doi:10.22306/al.v9i4.341 *Received: 08 Oct. 2022; Revised: 09 Dec. 2022; Accepted: 21 Dec. 2022*

MODELLING AS A TOOL OF MAKING THE COMPANY'S LOGISTICS MORE EFFICIENT

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Keywords: modelling, layout, design, manufacture, logistics.

Abstract: The subject of this article was connected with the problem of finding an effective layout of manufacturing mechanisms in a particular manufacturing hall in DELTA Company, where we were part of a project team. The project team's goal was to solve the problem associated with the actual layout with the help of modelling and designing. It was necessary to analyse the actual layout and also opinions and possibilities of changes in this particular manufacturing mechanism. It is the manufacturing hall. For the analysis of the actual layout, we decided to work with different analytical methods because there were a lot of elements in this manufacturing system which have their own characteristics that are also connected itself or with others. It was necessary to look at all of these characteristics and their connections, and the result will be based on a prime scheme model of design variations for finding an effective layout of manufacturing mechanisms for a particular hall in DELTA Company.

1 Introduction

Nowadays, logistics is one of the most important factors that dynamically effect the world economy. The common trend is globalisation, which is changing the traditional management of company objects and the management of the company itself. The literature made by *Malindzak, D.* [1] states that "the objects of logistics are financial, material and information flows, flows of people, goods and materials". In the publication of *Madarasz, L. et al.* [2] is mentioned the fact that "by process management, we understand the provision of a predetermined goal by means of controlling specific devices based on evaluation and processing information that aforementioned devices will receive back not just about the object itself, but as well as about the effects of the environment on this object." This leads to the so-called global optimisation, which requires considerable attention from experts and engineers whose goal is to continuous improvement, innovation and elimination of system deficiencies, which will ultimately lead to an increase in the quality of work, products and the working environment itself while maximising the use of capacities and potential while incurring minimal costs connected with it. The definition of the global goal by *Takala et al.* [3] states that a global goal "is given by optimisation criteria" meanwhile "logistics management directly or indirectly solves the problem of multi-criteria optimisation, such as maximum use of equipment capacities, minimisation of energy and material consumption, profit maximisation, etc." where "these criteria can be supportive or conflicting".

However, the goal of logistics is to meet these criteria, especially from a time point of view, which will lead to cost minimisation and profit maximisation [3]. Practically optimising the problem and finding an effective solution and subsequently achieving the global goals can be easily achieved not only thanks to an in-depth analysis of the problem itself but also by fulfilling smaller sub-goals. One of the tools with which it can be achieved is the process of modelling and planning. *Straka, M. et al.* [4] relies in their work on the fact that "modelling is the process of replacing a dynamic system with its simulation model" and also "modelling includes the creation of non-simulation models, and their use can also be used for production purposes."

During modelling, we can not forget about the rule, which is a state in *Hradecka, J.* publication [5] "when planning and creating, it's also necessary to pay attention not only to the practical, aesthetic but also to the ergonomic side" which will lead to the effective layout. When we are talking about layout, we mean objects that are organised and arranged according to a certain taste under certain conditions. In our case, it will be from the point of view of architecture. The interior design tries to create a functional layout as a part of the overall concept.

2 Literature review

When it comes to the definition of redesign, there are plenty of meanings. For example, it depends on the dictionary that we use. In Merriam-Webster dictionary, redesign is definite as a "revise in appearance, function or content [6]. When it comes to Cambridge dictionary, redesign is the definition of changing "the way something looks, is made, or works" [7]. Portal Seobility states that redesign is "visual upgrade or rearrangement of an existing" subject, system, etc. [8] easily said it is a plan for making changes. In the publication, Universal Principles of Design by Lidwell, W. et al. [9] mentioned that the key principles of design were selected from various design disciplines based on several factors. The authors also stated the fact that even the best designers sometimes disagree on the principles of design. When they do so, however, there is usually some merit attained at the cost of the violation.

Therefore, unless you are certain of doing as well, it is best to advise the principles [9]. But we can sum it up in the following steps:

1. definition of a goal – what we want to achieve,
2. who is responsible for the redesign,
3. design process – examination of the monitored object, its elements and description of how it works, limitations,
4. modelling – creation of an idea of the monitored object and its functioning,
5. verification of correctness,
6. verification of truthfulness,
7. testing,
8. application [4,8].

Modelling includes the creation of models and designs other than simulation, and their use can be for other purposes as well. It is important to remember that when creating and designing a layout, it's important to know the dimensions of the space we are working with. In addition, it's necessary to pay attention to requirements such as:

- structures,
- security,
- medical and psychological,
- economic,
- manufacturing,
- and others.

It is also important to be aware of the basic functions of the space with which we are working, i.e. all activities must be kept in mind, as well as the functions mentioned above that will be performed and occur at the given workplace. In this case, it's necessary to consider the fact that in a specific production hall, the workplace will mainly involve the movement of people, material handling equipment, and the movement of storage handling equipment. If we are planning the layout of the workspace, it's necessary to take into account a place for relaxation and rest, as well as other facilities. In addition, we must pay attention to the following:

- environmental quality (heat, light, ventilation, air extraction, air circulation, …)
- the comfort of space and security
- spatial solutions
- necessary workplace equipment [10].

3 Methodology

The DELTA Company, which is the subject of the investigation, is currently one of the world leaders in refrigeration in the field of hermetic compressor manufactures. The idea of DELTA Company is continuous improvement and innovation to increase the quality of products, work but also the environment where we work or live. Because the company prefers modernisation, it decided to innovate one of its production processes in a particular manufacturing hall in one of its factories. The project we were a part of was financed by various investors, who, however, all set one condition, which was presented by the global optimisation of the entire production hall and not only the production process. The problem which we worked on was associated with finding an effective layout of the manufacturing mechanism in the particular manufacturing hall, which we mentioned earlier. Reconsidering the condition of investors, we set our goal, which was not also to find the most effective layout of a particular manufacturing hall but we needed to include the most effective layout of all mechanisms. Thanks to this, we can get closer to global optimisation. But before that, we needed to start by analysing the current state. For this purpose, we used system analysis.

System analysis is a method of general systems theory for exact and empirically intuitive investigation of basic properties and target systems in various areas of human activity. In the analysis process, we look for individual systems and try to modify or replace activities, connections or relationships in the given system. The process of system analysis represents the main activities, such as the definition of the problem (what we are investigating), the research and analysis of the associated systems, the determination of the appropriate method of solving the given problem, the introduction of a new proposal and the subsequent evaluation and feedback. For this reason, system analysis represents a relatively wide set of different methods and procedures for the most detailed analysis and analysis [11]. System analysis is a suitable tool for analysing the state of the system, as it examines not only its elements and the relationships and connections between them but also the elements, their properties, and the connections between them. Thanks to this, we can get to know the system's functioning in detail and subsequently derive individual results of observations and evaluations from the research. This analytical method is used especially in cases where we want to improve the given system or completely replace and create a new one, which was our case.

3.1 Current state analysis

After we decided which type of analysis we would use, we could start with an analysis of the current state of the company's manufacturing hall.

3.1.1 Manufacturing process

Before we could start with modelling and creating a design of a particular manufacturing hall, it was necessary to understand how the production works and what limitations may occur in the process. Usually, it all starts with entering materials into production, which in these cases are direct and indirect materials. Direct material is supplied in 900 kg blocks of Aluminiu from the supplier, and then they are processed into 8 kg ingots in one of the manufacturing halls in DELTA Company. Indirect materials are rotor packets, which are manufactured directly in the company. The real production process begins with preheating rotor packets at a temperature of 450 °C at the induction heating robot. Meanwhile, the ingots are melting in a melting furnace at a temperature of 750 °C. Both temperatures must be at exact numbers to maintain the production process's accuracy, which leads to the final product's final quality. The next step is a new innovation in the production process: the centrifugal casting of rotors. Then the process continues with chilling, and subsequently, the finished products are moved to the finishing station. Under final processes, we can imagine processes such as cutting, rolling and, of course, quality control. The last step is to load the final products into pallets. More specific information is in the publication of *Spirkova, S.: Analysis of the possibility of changing the layout of production facilities in a particular company* [12].

3.1.2 Requirements

Even if we learned how it would work, checking all the details connected with the new production process was necessary. First, we started with the production process, machinery and equipment itself. There were a lot of technical (separation requirements for machinery and equipment), technological (efficiency, performance, speed), mechanical (temperature transfer and absorption) and one of the most important time requirements (scheduled times within the technological and production process) which must be observed, because then the final product will not be able to satisfy the final quality of products, which is most important. Because we are speaking about global optimisation, it was also necessary to check all requirements for the workplace, inputs, and outputs cause they're also part of the successful completion of the product. As we are speaking about, workplace requirements include manufacturing mechanisms and also handling space. But what is specifically important it's the quality control of inputs before they enter the production process. If it comes to direct material, it is necessary to have 99.9% content of Aluminium. Indirect material includes quality requirements such as strength, hardness or weight, but also measurements where important are length, diameter, thickness and angle of the rotor. All of the inputs must satisfy exact requirements, which will lead to reaching the highest quality of the final products, which is connected with requirements for output. The company demands control of compliance with production and technological processes, quality and measurements of final products. It's necessary to mention daily manufacturing standards, which we couldn't forget because they must be strictly observed according to the stated manufacturing plan, which you can see in Table 1 [12].

After observing and recording all requirements, we could start analysing the current state of the company's manufacturing hall. Supplying the production process is based on forklift and handling units. It's good to point out that some special handling units are used in the company, which are connected with supplying the ingots. More detailed information and photos are in *Spirkova, S.* publication [12] which I mentioned earlier. The supplying system may be considered a small detail, but in the end, it is also an important part of the system, and we are speaking about global optimisation, so it was necessary to notice that in our analysis. The whole place looks really crowded, which can lead to many collisions and injuries. Due to that, we decided that we would make an FMEA analysis.

Table 1 Daily manufacture standard

Request for individual manufacturing lines			
Manufacturing line	The average weight of used Al (g/pcs)	Manufacturing cycles (s/pcs)	Daily intake (pcs)
T	184	10.7	3800
J	204	10.7	1500
NB	163	7.4	9500
EM	169	6.7	9100

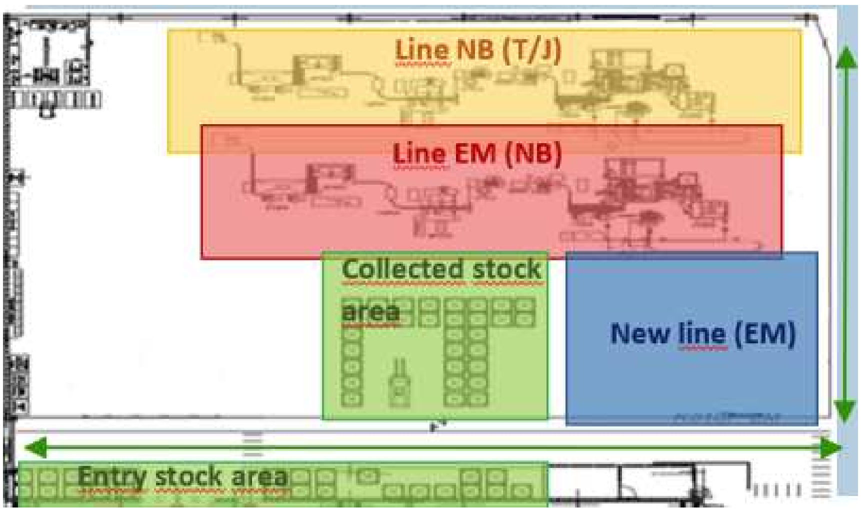

Figure 1 Layout of a particular manufacturing hall

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Failure Mode and Effect Analysis (FMEA) belongs to the group of basic analytical methods, but it is mainly used in the field of quality, reliability and safety management. It acquires its use not only in the field of production, services, and many other industries and processes. The first step is the definition of the problem, the error. In the second step, we approach the numerical expressions, which we calculate based on the monitoring and evaluation of the individual investigated phenomena. It is, therefore, necessary to find out the values of the occurrence of the error or problem and their significance and assign the degree of detection of that problem and error. The last step is the product of the individual values, which will give us the so-called risk number. According to experts, the risk number should not exceed 125. This value is considered critical, and errors or problems whose risk number exceeds this value must be corrected or eliminated. We must not forget the values that approach this value, where it is also necessary to consider their correction [13,14].

Thanks to all information mentioned earlier, conversations with employees and managers, and our observation. We were able to puncture risks and problems connected with this layout, which you can see below.

The analysis of errors and risks in the particular manufacturing hall can be easily found in *Spirkova, S.* publication [6]. FMEA analysis describes in detail all subjects of analysis, the manifestation of errors, their potential causes and effects, occurrence, detections and also possibilities of control, which led us to risk number. Since it is global optimisation, it was also necessary to recalculate the costs associated with the production process with this particular layout. You can see the leading indicators and monetary expressions connected with the current layout in Table 2 [12].

The total costs associated with this workplace amounted to a total of 4.310 euros. The costs in the table are averaged according to the data that the company monitored for a period of 5 years. However, we have also included a potential risk indicator in the table. It represented up to 50 possible risks, which is relatively large given the dimensions of the production hall of 42,000 x 36,500 cm. We obtained a potential indicator of safety risks based on the FMEA analysis we created. As part of this analysis, we made Table 3 based on observations.

Table 2 Costs and indicators associated with the current layout

Leading indicators and monetary expressions	
Indicators	Expressions
Fuels consumption (euro/month)	2280
Electric energy consumption (euro/month)	230
Maintenance costs (euro/month)	1125
Labour costs (euro/month)	675
A potential indicator of security risks	50

Table 3 FMEA analysis

Analysis of errors and risks in the manufacturing hall									
Nr.	Subject of analysis	Manifestation of error	Potential effect	Potentional cause of the error	Possibility of control	Meaning	Occurrence	Detection	Risk nr.
1.	workplace enviromen	crowded working space	chaotic movemts	wrong decisions of managment	system aproach	6	20	2	240
		small space for manipulation and movements	opacity	wrong decisions of managment	system aproach	10	11	3	330
2.	working methods	improper way of using devices	high change of failures	human factor	education and motivation for taking responsibility	3	3	9	81
		losses and wainting	production ineffeciency	human factor	work organization	10	8	1	80
3.	employees	inattention	high change of risks	human factor	education and motivation for taking responsibility	10	2	2	40
		weak/bad qualification	faulty piece	human factor	trainings	10	6	1	60

Table 3 includes the basic areas of risks, their manifestations and potential impact. The areas of risk were mainly represented by the workplace environment, work methods and the employees themselves. We then assigned the most common possible manifestations of risks to these areas. Each risk was assigned a degree of importance, which we chose according to the degree of danger from the interval from 1 to 10. The greater the degree of importance, the greater the risk. The greatest degree of danger occurred in the area of the workplace environment, where this risk manifested itself in the form of a small space for manipulation and movement, in the area of methods in the form of losses and waiting, and in the area of employees in the form of inattention and unqualifiedness [12].

Next step, according to the results of observations and monitoring, we assigned values for the number of occurrences of given risk manifestations. Subsequently, we assigned detection values to each of these manifestations of risks, which represent the values of the expected chances for finding out whether or not it is a risk. Values were assigned from an interval of 10 to 1, where the value with the largest number was likely to be the most noticeable. We then multiplied all these indicators to obtain a risk number. The risk number represents the value by which we determine the degree of danger. Whether the risk needs to be eliminated or removed, we find out according to the limit value, which is given as the number 125. In our case, we exceeded this value in 2 cases, in the form of a risk associated with an overcrowded workplace space and a small space for manipulation and movement itself. The risk number for an overcrowded workplace was 240, which is almost two times the limit value. Much worse was the risk number for the small space for manipulation and movement, which reached a value of up to 330, which is even more than 2.5 times the limit value. Both cases recorded alarming values and gave us an idea of the magnitude of the danger, which must be eliminated as much as possible or removed completely. The other values were around the values of 80, 60 and 40. These values are not so alarming, but in general, the FMEA analysis gave us an idea and an indication of the main problem of creating risks and the dangers associated with them [12].

4 Discussion and results

The analysis of the current state helped us to set our goal, which was simply to design and create the most effective layout where will be minimal risks and errors, which will lead to global optimisation in the particular hall of DELTA Company.

4.1 Modelling as a turning point

The aim of this work was the analysis of the possibilities of efficient distribution of production equipment in the production hall, while the problem is related to the search for efficient distribution of production equipment in a specific production hall. This task also results from the results of the FMEA analysis from the previous chapter, where deficiencies were identified precisely within the workplace environment. We were able to come up with results thanks to the workplace modelling process.

4.1.1 Model nr. 1

In this model, we keep maintaining material flow and the original area of manufacturing lines and the entry area stock. We suggested removing the kanban table, washing machine and cylinder cover because these types of machinery were not connected to our production process and also just to make the whole place less crowded. We also suggested adding a new line in the original position of the kanban table and cylinder cover and replacing the washing machine with the collected stock area. You can see the first variation of the model below.

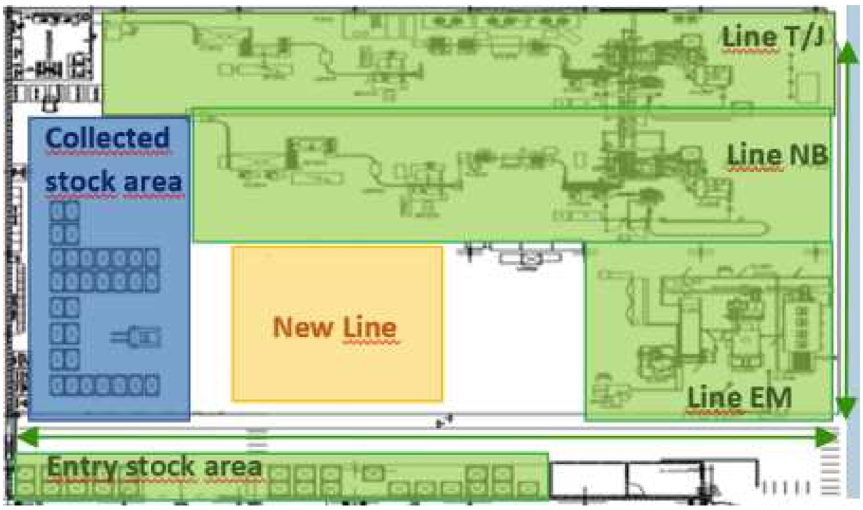

Figure 2 Variant nr. 1

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But then there was a question if this is really global optimisation and if we will keep all the old lines and just add a new one. So that was the reason why we decided to make a second model.

4.1.2 Model nr. 2

Again in this particular layout, we decided to keep maintaining material flow and entry stock area. We also insist on removing the kanban table, washing machine and cylinder cover for the previously mentioned reasons. But we also suggested removing line T/J because this particular line was the oldest one. Conversations with managers and employees confirmed that there were often a lot of problems and they required to be repaired all the time. So after removing the mentioned machineries and equipment, we suggested relocating a line NB in an original line T/J and relocating the production process from T/J to the NB line. Next, we did the same with lines NB and EM. We also replaced the cylinder cover with the collected stock area, which ultimately created a new larger space, which you can see below.

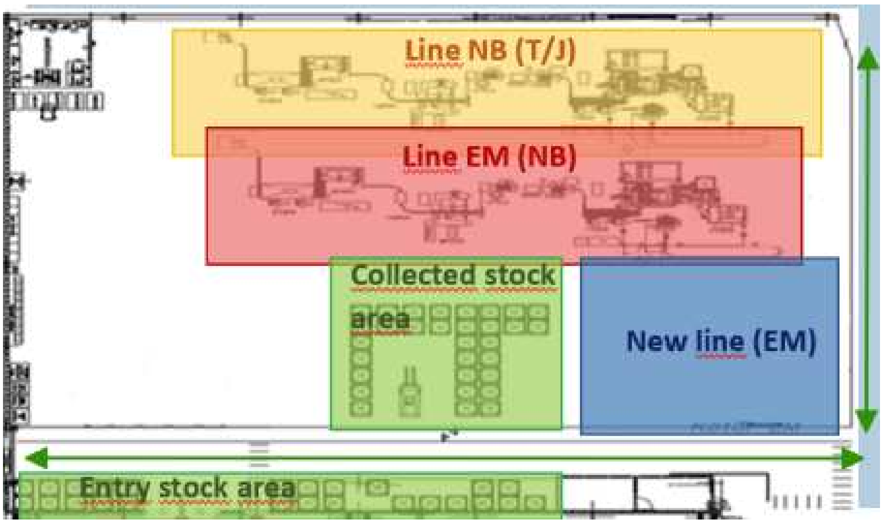

Figure 3 Variant nr. 2

4.1.3 Model nr. 3

After modelling variant nr. 2, we realised that this new space was located at the end of the manufacturing hall, and we would like to add the collected stock area in the end so there will be less manipulation with the final products. Based on that, we just slightly changed variant nr. 2, everything is almost the same, but the change is in the relocation of the new line and collected stock area to the other side of the manufacturing hall, which you can see below.

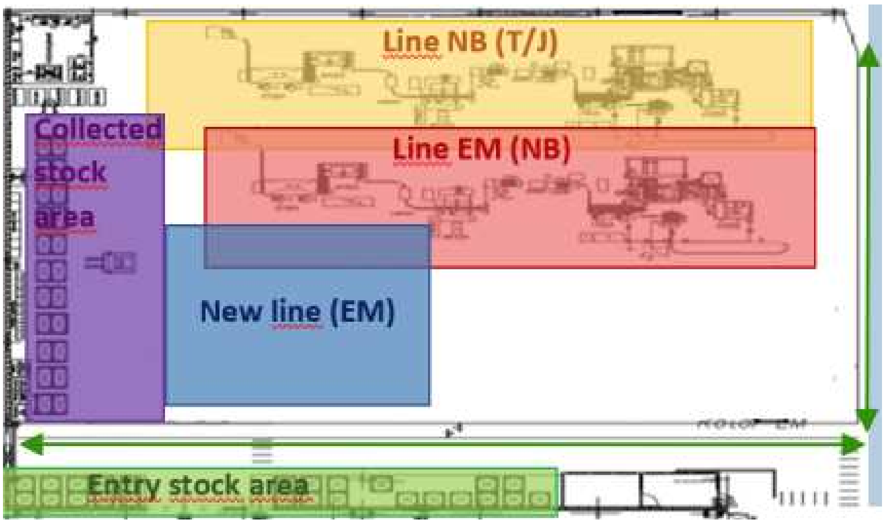

Figure 4 Variant nr. 3

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4.2 *Results of the modelling process*

Our next step was to submit our models to the company. The company project team decided to work with our last design, which was slightly edited. After studying our models, the company's project team decided to develop a new layout, which will be the final model.

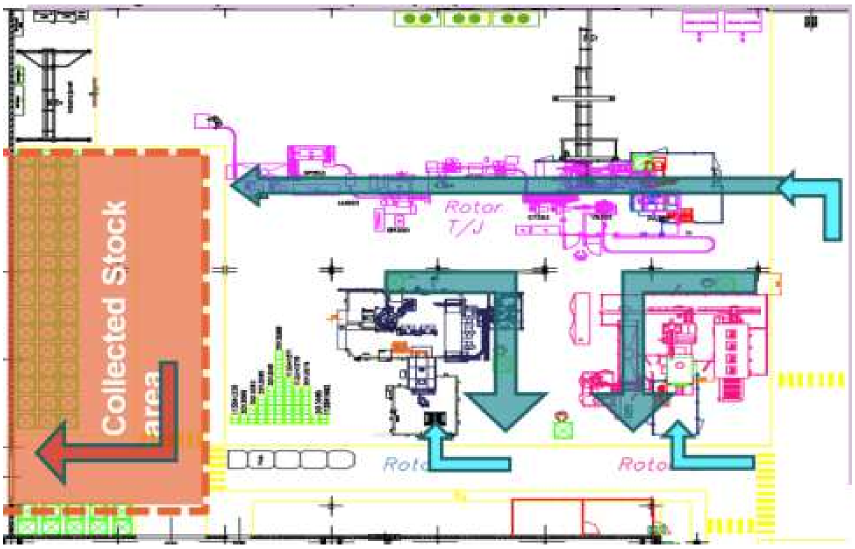

Figure 5 Final layout

It was decided to remove line T/J and replace the production process with line NB. They also edited the new line and line EM layout, so it will take a smaller place and keep our suggestion to produce rotors NB at line EM and rotors EM at a new line. The washing machine with the collected area was replaced, but for a specific reason, they decided to keep the kanban table for future plans. This whole decision is also connected with empty space in the back of the hall. As we look for results, whether it is the global optimisation or not, the company project team defines new monetary expressions and leading costs connected with the new layout, which is in Table 4 [12].

Table 4 Costs and indicators associated with the new layout

Leading indicators and monetary expressions	
Indicators	Expressions
Fuels consumption (euro/month)	1115
Electric energy consumption (euro/month)	55
Maintenance costs (euro/month)	425
Labour costs (euro/month)	0
A potential indicator of security risks	0

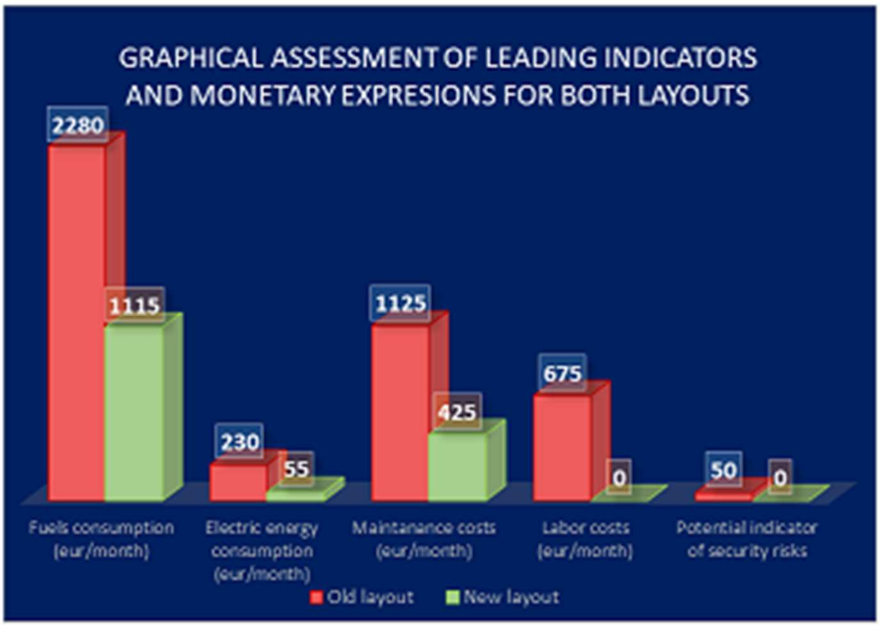

Figure 6 Comparison of the costs

In the end, we can state that even if our model was not final, it was the basis for the final layout, but that was already the company's intention for the future, which we couldn't know about, but we still influenced that. We helped to make an effective layout for global optimisation, and our last step was to review what was achieved. When we compared the results, we found out that the company can save 68.75% of the original monetary, while it decreased from 4310 euros to 1595 euros per month, as you can see in Figure 6 [12].

We can consider this a huge achievement, but a small "huge" problem is connected with it. Company states and insist that with this particular layout, it can be reached unbelievably zero potential indicators of risks and problems, which, to be honest, is not possible, and we can call it utopia because it's practically impossible to achieve something like that. Even if we made the most effective layout and succeeded in global optimisation, there is no proof that it can be much better in the future and that nothing will happen. It's impossible to state that there will be no collisions or injuries and no risks and errors. If we neglect this "fact", we can still state that saving almost 69% of original costs is a pretty nice achievement and satisfaction, because all the money that will be saved can be used for new inventions in the future so the company can continue to fulfil its motto.

5 Conclusion

The purpose of the article is to point out the importance of modelling in terms of industrial engineering. Modelling and redesigning the investigated object provides an opportunity to study the expected results of different types of designs or models far cheaper than manufacturing prototypes, not to mention trying it in real life. It's easier to point out what is wrong and what's not working and make collisions or errors in the system, which give us to givin the best chance for an optimal result in just a few variants. Thanks to modelling, we can test and improve hypotheses and make it the most efficient system possible. What is also important is that it helps us to make and test real-world problems safely without any further harm. We could simulate things in a few hours or months, which could take years if we did not simulate them. Modelling saves time and lowers costs but creates safe and effective solutions. In the current position of technologies and usage of Industry 4.0 in companies, there is no doubt that modelling and redesigning is a key parts of the way to efficiency and competitiveness. The logistics industry will for sure continue to advance and integrate new technologies and methods to make companies more efficient. In the upcoming years, strong and adaptable companies will survive, while resistant companies will languish and fall far behind their competitors.

Acknowledgement
The VEGA Grant Agency funded this research. The submitted paper is a part of the project "Research and development of new smart solutions based on the principles of Industry 4.0, logistics, 3D modelling and simulation for streamlining production in the mining and building industry" VEGA 1/0317/19.

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Review process
Single-blind peer review process.