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Application of Simulation in the Optimization of the Blood Plasma Storage Process

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Abstract: The paper deals with the process of optimizing the creation of the output product, which is the Cobas HIV-1 blood plasma separation card. The capabilities of the Tecnomatix Plant Simulation software will be used in this process. The application of simulation software will help to reveal the possibilities of improvement during the entire production process of the said product and to debug all potential improvement errors on the digital model without physically interfering with the current production process. The paper contains a basic theoretical clarification of some basic terms. The following content describes individual parts of the production process in question. An analysis will be carried out, on the basis of which the most significant bottlenecks will be revealed. The data used to create the simulation were collected based on the recording of working time and its use on the given production line. This kind of observation also revealed initial bottlenecks. For these bottlenecks, a methodology for their effectiveness and criteria for their optimization is subsequently proposed. Subsequently, an optimization solution is proposed, which is verified and evaluated by simulation. The collected data were then transferred to a digital model in the form of a simulation. Based on the results of the simulation, the given optimization proposals will be evaluated at the end. Production on the line has been optimized gradually and thanks to this we can see several variants that can be compared, and the best one can be chosen. The development of the entire optimization process is the possibility to increase the production output from the original 350 produced pieces up to 699 pieces in the same time horizon. In the process of optimization, methodologies were created that followed it and gave instructions for the optimization of productions of a similar nature. In addition to the mentioned optimization simulation variants, the paper also contains a design solution proposal in the form of 3D models, when several workstations are united into one workstation.

Keywords: optimization; digital model; simulation; bottleneck

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1. Introduction

Simulation is a process in which an entire process is imitated using computer technology. The essence of simulation is experimental activity. The goal of creating a simulation is mostly to optimize or improve the properties and efficiency of the simulated process. Many people think that these technologies are used only in the field of engineering and industrial production and mainly in the automotive sector. This fact is probably true, but in the current era of digitization and constant innovation in various scientific and social sectors, the implementation of simulation often finds its application. One could conclude that simulation technologies can be implemented wherever there is a transformation process that can be mapped and described in some way. These technologies can currently be integrated with elements of virtual, mixed, and augmented reality, with which they can be further developed and transformed. One of the contribution's goals is to clarify theoretical knowledge in the field of computer simulation. Getting to know the issue is an essential part of the job. It will ensure that the analysis, design, and implementation of solutions lead to the desired results with an emphasis on the elimination of inaccuracies and errors [1–6].

Another goal is a detailed analysis of the current state of the production process that deals with the production of medical devices, specifically the production of Cobas HIV-1 blood plasma separation cards. The task is to analyze the process as a whole, but at the same time to examine in detail each unit that is in the process. This elaboration will allow us to reveal the bottlenecks of the process, in which optimization will subsequently be proposed. We will implement optimization proposals in the form of several variants, from which the most suitable one will be determined with the help of analysis. The production line producing the mentioned product is currently functional as described below. Bottlenecks and parts of the bar that slow down and subsequently limit the activity of individual workplaces are either directly some workstations that do not keep up with capacity and disrupt the overall balance of the production process, or the production process is slowed down by transport between individual operations. Some features of individual parts of production can be seen in Table 1, which shows the production process in its current state. It is visible that the busiest operation is pressing the final layer, the application of the final layer, and the speed of the conveyor belts can also be a problem.

Table 1. Process simulation results in their original form.

Operation	Output Name	TPH (ks/hod.)	Production	Transport
Drain	Cobas HIV-1	350	52.94%	47.06%

1.1. Simulation

The increasing complexity of products, processes, and systems is one of the many reasons why simulation is increasingly used in the planning, implementation, and operation of technical systems. As an integral part of the digital factory concept, simulation helps reduce time to market and supports decision-making processes. Simulation is particularly useful for analyzing a system where its behavior changes dynamically over time and a mathematical solution cannot be calculated with reasonable effort [6–8].

Steps in creating a simulation:

The scope of the simulation can range from a sub-area of a manufacturing facility to a globally distributed supply chain network. In manufacturing and logistics, simulation helps identify bottlenecks, high inventory levels, feasible amounts of throughput, and appropriate management strategies. A typical simulation project process consists of [9–12]:

- Description of the target problem,
- System analysis,
- Collection of data,
- Formalization and implementation of the model,
- Experiment and analysis of simulation results.

The simulation is always based on a model, which is a simplified reproduction of the planned or existing system. Thus, simulation results can only be as good as the model and data on which the simulation experiment is based. In order to achieve feasible results with reasonable effort, the level of detail of the simulation model should be neither too detailed nor too general [12,13].

1.2. Advantages of Simulation

The implementation of simulation both in the process of analysis and in the process of designing the improvement of the process itself brings several undoubted advantages [14–17]:

- Conservation of resources—business process modeling and simulation are more important than spending time and money to build and implement a process only to find it flawed. Finding and solving problems during the simulation allows you to save time and money because it has no impact on the processes that are currently being carried out in the organization.

- Visual output—business process models provide an easy-to-read visual overview of processes and model designs. Running simulations based on BPMN models will reveal visible connections between different tasks and then determine where tasks need to be added or removed from the process flow. Visual outputs from simulations facilitate communication of past and future process changes with managers and stakeholders.
- Testing the behavior of the process—testing the behavior of business processes before they are created gives a good indication of how they will work in the real world.
- Problem-solving—behavior analysis makes it possible to recognize functional processes from non-functional ones. It is easier and especially less expensive to debug simulated problems than to fix problems in the real world.
- Education and training—simulations are a good and cost-effective way to give new employees hands-on experience and experience with processes and systems without affecting real-time work processes.
- Accurate results—the results obtained from the simulation are usually accurate and help reveal what can be expected when the process transitions from the virtual world to the real world.

1.3. Types of Simulation

Simulation can be used for physical phenomena, business processes, movement of employees and transport, as well as production and logistics operations. There are mainly two different types of simulation [18]:

- Continuous simulation,
- Simulation of discrete events.

Simulation of discrete events is also called event-oriented simulation. From the point of view of the simulation, in this case only those moments of time or events in which the state variables of a system change. A classic example of discrete systems is most production and logistics systems. In addition to next-event timing, there is an alternative approach called fixed-increment timing, where time is divided into small time slots and the system state is updated according to a set of events/activities happening at that time. Since not every time interval needs to be simulated, the time simulation of the next event can usually run much faster than the corresponding fixed-increment time simulation [19–21].

2. Literature Review

According to [2,9,22], due to the progress in the digitization process of the manufacturing industry and the resulting data available, there is tremendous progress and great interest in the integration of machine learning and optimization methods at the production level in order to improve manufacturing processes. Optimization can take place in two different ways: on the one hand, it is about improving the quality of the product itself; on the other hand, the production process can be changed for the better. According to [9,15,20,22–24], the implementation and continuous application of process analysis is a fundamental factor in increasing the economic stability and efficiency of the enterprise. To be excellent and competitive, companies design, manage, and improve processes to meet customer and stakeholder requirements, then use all available means, including simulation. The authors [25–27] use the term sustainable production in the context of optimization, they deal with the possibilities of optimization based on mathematical models with the aim of maximizing productivity and reducing costs by identifying key processes and parameters affecting production efficiency. According to [10,14,18,28], the control of the production process is an important issue. Manufacturing processes are affected by many factors and some processes are very complex, so statistical methods can be used to monitor and control manufacturing processes to improve quality and efficiency. Methods of continuous improvement of production processes should be used. In the contributions [8,11,15,29], the authors focus on the interdependence of processes for the creation of complex production. It is necessary to examine such a dependence also when creating simulation models and subsequent outputs from them. The authors [6,7,14,19,20,30] dealt with the slimming of production based on a detailed analysis of production parts and, after its evaluation, its subsequent optimization with the aim of minimizing production costs. It would be possible to say that the analysis and subsequent optimizations in this contribution also aim to reduce production costs, respectively to maximize production output. Based on the evaluation of the results of the analyzes carried out with the help of simulation, it is also possible to say that by unifying several production stations into one, the production process has been significantly streamlined, as well as saving both space and time, both in production and in the transport of material between the united production stations.

3. Card Manufacturing Process for Blood Plasma Separation

The output of the analyzed process is a plasma separation card called Cobas HIV-1, which can be seen in Figure 1. Cobas HIV-1 is an in vitro nucleic acid amplification test for the quantification of human immunodeficiency virus type 1 (HIV-1) in EDTA plasma or from a dried plasma spot infected with HIV-1. This test is intended for use in conjunction with the clinical picture for the clinical treatment of patients infected with HIV-1. This test can be used to confirm HIV-1 infection in antibody-reactive individuals and to assess a patient's prognosis by measuring baseline HIV-1 levels or to monitor the effects of antiretroviral therapy by measuring changes in HIV-1 RNA levels during treatment.

Figure 1. Cobas HIV-1.

The card fundamentally changes the way plasma samples are collected and processed, enabling reliable quantitative testing of HIV patients living in remote areas—even in areas of extreme heat and humidity—while meeting WHO's requirements to determine HIV viral load before starting treatment.

3.1. *Description of the Process in Question*

To carry out a thorough analysis of the process in question, it is necessary to create a real picture of the process, which in our case is represented by a simulation in the Siemens TX Plant Simulation program. As we can see in Figure 2, the process consists of production stations that perform the processes of cutting, heating, pressing, bonding, disinfection, positioning, application, and packaging. Each of these operations must be appropriately simulated and thoroughly analyzed.

3.2. *Analysis of Process Inputs*

In this subchapter, we will take a closer look at the inputs that enter the process in question. Let's take a closer look at the function of individual inputs and their importance in achieving the desired output.

3.2.1. Base Layer Input

As the name of the operation implies, the base layer of the manufactured product enters the process by entering the base layer. The base layer represents the most important part of the product because it performs the main function of the product. The separated plasma required to perform the HIV-1 viral disease test is preserved in this layer.

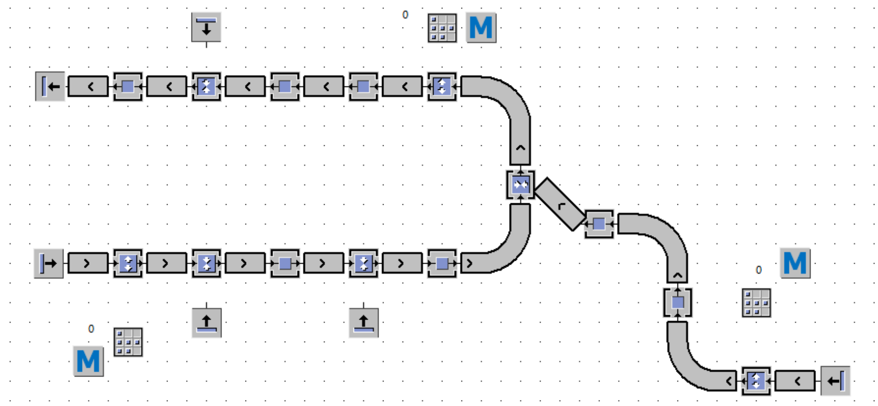

Figure 2. Cobas HIV-1 manufacturing process in a 2D model in simulation software in its original state.

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

The base layer is divided into 3 sections as we can see in Figure 3a. In each of these sections, a sample of the tested subject's plasma is preserved. A larger number of conservation sections significantly reduces the risk of sample contamination.

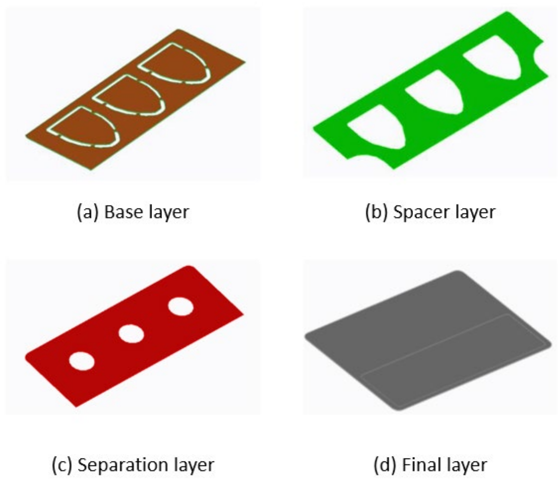

Figure 3. Individual layers of Cobas HIV-1.

3.2.2. Distance Layer Input

The spacer layer, which can be seen in Figure 3b, serves to create a gap between the base and the separation layer. It enters the process using the spacer layer input. The gap created by the spacer layer is necessary to prevent contamination of the base layer with unwanted components of the blood sample, which are separated in the previous separation layer Figure 3c. The separated plasma sample is the only component of the blood sample that can be preserved for a long time without its deterioration. Precisely for this reason, it is essential that the separation layer of the product performs its function with the greatest possible precision.

3.2.3. Input of the Final Layer

The last part of the product that enters the process is the final layer. The function of this element is the necessary conservation of all previous layers. After the base, spacer, and separation layers have been successfully merged, the final layer visible in Figure 3d is finally added. With this, all the elements of the product are combined, and the final form of the product is created in the form of a card for the separation of Cobas HIV-1 plasma.

3.3. Analysis of Elements and Process Flow

In order to successfully achieve the desired output from the process, it is necessary for the inputs of the process to undergo several operations. Each production operation takes place at a separate work position. Each work position is processed and displayed in the form of a 3D model. These 3D models are subsequently used in process simulation as well as in proposals for optimization.

3.3.1. Cutting Operation

The cutting operation process begins with the input of the base layer web, which moves along the conveyor belt to the shearing station where this web is cut into the required base layer shape.

The cutting operation (Figure 4) ensures that the inputs, in our case the strips of the respective layers, are adjusted to the necessary dimensions for their successful transformation into the final product. The average time required to perform this operation is 3 s. The sensors ensure that the input is cut in the correct position and with the necessary dimensions. After performing the operation, the object of the process is moved to the next operation by means of a conveyor belt to the pressing station, where they are connected to the spacer layer. The spacer layer is prepared at a site outside our process and enters the process through its own input.

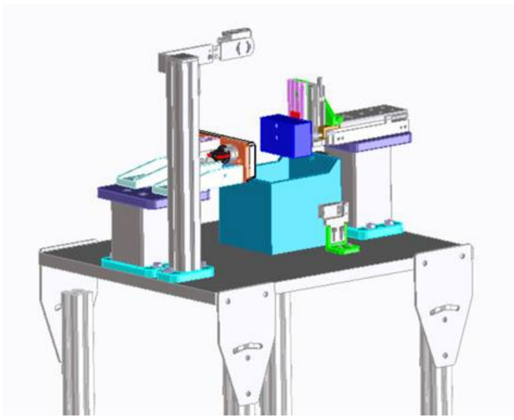

Figure 4. Cutting operation.

3.3.2. The Operation of Pressing

The pressing operation is necessary for the process to join the individual layers into a complete form and thus into the form of the corresponding output. The press plate, which is shown in yellow in Figure 5, is pressed against the object of the process by means of a pneumatic system, thereby bonding the respective layers. Another function of pressing is simultaneously pressing the respective layers into the desired shape. Specifically, the final layer must be pressed into the desired shape before application. The average time required to perform a pressing operation with as little error as possible is 3 s. After the successful connection of the base and spacer layer, the semi-finished product continues to the disinfection station to prevent contamination.

3.3.3. Operation of Disinfection

Since the output of the analyzed process is used to identify a viral disease, it is necessary that there is no contamination of the final output in the production process. This function is fulfilled in the process of the disinfection operation. This operation always follows the pressing of layers prone to contamination. Disinfection is performed using UV radiation, which is emitted by the UV lamp visible in Figure 6. The duration of this operation is on average 5 s. Disinfection is followed by the pressing of the separation layer, which enters the process from an external location, just as the spacer layer did. After the successful connection of the semi-finished product with the spacer layer, disinfection follows again.

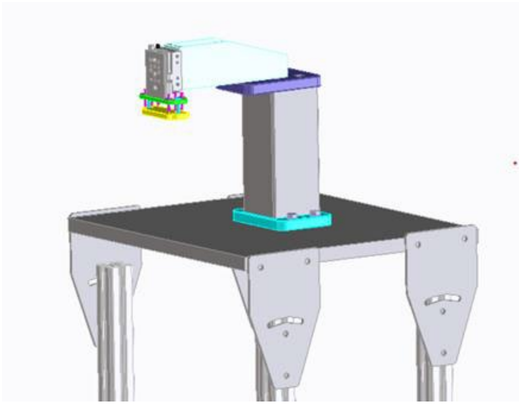

Figure 5. The operation of pressing.

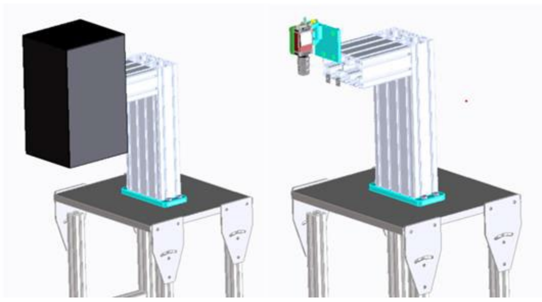

Figure 6. Disinfection operation (with cover/without cover).

3.3.4. The Operation of Saving to a Position

Before each operation in our production process, it is necessary that the input is stored in the required position with a certain accuracy. Each station in the production process has implemented tools to ensure this entry position. However, applying the final layer of our output requires a particularly high degree of precision. In Figure 7 we can see a special process station that provides the function of saving to the appropriate position with the required higher degree of accuracy. The average duration of this operation is 2 s.

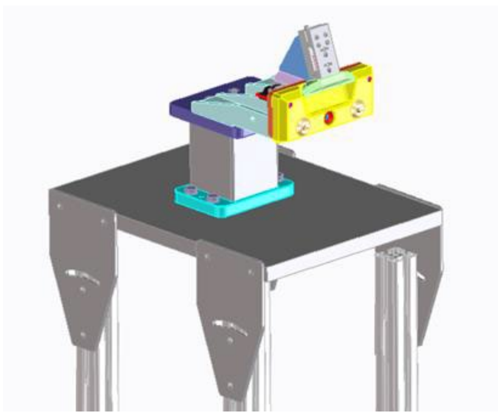

Figure 7. The operation of saving to a position.

3.3.5. Final Layer Application Operation

By joining the base, distance, and separation layer, we created a semi-finished product, which still needs to be joined with the final layer. Since the final layer of our product has complicated contours, it must be adjusted accordingly to the required parameters after entering the process. Before joining the semi-finished product and the final layer, the final layer goes through the operations of cutting, pressing, and centering to the appropriate position. Just as the final layer of the product requires a higher degree of precision in its placement, it also requires a higher degree of precision in its application. This activity is provided by the final layer application station, which can be seen in Figure 8. The final layer application represents the longest operation in the production process, which can indicate to us one of the potential bottlenecks in the process that can represent an obstacle in achieving optimal material flow.

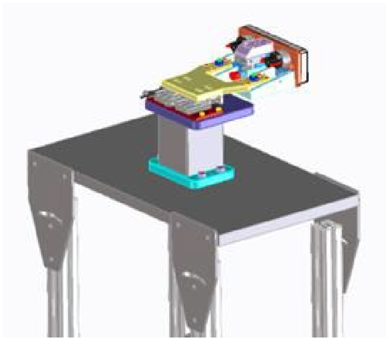

Figure 8. Final layer application operation.

By connecting the final layer, the resulting semi-finished product must be finally cut into the desired shape, which is taken care of by the cutting station. After the final cut, the final output of the process is the Cobas HIV-1 card, but even this final output needs to go through several stations. Specifically, these are disinfection and turning stations. Disinfection is necessary to avoid contamination of the final output. At the turning station, the output is brought to the required position before the packaging operation.

3.3.6. The Operation of Rotation

This is an operation that is performed before the packaging operation. The final output must be rotated 180° before packaging, which is ensured by the rotation station. The relatively low complexity of this operation ensures its short duration, which is on average around 1 to 2 s. In Figure 9, we can see, in addition to the rotating member of the station, a member that ensures the exact position of the product.

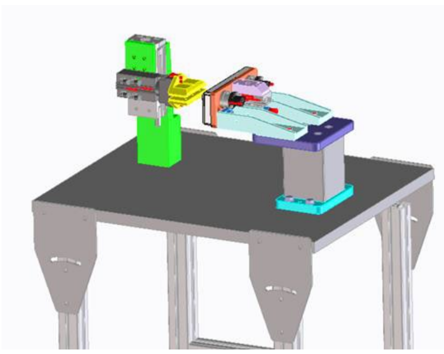

Figure 9. The operation of rotation.

3.3.7. The Packing Operation

After reaching the final form of the product, it is necessary that the output be preserved accordingly, which prevents its contamination and deterioration. The packaging operation takes care of this activity. Figure 10. As we can see in Table 2, this is a relatively complex operation, the duration of which is 5 s on average.

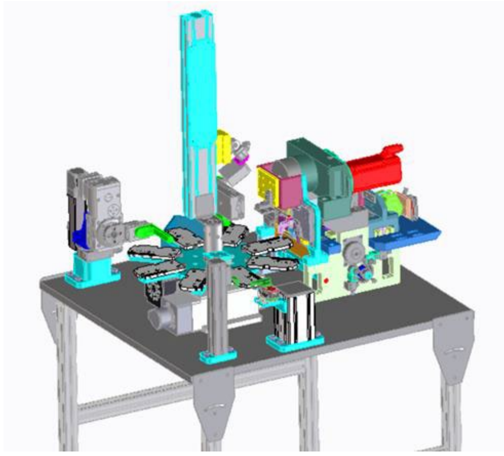

Figure 10. Heating operation.

Table 2. Share of activities in the simulation process expressed in %.

Operation	Work (%)	Waiting (%)	Blocking (%)	The Duration of the Operation (s)	Speed (m/s)
Cutting 1	13.33	0.76	85.91	3	-
Pressing spacer layer	24.75	0.31	74.94	3	-
Disinfection 1	38.17	0.50	61.33	5	-
Pressing separation layer	21.08	6.18	72.74	3	-
Disinfection 2	32.07	0.94	66.98	5	-
Cutting 2	9.74	0.76	89.51	3	-
Pressing the final layer	99.52	0.48	0.00	20	-
Position	9.89	90.11	0.00	2	-
Application of the final layer	49.30	50.70	0.00	10	-
Final trimming	9.83	89.18	0.98	2	-
Warming up 1	39.11	60.89	0.00	4	-
Turning around	19.56	80.44	0.00	2	-
Packaging	48.68	51.32	0.00	5	-
Warming up 2	38.89	61.11	0.00	4	-
Conveyor belts	-	-	-	-	0.5

3.3.8. Heating Operation

For the successful fusion of the applied layers into a single whole so that the desired output is created, it is necessary for the object of the process to undergo heat treatment. This heat treatment is provided by the heating operation. In Figure 11, we can observe that the heating station is structurally similar to the disinfection station. The difference is that the UV lamp used for disinfection is replaced by a heating element. The average duration of this operation is 4 s.

The final packaged product then proceeds to the output, from where it is further moved to the warehouse or directly to the expedition to the consumers.

After getting familiar with the outputs and individual operations of our analyzed process, it is necessary to analyze the process as a whole. In order to be able to optimize the process, we have to reveal the bottlenecks of the process. Process bottlenecks represent parts of the process that have the potential to be optimized with the benefit of higher effects.

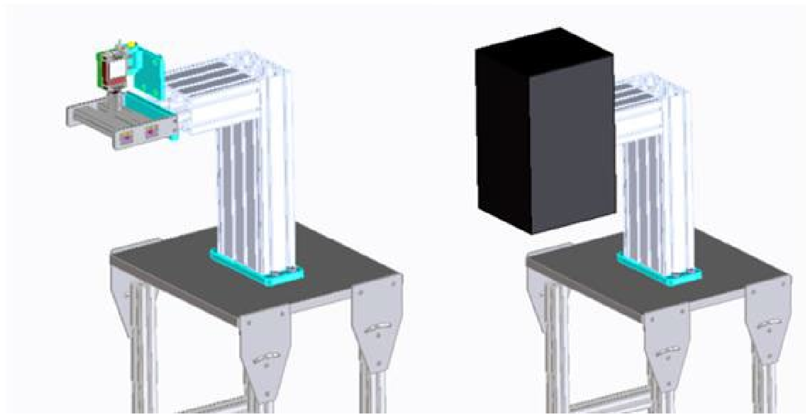

Figure 11. Heating operation (without cover/with cover).

4. Methodology and Analysis of Processes and Subsequent Proposals for Optimization in Bottlenecks

However, before we start revealing the bottlenecks, it is necessary to know the basic parameters of our process, which we can read from Table 2. (Duration of the operation, speed). The information necessary to reveal the bottlenecks of the process will be provided by the outputs from the simulation in the TX Plant Simulation software, see Table 2 (Working, Waiting, Blocking).

Table 1 provides information regarding the output of our process. We can calculate that 350 pieces of the desired output are produced in one hour of process activity. More than 47% of the time spent is taken up by transporting products between individual operating stations. This fact indicates one of the first bottlenecks that conveyor belts can represent. However, information about the output itself is not sufficient to determine the efficiency of our process. Table 2 provides us with more detailed information about the activity of individual process operations (Work, Waiting, Blocking).

Using the percentage share of the activities of individual operations, we can evaluate the behavior of the entire process. We can observe that all the operations preceding the pressing operations of the final layer have a relatively high blocking rate. This means that these stations are forced to suspend their operations until the station behind them is able to complete its operation. From the output data, we can therefore determine that one of the main bottlenecks of the process in question is the area related to the final layer of the output. By optimizing this bottleneck, we expect the most significant positive effects. In Figure 12, we can see the simulation in 3D form before the implementation of optimization measures.

4.1. Optimization of Conveyor Belts

From the information provided by the outputs of the simulation process, we were able to determine several bottlenecks in the production process. These proposals will address specific optimization of these bottlenecks. When a bottleneck is revealed in the area of conveyor belts, the optimization criterion can be the improvement of the flow of the production process and the increase of the production of the entire line due to the improvement of transport between individual production positions. Transport in the process represents one of the revealed bottlenecks of the process in question. Almost half of the time that the product spends in the process is transported between individual operating stations. The first optimization proposal deals with this unfavorable fact. From Table 2, we also know that the conveyor belts move at a speed of 0.5 m/s.

The optimization proposal represents the replacement of these conveyor belts with twice the transport speed, i.e., with a speed of 1 m/s. After performing this optimization, we achieved the following outputs from the simulation.

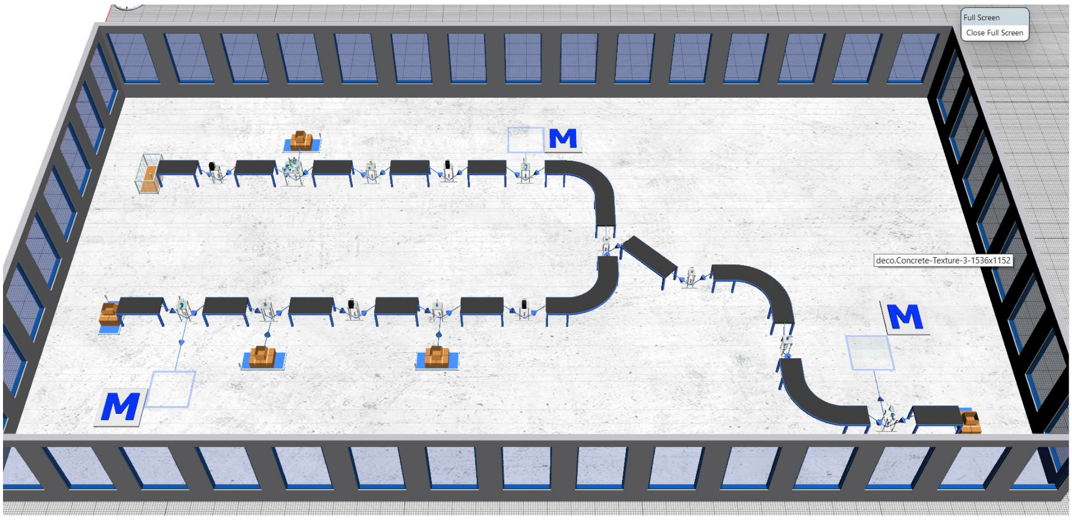

Figure 12. The production process is in the digital form of a 3D model in the simulation software TX Plant Simulation, the original state of production.

In Table 3, we can see the values of the output of the process after introducing the optimization of conveyor belts into the process in question. We can state that although the percentage representation of transport decreased by almost 17%, the number of exits achieved per unit of time increased by only 2 pieces. This fact proves to us that although this optimization has achieved a slight improvement in the efficiency of the process, the conveyor belts do not represent a significant bottleneck in the process, and implementing such a solution in practice would not be inefficient and too expensive considering the total costs associated with replacing the current conveyors with new ones.

Table 3. Output values for the optimization of conveyor belts.

Operation	Output Name	TPH (ks/hod.)	Production	Transport
Drain	Cobas HIV-1	352	69.23%	30.77%

The results of the processes after optimization number one can be seen in Table 4.

Table 4. Percentage share of operations after optimization of conveyor belts.

Operation	Work (%)	Waiting (%)	Blocking (%)	Speed (m/s)
Cutting 1	13.13	0.06	86.61	-
Pressing spacer layer	24.75	0.19	75.06	-
Disinfection 1	38.19	0.33	61.47	-
Pressing separation layer	21.08	5.97	72.94	-
Disinfection 2	32.08	0.67	67.25	-
Cutting 2	9.75	0.06	90.19	-
Pressing the final layer	99.72	0.28	0.00	-
Position	9.94	90.06	0.00	-
Application of the final layer	49.44	50.56	0.00	-
Final trimming	9.89	89.62	0.49	-
Warming up 1	39.33	60.67	0.00	-
Turning around	19.67	80.33	0.00	-
Packaging	49.16	50.84	0.00	-
Warming up 2	39.19	60.81	0.00	-
Conveyor belts	-	-	-	1.00

4.2. Optimization of the Final Layer Pressing Operation

The area related to operations dealing with the final output layer emerged as one of the other bottlenecks. This optimization proposal specifically deals with the final layer press station. The chosen optimization criterion, in this case, was an increase in line production when design changes were made in this operation. Before creating the simulation, a methodological procedure was created for this part of the optimization of this production process (Figure 13).

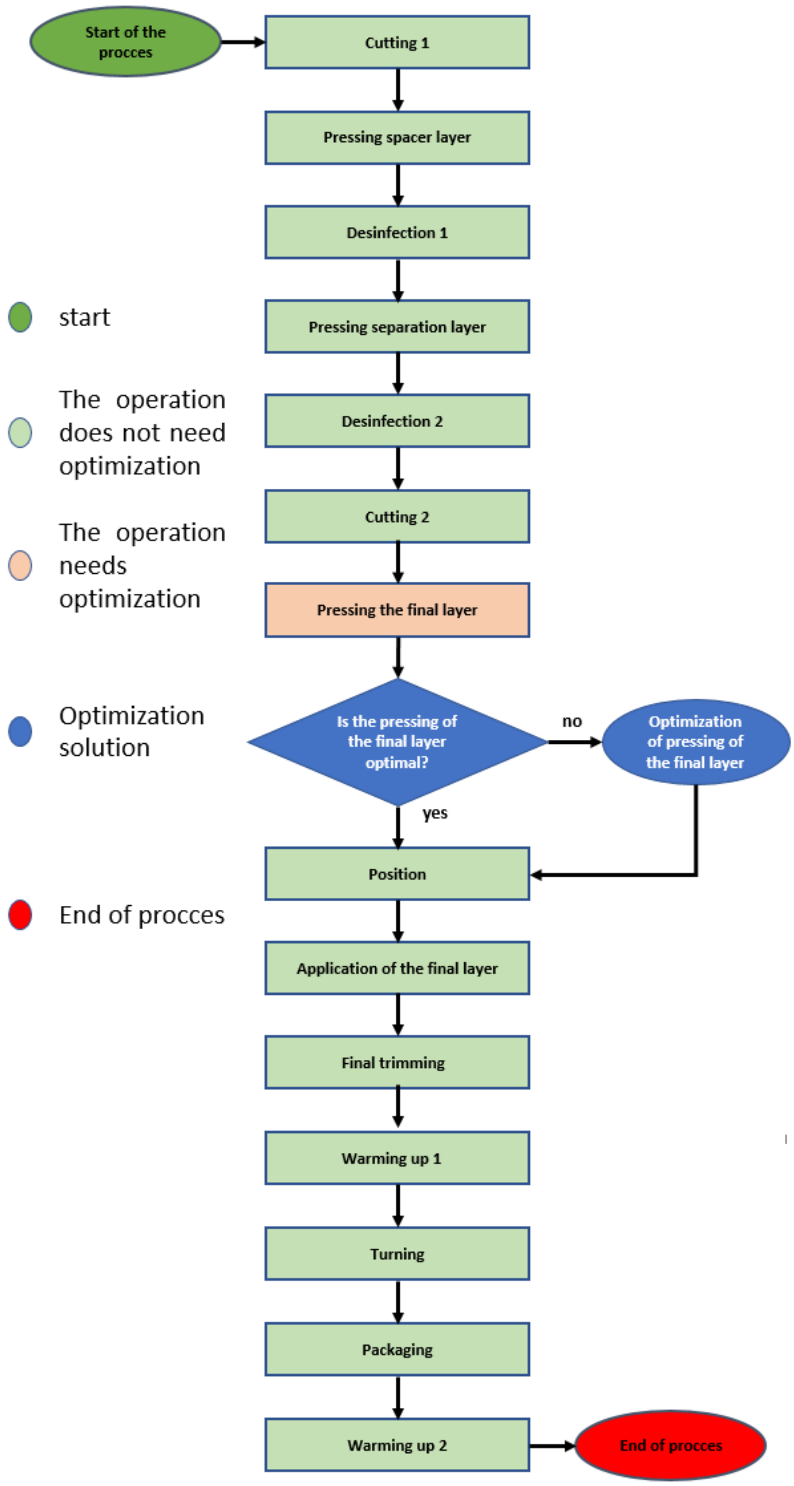

Figure 13. Methodical procedure for solving optimization at the final layer pressing workplace.

The final layer of the output in question has complicated contours, therefore even pressing it into the desired shape represents the longest operation in the entire production process. Specifically, this operation takes 20 s. By optimizing the design of this station, we are able to reduce this time to the level of 15 s. After performing this optimization, we achieved the following results.

In Table 5, we can see how the optimization of the pressing operation of the final layer affects the output values of the process in question. The number of manufactured pieces per unit of time increased by 116 pieces. This fact indicates that it is indeed a significant bottleneck in the analyzed process.

Table 5. Output values when optimizing the final layer pressing station.

Operation	Output Name	TPH (ks/hod.)	Production	Transport
Drain	Cobas HIV-1	466	52.94%	47.06%

There was also an increase in the percentage of the work activity of all stations that are in the process before the final layer pressing station. In Table 6, we can see that it was an increase in the average value of approximately 3%. We have shown that operations dealing with the final layer have great potential for improvement.

Table 6. The percentage of activity of the operations after the optimization of the pressing of the final layer.

Operation	Work (%)	Waiting (%)	Blocking (%)	Speed(m/s)
Cutting 1	15.75	0.76	83.49	-
Pressing spacer layer	29.67	0.31	70.03	-
Disinfection 1	46.39	0.50	53.11	-
Pressing separation layer	26.00	6.85	67.15	-
Disinfection 2	40.28	0.94	58.78	-
Cutting 2	12.17	0.78	87.06	-
Pressing the final layer	99.52	0.48	0.00	-
Position	13.22	86.78	0.00	-
Application of the final layer	65.83	34.17	0.00	-
Final trimming	13.11	85.58	1.31	-
Warming up 1	52.22	47.78	0.00	-
Turning around	26.06	73.94	0.00	-
Packaging	65.00	35.00	0.00	-
Warming up 2	51.87	48.13	0.00	-
Conveyor belts	-	-	-	0.5

4.3. Optimization of the Application of the Final Layer

Therefore, if we know that the operations associated with the application of the final layer of the output of the process in question represent a significant bottleneck, it is necessary to optimize these operations in a more significant way. This optimization proposal is radical in a significant way but has the highest potential to produce the desired effects. The chosen optimization criterion in this case was an increase in line production when structural changes were made and the unification of several operations. This step should save the time of moving along the conveyors, between individual operations. Before creating the simulation, a methodological procedure was created for this part of the optimization of this production process (Figure 14).

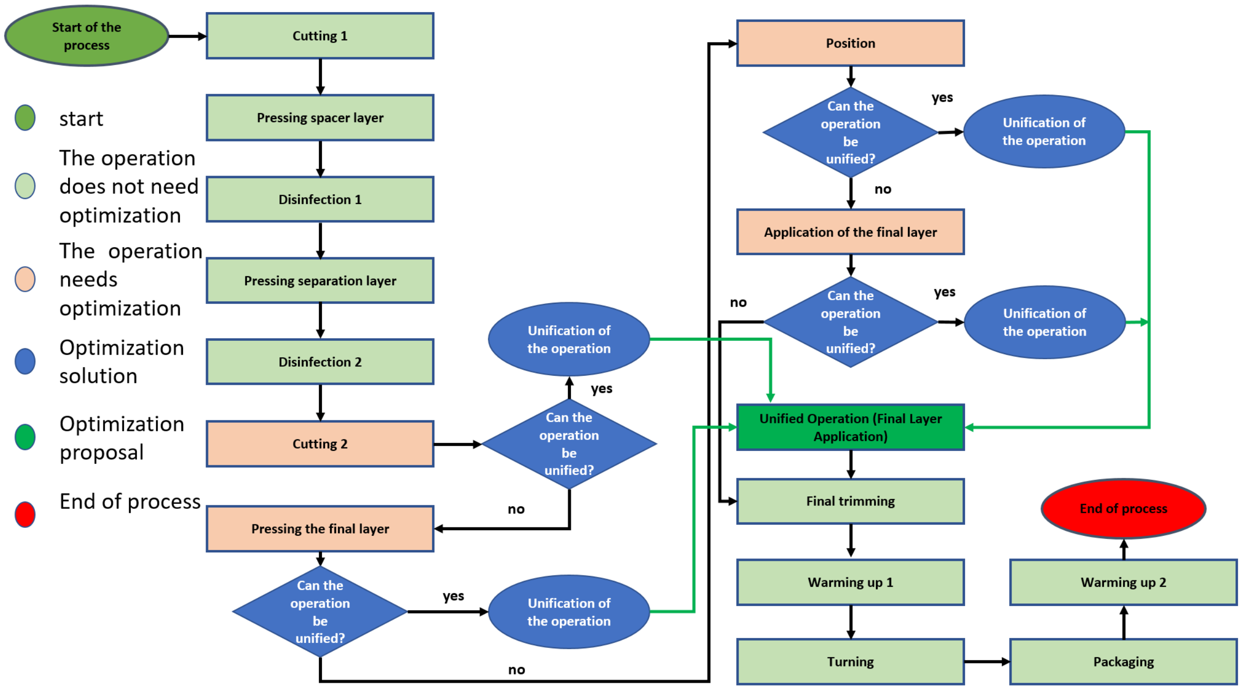

Figure 14. Methodical procedure for solving the optimization during the application of the final layer using the unification of several operations.

In Figure 15, we can see 3D models of all the stations that deal with operations related to the application of the final layer of the product. This is specifically the operation of cutting, pressing, placing in position, and the operation of applying the final layer. Since we know that these operations deal with one type of input and follow each other immediately, it is possible to propose such a design optimization solution in which one station would perform several operations at the same time. This eliminates the need for conveyor belts between individual stations, which significantly saves time.

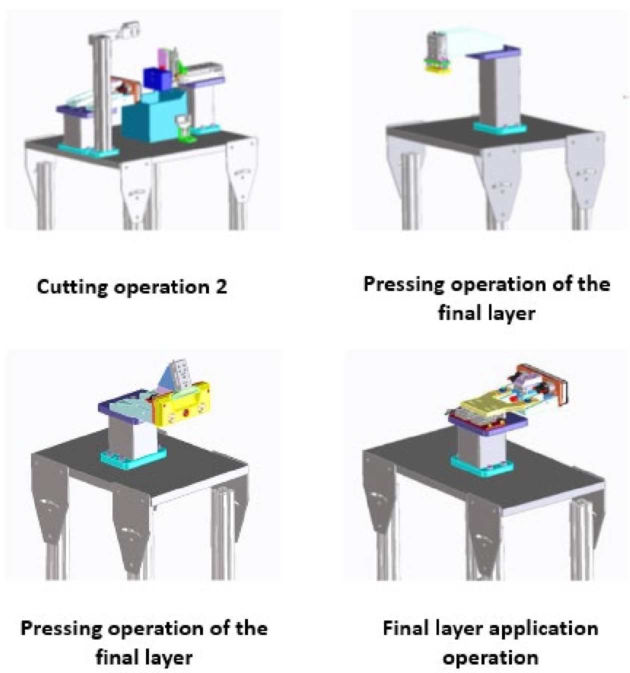

Figure 15. Operations that are subject to optimization.

In Figure 16 we can see the concrete design solution of our optimization proposal. It is a station that can perform all the mentioned operations related to the application of the final layer at the same time. With this optimization, we are able to save an average of up to 30 s per input on the overall application of the final layer.

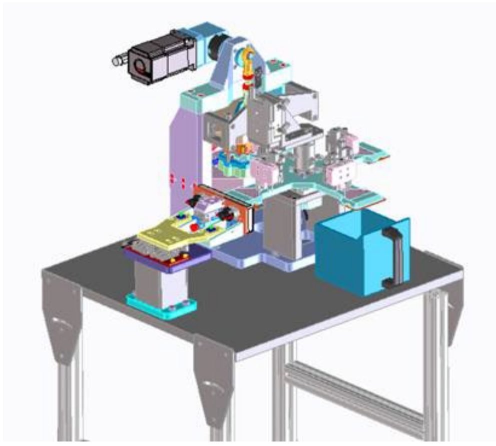

Figure 16. Design optimization solution for the application of the final layer.

In Figure 17, we can observe significant changes that the optimization caused in the simulations. Compared to the original state of production in Figure 12, before the optimization, there were stations ensuring the treatment of the final layer before its application. After introducing the structural design into the simulation, the stations were unified, which saves time and also space in the production hall.

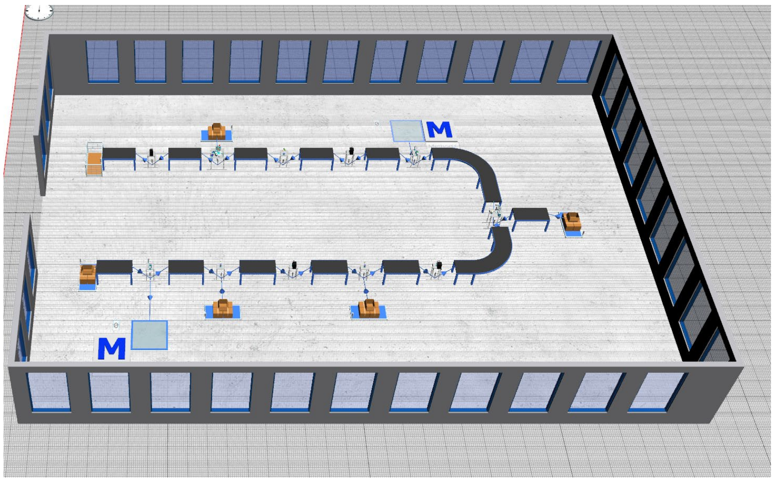

Figure 17. Optimization of the application of the final layer in a 3D simulation environment.

Table 7 shows us the values that the output of the process in question will reach after the introduction of the optimization of the final layer application. Compared to the original state of the process, almost twice as many outputs are produced in the same unit of time, in our case, in an hour. We can therefore conclude that this optimization has a significant effect in the area of increasing the efficiency of the process.

Table 7. Output values when optimizing the application of the final layer.

Operation	Output Name	TPH (ks/hod.)	Production	Transport
Drain	Cobas HIV-1	699	52.94%	47.06%

As can be seen in Table 8, the final layer application station continues to be a significantly busy operation. However, the blocking percentage of the stations located before the final layer application station is greatly reduced, indicating a reduction in the impact of the bottleneck on the subject process. Additionally, the percentage of waiting stations behind the final layer application operation has been reduced.

Table 8. Percentage share of operation activity after optimization of the application of the final layer.

Operation	Work (%)	Waiting (%)	Blocking (%)	Speed (m/s)
Cutting 1	20.67	0.76	78.58	-
Pressing spacer layer	39.50	0.31	60.19	-
Disinfection 1	62.78	0.50	36.72	-
Pressing separation layer	35.84	8.81	55.35	-
Disinfection 2	56.68	0.94	42.37	-
Application of the final layer	98.63	1.37	0.00	-
Final trimming	19.61	78.43	1.96	-
Warming up 1	78.29	21.71	0.00	-
Turning around	39.07	60.93	0.00	-
Packaging	97.46	2.54	0.00	-
Warming up 2	77.78	22.22	0.00	-
Conveyor belts	-	-	-	0.5

4.4. Evaluation of the Performed Optimization Proposals

After simulating all proposals for optimizing the process in question and obtaining the necessary outputs, it is necessary to determine which proposal will bring the most positive effects to the process. It should be remembered that the main goal of the optimization was to increase the efficiency of the process. All three process optimization variants were designed with this goal in mind. In Table 9, we can see a comparison of the outputs of individual optimization proposals.

Table 9. Comparison of optimization proposals.

	Number of Outputs Per Unit of Time (pcs)	Average Percentage of Station Work (%)	Average Percentage of Blocking Stations (%)	Average Percentage of Stations Waiting (%)
The original process	350	32.42	32.31	35.26
Optimization of conveyor belts	352	32.54	32.43	35.03
Optimization of the final layer pressing operation	466	39.79	30.07	30.14
Optimization of the application of the final layer	699	56.94	25.02	18.05

When we look at the simulation models, either in the 3D environment (Figures 12 and 17) or at the 2D display of the given simulations (Figure 18), we see in the optimized model a significant form of shortening and outwardly simplifying the entire production process.

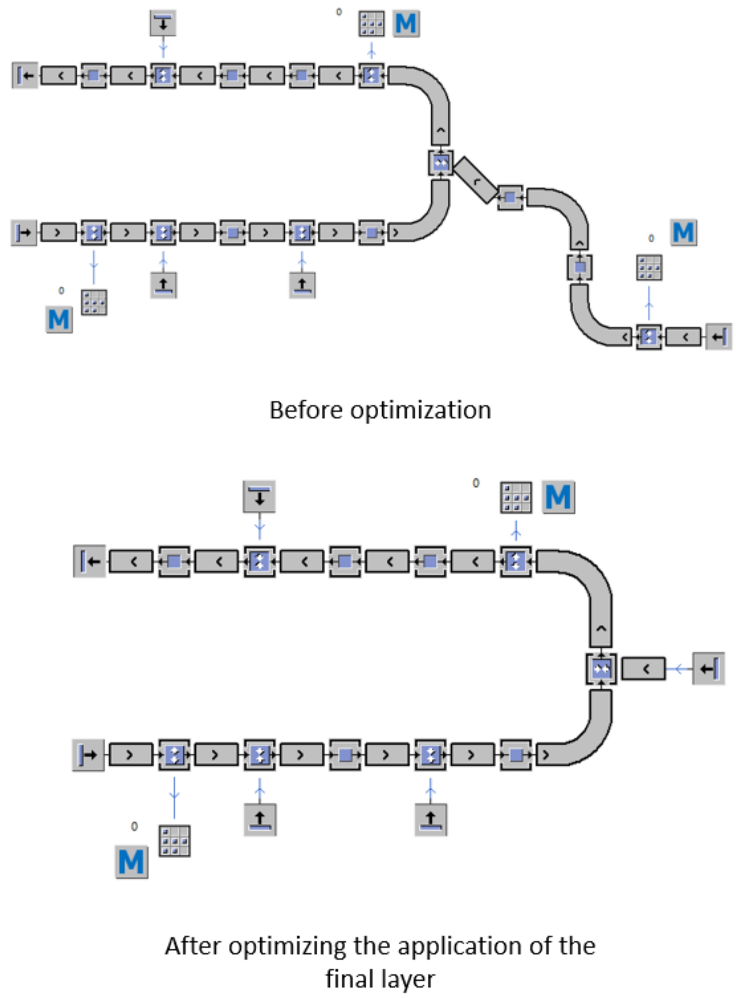

Figure 18. Comparison of 2D simulation models, before and after optimization.

We can observe a correlation between the percentage representation of the workload of individual stations and the number of outputs produced per unit of time. This fact is based on a logical fact. The more work the equipment in our process can do, the more products we are able to produce, and thus the efficiency of the process in question is radically increased.

5. Discussion

Heiner Winkler and the team in their contribution: Optimizing production processes in SMEs: Practical methodology for acquiring process information (2022) deal with the optimization of the production process and its methods, just as we have. It describes process analysis and ways to improve the given process. This contribution also contains a complete process analysis with a description of the individual parts and elements of the given function and, in several variants, proposes optimization solutions for the given process. In the contribution of Winkler and his colleagues, they consult the analysis of the process with the workers who figure in this process. In addition to the involvement of employees in the process, the authors also highlight the successful application of digitization in this production process. Based on it, there was a reduction in waste in the analyzed production. The process analyzed by us does not deal with workers but also suggests possible changes to improve this process, which also describes the design proposals of the given work positions in the form of 3D models. These models served as the basis for digitization in the manufacturing process we investigated. Based on its digitization, it was subsequently possible to perform experiments in optimization variants [3,21,22]. All proposed optimization variants are also verified using simulation models that provide relevant results for these designs. In addition to optimization proposals, our contribution is also a methodology that can be applied to both homogeneous and heterogeneous production processes and their optimization. They need to be modified for specific processes and certainly cannot be fully applied in all optimization processes. However, it is possible to reflect and be inspired by them when solving optimization. In the conclusions of their paper, the authors [3] do not describe their results in quantified values, but they state the beneficial effect of digitization in their improvement. In our contribution, looking at the best optimization variant, it is possible to say that under certain circumstances the output from the production process was almost doubled and also elements of digitization were used, under which the simulation clearly falls. The results of the contribution [24] show that it is necessary to work with a large amount of relevant data in order to achieve a high degree of optimization, otherwise, the optimization process itself may fail and cause errors in its implementation, either in the form of digital, mathematical, or finally in real life production. In our contribution, we worked with real and observed data, which we subsequently implemented in simulation models in which optimization variants were performed. In the contribution [30], its authors dealt with the optimization of production processes in the machining of metal materials. From the point of view of the need for optimization, it does not matter whether it is the processes of heavy engineering or the production of medical devices, the result should ultimately be the improvement of the given process. The result of this contribution is the optimization of the precision of the manufactured parts based on the performed analysis. In our case, the result is an increase in the final output of the transformation process while streamlining it and maintaining product quality. From an economic point of view, both one optimization result and the other are important for companies. From the contributions that are listed in literary sources, one could find a number of comparisons that are more or less related to the issue of our contribution. The most important factor in its processing was to point out the meaning of digitization and the possible results it can bring in the context of implementation into business processes.

6. Conclusions

After a more thorough analysis of Table 9, we can conclude that the proposal for optimizing the application of the final layer brings the desired results to the highest degree. However, it must be admitted that it also has the greatest influence on the form of the production process. Designing this type of optimization also requires great engineering skills. However, when implementing this optimization, our process can produce almost double the amount of output in the same unit of time compared to the original process. It has also slimmed down both in terms of the number of production stations and the transport time between them. Devices with this optimization have the highest load and lowest downtime in terms of blocking and waiting compared to other optimization designs. If the simulation is carried out effectively, it allows for achieving excellent results in the field of innovation, which can be a decisive factor of competitiveness. This post was focused on achieving higher efficiency in the production process using the simulation software TX Plant Simulation. The main goal of this contribution is to increase the efficiency of the production process of a product that serves to protect human health. This increase in efficiency is achieved through simulation software, which has huge potential for innovation. Looking at the presented methodologies of the individual optimization proposals, it is possible to conclude that they can be applied to other production processes after minor or major modifications, and any production process can be optimized based on them. For this purpose, the use of simulation as a means of verification or presentation of a given optimization is the most suitable means. Simulation is one of the most important parts of digitization. Creating simulations of real processes and their subsequent optimization significantly affects the efficiency and speed of introducing innovations into production processes.

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