INCREASING THE PRODUCTION CAPACITY OF BUSINESS PROCESSES USING PLANT SIMULATION

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Abstract

In the paper, we solved the problems regarding the improvement of the production process of allocating material to the inlet of a production hall using the Plant Simulation software in a selected company. The solved problematics are high costs for the shipping company, elimination of the necessity to transfer the semi-finished product from the external warehouse to the production hall and non-effective layout. We deal with the characteristics of the current state of the production process in the production company and create its model in Plant Simulation. Thereafter we propose solutions that can make that process more efficient. The software enables the comparison of complex production alternatives.
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1. INTRODUCTION

In today's digital age, simulation is an important part of our lives. With the help of simulations, we can reflect the actual state of various fields of interest. Whether it is the technology industry, the gaming industry, building design, and so on. Simulations can often save many financial and time resources. In this paper, we will attempt to improve the current state of material picking using Siemens' Plant Simulation software, which is currently one of the best simulation systems available [1, 2].

Customer requirements for quality, delivery time, material, etc. are constantly increasing. All companies operating in the industry try to meet these requirements. Uncertainty in the market today represents a high risk. Therefore, in order to increase their competitiveness, companies focus on providing customers with more than they need [3, 4].

The development of technology allows managers of companies to opt for the use of simulation programs, which are becoming more and more trendy. Simulation programs are tools used to test the effects of various decisions on a model and then evaluate production capacity, operating time, and other production parameters. They also eliminate the possibility of introducing a change in the process that would not be beneficial [5, 6].

We can achieve the prediction of market events by using software support, namely simulation programs. The development of production technologies forces companies to use these programs because they represent the expected production process in a relatively short time. When we use these tools, we verify the technological design even before production and adjustments in production are not necessary [7, 8].

With the help of Plant Simulation software, it is possible to simulate the production process in a company in its current state and suggest ways to improve it. Successful companies in various industries, regardless of their size, currently use Plant Simulation. They rely on the power of simulation every day to gain a competitive advantage in the market. Plant Simulation allows us to model and simulate production systems and their processes. The daily use of Plant Simulation significantly increases the degree of flexible decision-making and becomes a

strategic advantage in business management. Plant Simulation avoids delays in the search for compromises and helps in the direct introduction of solutions that have been verified in advance by simulations.

2. CREATION A SIMULATION IN PLANT SIMULATION 14

We started to create a simulation directly in a 3D environment for a better visualisation of the location and the layout of elements, buildings, machines, etc. in space. At the beginning of creating the simulation, we created an access path, which is the main pillar of the entire simulation. We will focus on in the next part of the paper. We inserted it with the command/button Track Function. It is possible to create a path in different ways. In this article, we chose to create a path using segments (Fig. 1), where we entered precisely measured data according to GPS. Since it is necessary to ensure the cycle in which a truck will move, we modelled the road with a high priority. Thanks to this, after taking the material to the production hall, the truck returns to its original location and loads the following load.

Segments – .Models.Frame.Cesta_ku_hale2

I...	Tange...	Length [m]	Curve...	Radius [m]	Ver...	ΔZ [m]	X [m]	Y [m]	Z [m]
1						0	123.800	-71.800	0.100
2	-90	48				0	123.800	-23.800	0.100
3	0		90	15	□	0	138.800	-8.800	0.100
4	0	8				0	146.800	-8.800	0.100
5	0		90	35	□	0	181.800	-43.800	0.100
6	0	6				0	181.800	-49.800	0.100
7	0		-90	30	□	0	211.800	-79.800	0.100
8	0	60				0	271.800	-79.800	0.100
9	0		90	12	□	0	283.800	-91.800	0.100
10	0	60				0	283.800	-151.800	0.100
11	0		90	12	□	0	271.800	-163.800	0.100
12	0	204				0	67.800	-163.800	0.100
13	0		-90	13	□	0	54.800	-176.800	0.100
14	0	60				0	54.800	-236.800	0.100
15	0		-90	12	□	0	66.800	-248.800	0.100
16	0	14				0	80.800	-248.800	0.100
17	0		-90	6	□	0	86.800	-242.800	0.100
18	0	15				0	86.800	-227.800	0.100
19	0		-90	10	□	0	76.800	-217.800	0.100
20	0	13				0	63.800	-217.800	0.100
21	0		90	7	□	0	56.800	-210.800	0.100
22	0	34				0	56.800	-176.800	0.100
23	0		90	11	□	0	67.800	-165.800	0.100
24	0	204				0	271.800	-165.800	0.100
25	0		-90	14	□	0	285.800	-151.800	0.100
26	0	60				0	285.800	-91.800	0.100
27	0		-90	14	□	0	271.800	-77.800	0.100
28	0	60				0	211.800	-77.800	0.100
29	0		90	28	□	0	183.800	-49.800	0.100
30	0	6				0	183.800	-43.800	0.100
31	0		-90	37	□	0	146.800	-6.800	0.100
32	0	8				0	138.800	-6.800	0.100
33	0		-90	17	□	0	121.800	-23.800	0.100
34	0		90	10	□	0	111.800	-33.800	0.100
35	0		-90	10	□	0	101.800	-43.800	0.100
36	0	20				0	101.800	-63.800	0.100
37	0		-90	8	□	0	109.800	-71.800	0.100
38	0	12				0	121.800	-71.800	0.100

OK   Cancel   Apply

Figure 1: Entering an exact route using the Segments function.

This method suited us mainly thanks to the possibility of adding curves ("turns") on the given route. In the other ways of creating the road, it is possible to feed individual parts of the route at an angle of 90° (without curves). We can see a preview of the road in Fig. 2. It is shown in green.

As the road passes through a part of the industrial area, it must be adapted to the surrounding businesses and warehouses. After modelling the route, in this paper we continued modelling the external warehouse, which is shown in Fig. 3. It was modelled from the ground up. We started by modelling the floor, on which we then placed the side walls and completed the administrative space for the workers, as well as the storage racks that serve as storage of the material. The procedure was as follows [9]:

- Floor – using the Cuboid entity, we designed a warehouse area with dimensions of 65 × 14 × 0.02 m (length × width × height).

- Side walls – with the help of the Factory Walls entity (company walls), we modelled walls with a height of 12 meters with the same dimensions as the floor. An opening for the entrance of a truck is created in the front.
- Storage spaces – we partially designed the interior space of the warehouse using the Rack entity.
- Space for the administration – the space is elevated above the main floor of the warehouse to ensure the necessary view of the entire area of the external warehouse.
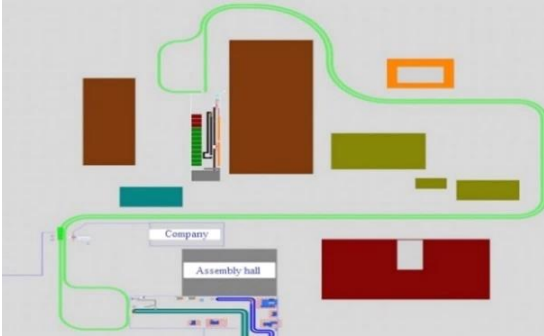

Figure 2: Example of a path in the simulation.
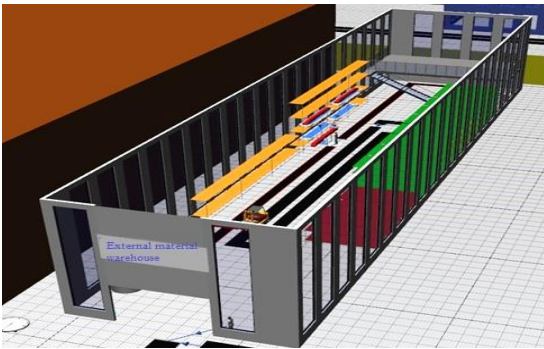
Figure 3: Example of a 3D design of an external material warehouse.

Since the entire simulation process begins in this warehouse, it was necessary to create the material as a duplicate of the original entity, which is included by default in the software. We gradually created forklifts that have the task of transporting the material both in the external warehouse and in the production hall.

The preparation for shipping the material starts with defining this entity as the source of the material (source). An important dimension of the material was its length of 6 meters. It is necessary to define which material is to be moved out in this way, and therefore we entered the already created material in the "MU:" field. A total of 4 material resources are placed on the shelves. The number of pieces that these resources will generate is unlimited and depends on the duration of the simulation.

For the goods picking operation, we used a SingleProc element, which we named as "Arrival". After connecting with the sources of the material, we set the operation time (Processing time), which is 6 minutes. This is the time between receiving of the production documentation by the warehouse worker and finding it on the rack. Due to the large area of the storage and the volume of material in it, it is not possible to pick the material faster. For the transport of material from the "Preparation" operation to the loading area for the truck, a forklift is used and moves along the marked route. This method is chosen due to the high weight of the material, which the worker would not be able to carry by himself. For each operation where the material is handled, a worker performs this operation. In the external warehouse, there are two operations – "Arriving" and "Unpacking".

The WorkerPool element is used to insert a worker into the simulation. It generates one worker in the simulation to handle both above-mentioned operations. For each operation, it was necessary to choose "Services" and define in the table and give the same name for both operations and set the number of workers to operate these stations. With this setting, we achieve uniform movement of one worker at both stations and his movement between them.

After defining the names for individual "Services", it is necessary to set this data in the WorkerPool element as well. With this setting, we clearly define that both operations are handled by one worker.

For the worker to be able to move safely around the warehouse space, we created a path for him that does not interfere with the movement of the forklift and the manipulation of the material. For the worker to move only on it, it is necessary to specify this choice in the WorkerPool settings.

To pick the material from the racks, we use the TransferStation element, which transfers the material from the "Pickup" operation to the forklift truck. We inserted it using the same element as the product and defined the speed at which it will move around the warehouse. Since it is mainly about safety, the selected speed is 3 m/s (approx. 11 km/h). At the same time, it is possible to transport only one item with the forklift. This is defined in Fig. 4.
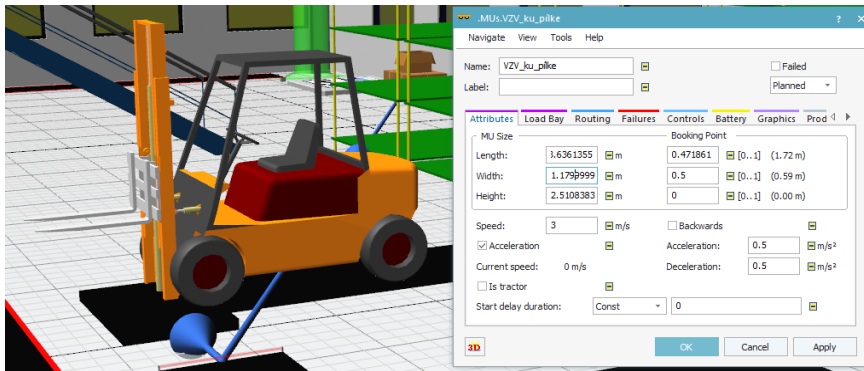

Figure 4: Forklift setup.

After loading the material, the forklift stops thanks to the defined sensor on the route and performs the unloading of the item in the „Warehouse-exit" operation. For this purpose, the TransferStation element was used, and we set it in the same way as for the loading. The only difference in the settings is defining where the element will take the material from and where it will be placed. This is what the "Parts From" and "Target is on" commands are for. In the case of the first, we indicated the path along which the truck moves, and in the case of the second, the "Unloading" operation. It is also important to check „Warehouse-exit", since it is about unloading the material.

While the warehouse worker picks the material and prepares at the loading area of trucks, the second warehouse worker will inform the shipping company to move the truck to the warehouse premises. For entering the truck into the simulation, we used the same procedure as when inserting the forklift. The only change in the settings was to change the speed at which the truck will move along the route from the external warehouse to the production hall. Here, the vehicle moves at a speed of 8.5 m/s, which is equivalent to 30 km/h. This speed is the maximum allowed in the premises of the industrial complex.

The actual loading of the material on the truck is solved using the "TransferStation". It serves to move the material from the unloading operation to the available truck, which is waiting in the warehouse premises. Since the movement starts in the warehouse, there is no need to change the preset value in the "Sensor position" field. This operation takes 4 minutes and 50 seconds, which had to be set in the Times tab. On the next tab, it was necessary to check the

Always stop target/container box, which means that the truck will never leave its position empty, i.e. without the material.

In the simulation, we solved this using the TransferStation, where it was necessary to set the sensor. It is set at the 572nd meter of the road. This will ensure that the vehicle is stopped, and the material is moved for an inspection operation by the gatekeeper. This takes 1 minute and 20 seconds. Another sensor, located at the 575th meter of the road, serves as loading of the material from the control operation onto the vehicle. The vehicle continues to the production hall. Every time TransferStation is used, it is necessary to observe the hierarchy of the loading and unloading process (Load, Unload) and the correct setting from where to load/unload.

The vehicle with the material heads to the production hall, where it stops at the 684th meter of the entire route using another TransferStation (Fig. 5). Here, the transfer of the material to the input control operation is ensured. After unloading the material, the truck returns back along the same route as it came and repeats the whole process from the "Arriving" operation.
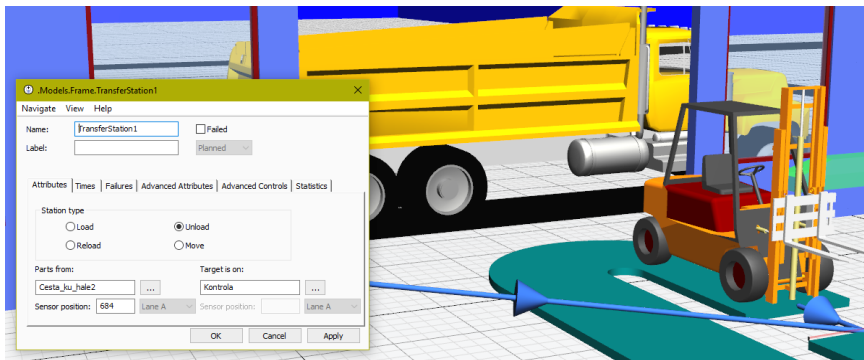
Figure 5: Stopping the truck and unloading the material for the entry inspection operation.

The material is transferred to the incoming inspection operation, where the blank is inspected before being released to the production sawing operation. Basic dimensions and surface irregularities on the material are controlled. The length of this operation depends on the inspected material. Estimated time is 2 minutes and 50 seconds (Fig. 6). This is a short time due to the ease of control.
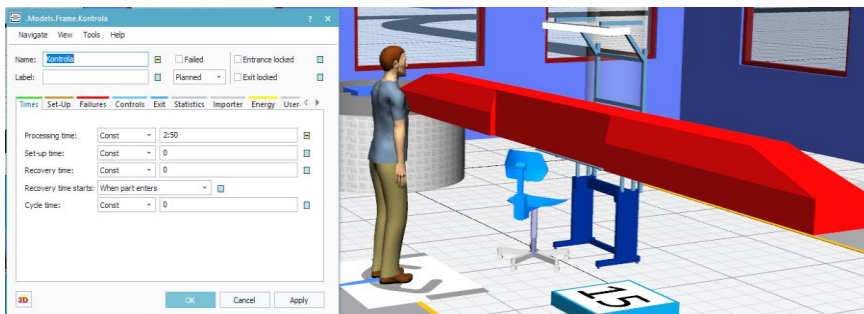

Figure 6: Setting the material control time.

There is also a counter on the ground for the number of pieces of material that passed through the entry control station during the simulation.

After the end of the input control operation, the material is loaded using the TransferStation onto a forklift. This transports the material to the band saw workplace, which is in the back of the production hall. The forklift needed a path to be designed along which it would transport the material. Since it is also a cycle where the forklift will load and unload the material continuously after it has been transported to the production hall, the path had to be a loop. The forklift intended for this was inserted using the same procedure as the previous one. The suggested path can be seen in Fig. 7 in green.
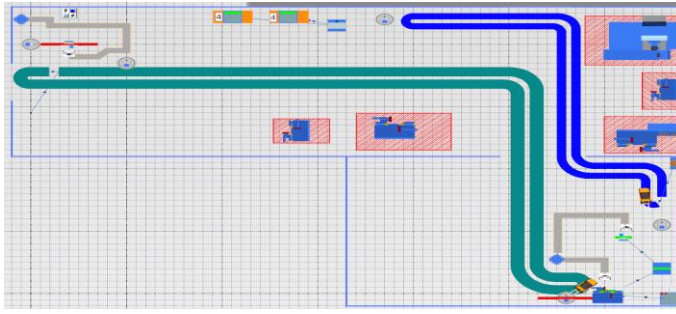
Figure 7: Design of the path from the entry control to the band saw workplace.

Another TransferStation element was inserted to stop the forklift and to unload it to the band saw workplace, which will perform the above-mentioned operations using the sensor selected on the 89th meter. After unloading, the forklift returns to the beginning of the loop, where it waits for the next delivery of material. Meanwhile, the material is processed on the band saw, which we inserted into the simulation through the DismantleStation element. The latter has the task of shortening the material to a length of 2 meters and storing the excess waste in a place designated for it. Since it is an operation that requires the so-called Successors (followers), it was necessary to define how this workplace will function. First, we set the Sequence box to Main MU after other MUs, which says that the main material will have priority over others. Subsequently, in the Dismantle Table, we determined the number of pieces and which specific parts this process will cover. After shortening the material, we get two pieces of the finished part and 10 pieces of waste. The duration of this operation is set to 4 minutes and 30 seconds, which is enough time to process one piece of material. The detailed setting of the DismantleStation is shown in Fig. 8.
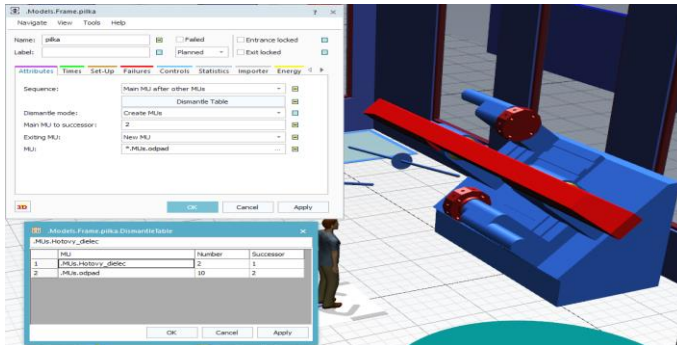

Figure 8: Setting up DismantleStation.

Other parameters in Fig. 8 we chose as follows. Dismantle mode was set to Create MUs, which means that the goal of the operation will be the creation of new entities and they will then be divided into two more workplaces. Main MU to successor: 2 – says that the main material that was processed (in our case material) will follow the "Waste" entity – it will be stored together with it. New MUs are selected as exiting entities (Exiting MU). In our case, these are the "Finished_part" and "Waste" entities. We determined the successors for one new workplace and one storage space for waste (Store), which will have the task of storing it.

There is also a counter of how many pieces are already stored at the waste storage area.

The main item, which is the starting entity from the band saw, is the finished part, which is already cut to the required length and is stored in a temporary buffer, from where it travels to the outbound inspection workplace after being machined. This is set with a longer time than the inbound inspection, as the finished parts are inspected more thoroughly and in more detail. The outbound inspection duration is set to 6 minutes and 20 seconds. As with any operation, a worker is used to operate the given station. After the work is done, the worker returns to their

workplace, which is a simulation of other work during the delivery of the next material for processing. In Fig. 9 we can see the setting of the outbound inspection workplace.
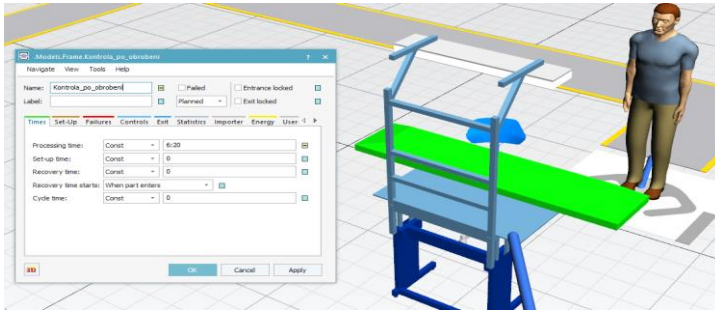

Figure 9: Outbound inspection.

After a thorough inspection of the finished part, this part is transferred using the TransferStation to another forklift. Then it travels to the storage of the finished parts in the production hall. Before unloading, another TransferStation is used to unload the finished product at the "warehouse hall" operation. From this operation, the finished pieces go to their storage place in the rack at the entrance part of the production hall. The display of storage spaces in the premises of the production hall, in the section of completion and assembly of finished machines, is shown in Fig. 10.
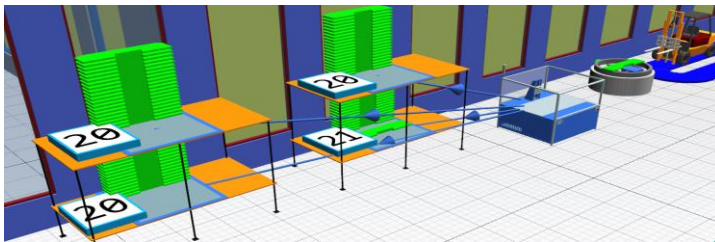

Figure 10: Storage space for finished parts in the premises of the production hall.

The fulfilment of all storage spaces that have a predetermined capacity or setting a time limit after which the simulation stops is the end of the simulation. In the simulation we are interested to know how many finished pieces can be produced in one work shift or machined and stored during the same period. Therefore, we set the duration of one work shift into the simulation control. One shift is 7 hours and 30 minutes in the selected company [9].

3. EVALUATION OF THE SIMULATION

If we were to assume a continuous course of the whole process, we would be able to produce and pick up 56 pieces of finished parts (Table I). The problem is the high costs of the transport company, which amount to 3000 EUR per month. This is the amount that is contracted between the manufacturing company and the carrier.

Table I: Results of analyses.

Object	Name	Mean life time	Throughput	*TPH*	Production (%)	Transport (%)	Storage (%)	Value added (%)	Portion
Drain	Finished part	10:50.3837	56	7	63.79	6.25	29.96	63.04	

The largest issue when cooperating with an external transport company is the instability of trucks due to the failure of personnel or to technical malfunctions of the vehicle. In this case,

the operation of the assembly line and the closely related problem of completing the finished products – presses – can be endangered. The resulting 3D model of the simulation can be seen in Fig. 11, which was processed in Siemens' Plant Simulation software.
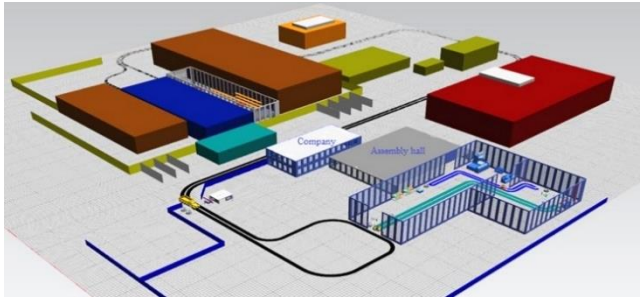

Figure 11: 3D simulation model processed in Plant Simulation 14 software.

4. PROPOSAL FOR POSSIBLE IMPROVEMENT OF THE BUSINESS PROCESS IN THE COMPANY

As can be seen from the simulation performed, which reflects the real state of the process, both the resulting duration of the simulation and the real duration of these operations are unacceptable to the company. Picking up materials for production order needs is very time consuming, and this circumstance is exacerbated by the fact that the external warehouse is located outside the company, away from the main building. Therefore, the goal of improving this situation is the location of the external warehouse in relation to the production hall, where the material is divided from the material to the finished product with the help of a band saw. The business has a space that is not used efficiently enough and contains a lot of free space. In the proposal, we will focus precisely on the use of this space and moving the entire external warehouse of material to the production hall and its connection to its rear part. In the simulation environment, we can see it in Fig. 12.
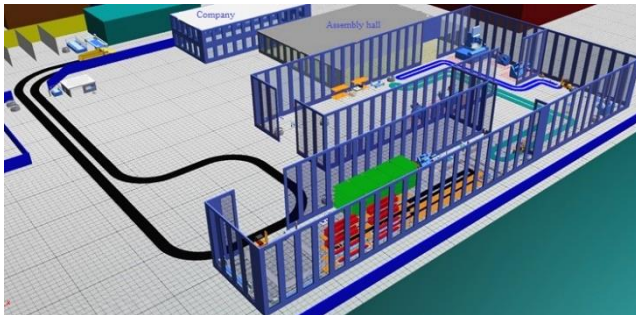

Figure 12: 3D environment of the Plant Simulation software.

The main change is the change of the route of the forklift from the material warehouse to the production hall for storing finished parts. The warehouse building was also adapted from the point of view of material input from suppliers. For this purpose, an opening was created for the entry of material for its following storage in shelves (Fig. 13). The administration for the warehouse has been removed, as the workplace itself is not needed for receiving production documentation, as it goes directly from the main warehouse.

A newly created road leads to the newly created opening, along which drives a truck with the purchased material. The purchase of the material is handled off-site, and in the simulation, it is specified for 30 pieces for one day, or one work shift. The path to the warehouse was modelled with a cyclical shape, i.e. the operation is repeated throughout the simulation (Fig. 14).
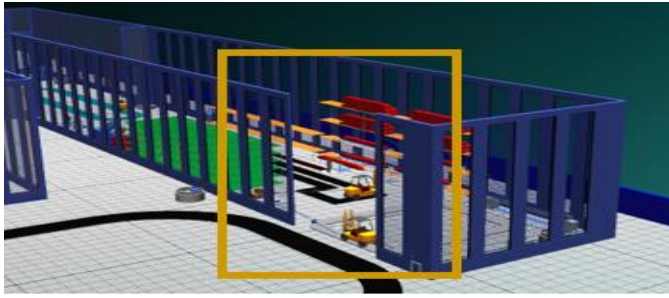
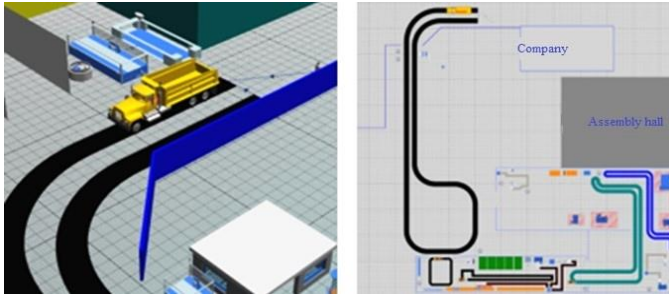Figure 13: Creating an opening for unloading new parts.

Figure 14: Material purchase in the simulation using a simple operation and the newly designed route for the truck with the new material.

In the simulation, it was also necessary to ensure the unloading of the material and its storage in the racks using a simple operation. A space was also created for forklift handling. It is used by the newly created route, which was also modelled with an emphasis on the cycle. The modelled route is shown in Fig. 15.
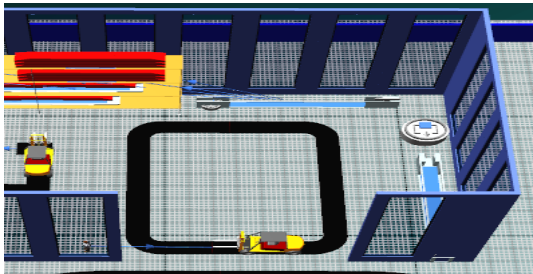

Figure 15: Route for the movement of the forklift inside the warehouse.

Since the metallurgical warehouse was connected directly to the production hall, it was also necessary to change the trajectory of the forklift, which has the task of transferring the finished divided parts to the assembly areas in the production hall. The newly created route is shown in Fig. 16, is highlighted in green.
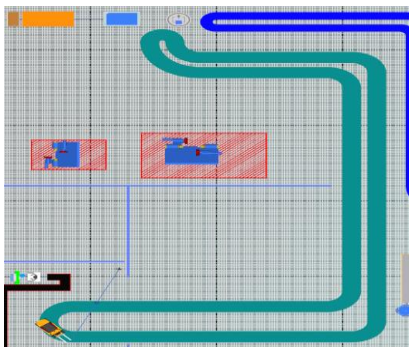

Figure 16: Forklift route from the warehouse to the assembly workplace in the production hall.

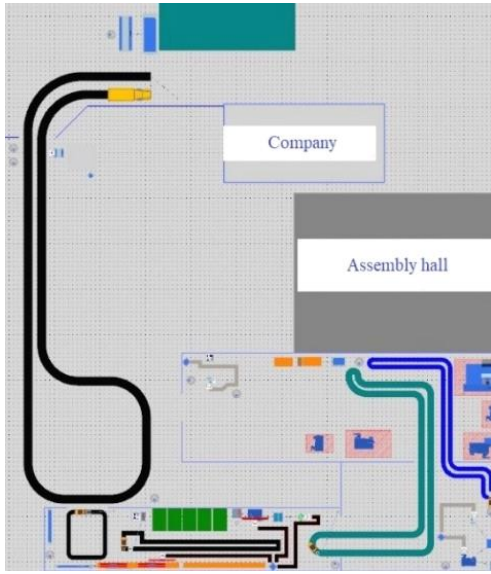We present the proposed model as viewed from above in the simulation software Plant Simulation in Fig. 17.

Figure 17: Top view of the proposed model.

This solution eliminated the need to transport the material from the external warehouse to the premises of the production hall, where the subsequent division of this material and its further processing took place in the premises of the assembly hall. In addition, a band saw was placed in the warehouse, which reduced the need to transport material within the production hall. The finished, already divided parts are brought directly from the warehouse, which are then assembled on the final equipment – presses.

Thanks to this solution, we reduced the costs for the company in the form of terminating the contract with the transport company, as well as the time needed to move the material before processing to the production hall. We acquired additional space in the rear part of the production hall, which in the future will serve to increase the space for the final assembly of equipment, or implementing another machining machine, thanks to which we will gain greater self-sufficiency in the field of material processing and the company will not be so dependent on the supply of processed materials directly from suppliers.

If we assume that the production process of producing the finished part in question will be cyclical and will take place during one day during a work shift lasting 7 hours and 30 minutes, after the end of the simulation we evaluate that the company can produce up to 145 pieces of the finished part at the same time as in in the case of the current situation in the company. In Table II we can see the result from the simulation software Plant Simulation.

Table II: Simulation result of the proposed solution.

Object	Name	Mean life time	Throughput	*TPH*	Production (%)	Transport (%)	Storage (%)	Value added (%)	Portion
Drain	Finished part	6:11.7054	145	19	47.35	34.70	17.95	40.35	

If this process were to be repeated without any problems over a longer time horizon, we would be able to produce the amount we detail in Table III. As starting time periods, we chose:
- 1 working week – duration of 5 working days,
- 1 calendar month – this is approximately 20 working days,
- 1 calendar year – this is approximately 250 working days.

Table III: Evaluation of the resulting solution in comparison with the real situation.

Period	Real state	Result
1 working week during one work shift (5 working days)	280 pieces	725 pieces
1 month (approximately 20 working days)	1120 pieces	2900 pieces
1 calendar year (approximately 250 working days)	14000 pieces	36250 pieces

In the case of the number of manufactured pieces, the new solution will improve the production process of the finished part in such a way that from the original 56 pieces per work shift, the number has increased to 156 pieces. The costs that the company will have to spend to implement this proposal are approximately 30.000 EUR. This amount includes the construction of a new building near the production hall and its connection to the newly built warehouse, the transfer of material from the external warehouse and the transfer of the band saw to the warehouse area.

Plant Simulation can currently be considered one of the most promising platforms for the design of production processes. Using Plant Simulation we have created a digital model of the production process in a specific production company, and the benefit for the company is that the simulation in Plant Simulation is able to create scenarios of the future state in the production company even at the time of the planning itself. The ability to use extensive analytical tools such as statistics, graphs and charts are the reason that the output is measurable and substantiated results, which are summarised in "Section 4. Proposal for possible improvement of the business process in the company" of this paper. The results obtained in this way provided the specified production company with the information necessary for quick and correct decisions in the early stages of the planning of the production process (monthly plans, capacity planning, delivery dates, quantity of units produced). Using Plant Simulation, we were able to create a simulation model of the processes already in operation as well as those in the preparation stage. The created simulations take on real values, with the help of which the user can experiment without interfering with the production.

5. CONCLUSIONS

Simulations can simplify and make more efficient many tasks in our personal and professional lives [10-13]. In this paper, we have dealt with the analysis of the as-is state in the company. In doing so, we have found that the current state is unsatisfactory and various measures need to be taken to improve and streamline the production process of selecting dense material. For this process, we used the Plant Simulation software from Siemens. We modelled the real situation between the external material warehouse and the production hall, where material had to be transported by truck. After evaluating the simulation and the real situation in the company, we proposed possible solutions that could make this production process more efficient and save the company considerable financial and time resources.

Thanks to the proposed solution, we were able to eliminate the route between the external warehouse and the production hall, which meant a high financial saving by terminating the contract with the transport company and moving the warehouse directly to the premises of the company's production hall. We simulated this process again to find out how the current state of the company's production process could be improved.

Finally, we analysed all the benefits of the proposed solution and evaluated its financial return, which represented a period of up to two calendar months, which is due to the time saved, or increase in the number of pieces of finished parts, a very favourable investment return period.

The use of Plant Simulation can be identified in the current hyper-competitive environment especially in companies in industrial areas. They rely on the power of simulation on a daily basis to give them a competitive advantage in the marketplace, and using Plant Simulation they

can model and simulate production systems and their processes or sub-processes. Using Plant Simulation on a daily basis significantly increases the level of flexible decision-making and thus becomes a strategic advantage in business management. Plant Simulation offers not to delay the search for compromise solutions, but to directly implement solutions that have been verified in advance by simulation.

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