, which are comparable regardless of industry type.

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