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Increasing the Efficiency of the Assembly Process Using the FMEA Method and Dynamic Simulation

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ABSTRACT
The efficiency of the assembly process is influenced by a wide range of different parameters. For their optimal setting, a thorough comprehensive analysis of the entire assembly process and identification of shortcomings in the form of bottlenecks or insufficient capacity utilization of assembly workplaces is necessary. As part of the presented paper, the use of the FMEA method in combination with dynamic simulation for analysis of the efficiency of its operation is presented on the example of a real assembly process. The obtained results showed the existence of a bottleneck in the supply area carried out by means of a single AGV set. The subsequent proposed solution, which consisted in the introduction of the use of another AGV set, brought an increase in the efficiency of individual assembly workplaces from the original values in the range of 75% to 85% to the level of 87% to 98%.

Keywords: analysis, simulation, productivity, operation, transport, AGV

INTRODUCTION

The efficient functioning of logistics processes is a key factor for the production of final products in many industries. However, securing them is not easy due to the complexity and robustness of the processes. For this reason, and for their analysis, they use various tools that will make it possible to identify possibilities for their effective implementation [1]. The proper functioning and operation of logistics processes requires the possession of information that will be the basis for identifying errors and detecting existing bottlenecks [2]. Their knowledge will subsequently enable to implement appropriate measures to ensure their efficient operation and process optimization [3].

Transport is an important component of most logistics processes [4]. Transport fulfils an important function and is often a decisive factor influencing the operational efficiency of logistics processes [5]. The current trend in transport within corporate logistics systems is automation.

Automated transport systems are often based on the use of different types of AGV systems [6]. In general terms, an AGV is defined as a vehicle moving itself without an operator (driver) along a strictly defined route [7]. Most often, AGV systems are used for handling in warehouses, for supply in production, but also provide the possibility of implementing this technology in the exteriors of production enterprises.

The advantage that AGV devices bring is manifested primarily in the form of continuous operation without limitations [8]. To control the operation of AGV systems, the use of various types of optimization methods, such as genetic algorithms [9], is usually necessary. In addition to the genetic algorithm method, other optimization methods have been proven in practice, such as Greedyho algorithms [10], non-dominated sorting cuckoo search algorithm [11] or Fuzzy control [12]. The design and operation of AGV systems cannot be effectively implemented without the application of simulation methods [13]. In addition, AGV systems also enable continuous collection of a wide range of data and thus help to evaluate them within various types of analyses [14]. This feature helps to increase productivity in logistics and production.

The dominant area of deployment of AGV systems is the area of supply [15]. Supplying is an activity that ensures the company to deliver products, semi-finished products, materials that are necessary for the process of final production and the provision of services. When supplying, the main task for production is to procure input materials in the right quantity, assortment, quality and time with minimal cost. In supply logistics, it is also important to determine by which means of transport the supply process will be carried out.

The aim of the paper is to present the use of the FMEA method and computer simulation for the identification of a bottleneck affecting its functioning, efficiency and resulting productivity on the example of a real logistics process, in the form of an assembly process of an automotive transmission. Based on the analysis thus chosen, a solution was then proposed, which was again verified by a simulation model.

ANALYSIS OF THE ASSEMBLY PROCESS

The entire assembly process (Figure 1) starts in the input warehouse, where there are racks with individual components. The route of the AGV set passes through the input warehouse, where the docking station for charging the AGV tow tractor is located. In this part, the selection of components intended for dispatch by an AGV set for individual assembly workplaces is carried out. The loaded AGV assembly continues along the route towards the assembly hall.

The AGV set supplies 14 buffers, which are located at individual assembly stations. These buffers work on the principle of FIFO (first in first out). Components are continuously moved from the containers to the assembly line, which consists of individual assembly stations that are connected to each other via a belt conveyor.

The direction of the conveyor runs clockwise. On the assembly belt, the gearbox being cmpleted is placed on special fixation pedestals, on which it is moved to the next assembly site after performing the relevant operation. Each assembly station is used to add a specific part of the automotive transmission.

The completed gearbox from the belt conveyor goes into the container of the finished gearboxes. It is then transported to a test station where its functionality is verified. The capacity of the test station is 8 transmissions, which can be tested at the same time.

FMEA process of automotive transmission assembly

For the analysis of the assembly of the automotive transmission, the FMEA Process method is used (Figure 2). The aim of its application was to examine and identify possible defects in the analyzed assembly process in order to eliminate them. The FMEA method was used with the intention to identify a bottleneck. The result of the analysis pointed to a bottleneck in the monarchy process in the form of insufficient capacity

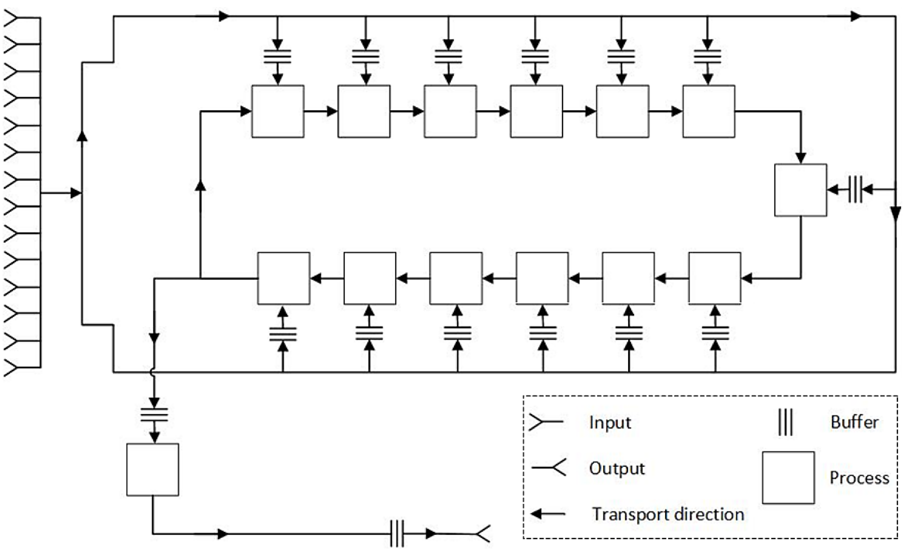

Figure 1. Block diagram of the car transmission/gearbox assembly process

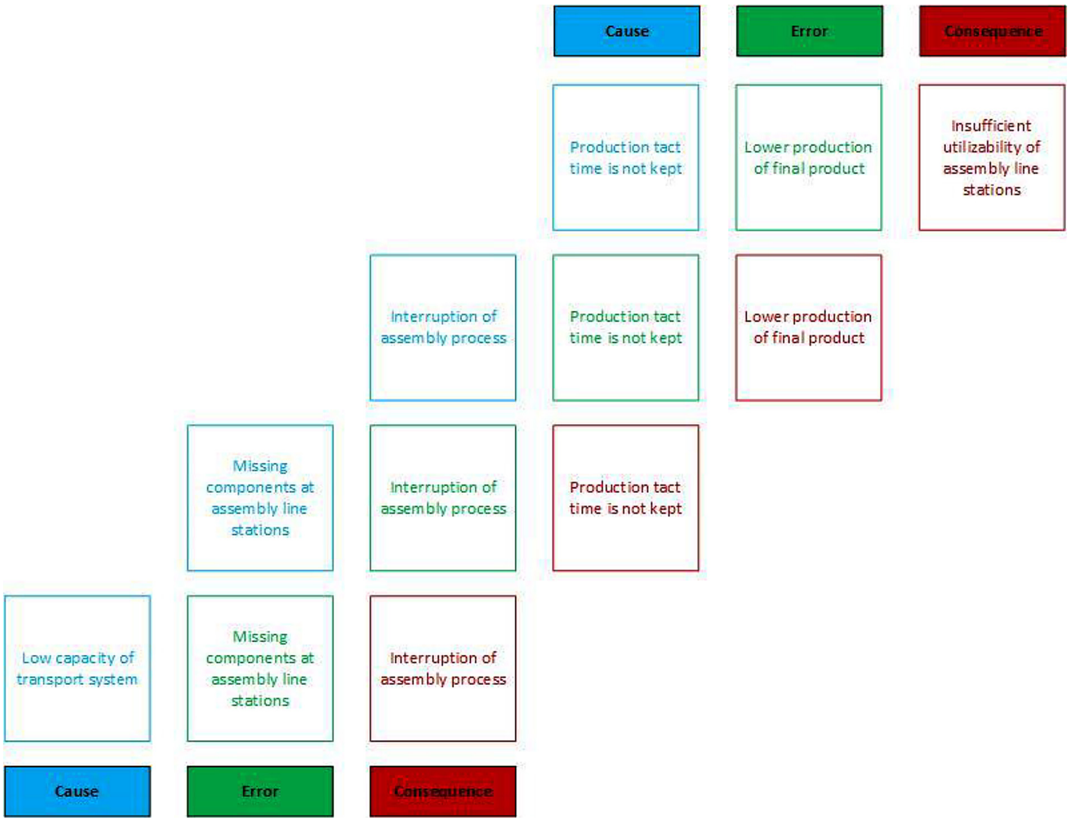

Figure 2. FMEA Process of automotive transmission assembly

utilization of assembly stations due to the fact that the existing transport system does not manage to supply assembly workplaces with components to the required extent.

At the same time, the assembly process was also comprehensively analyzed using a simulation model created in Tecnomatix Plant Simulation. The results of the performed analysis using a simulation model identified the same critical point of the assembly process as the analysis using Process FMEA, i.e. shortcomings in the process of supplying some assembly workplaces.

The main disadvantage of the described assembly process is the insufficient utilizability of individual assembly stations (Figure 3). The system used to supply assembly plants plays a decisive role in the existence of this shortcoming. The simulation model was also used with regard to the possibility of conducting a detailed analysis of the assembly process of the automotive transmission in order to identify existing bottlenecks.

Tecnomatix Plant Simulation software was used to create the simulation model. Tecnomatix Plant Simulation is currently among the top simulation tools in the field of logistics. It has special blocks for modelling intralogistics processes, including the supply of various types of workplaces by AGV systems. Based on the mentioned facts, the simulation software was used for the implementation of the presented research.

Analysis of the assembly process using a simulation model

The assembly process of the gearbox, as already mentioned, is supplied by one AGV set, which supplies the individual buffers with two pieces of components at a 220-second interval. The consequences of the problem are shown in the graph of workplace occupancy and graphs of the stock status of individual buffers (Figure 3).

Figure 4 show a resulting problem that arises already with the first two buffers. The stock levels in these buffers range from 0 to 2 components, which is undesirable because it signals outages during the assembly process. Buffers 3 and 4 manage to supply their assembly stations because the amount of material in these buffers is from 2 to 4. For this reason, there is a temporary shortage of components in buffers 1 and 2 at certain points in time, which is reflected at assembly stations in the form of interruption of the assembly process due to lack of material. This situation is negatively reflected in the number of finished gearboxes,

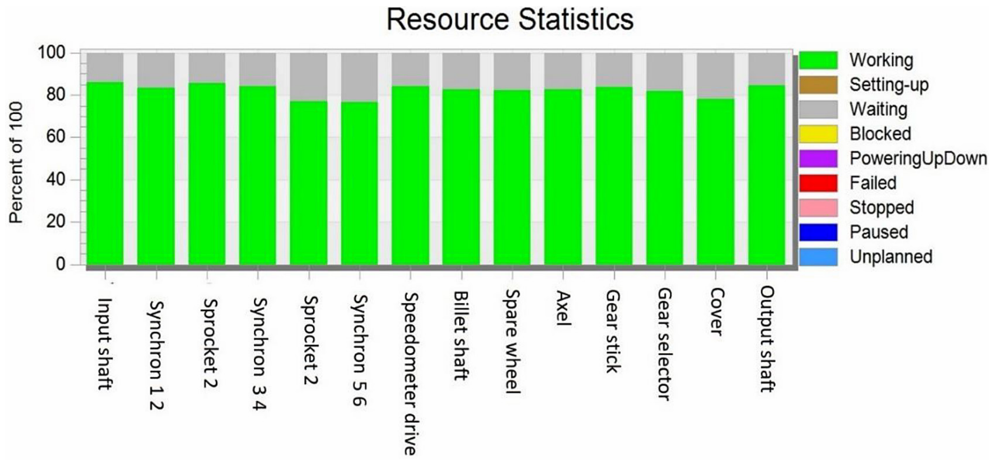

Figure 3. Capacity utilization of assembly workplaces in the current state

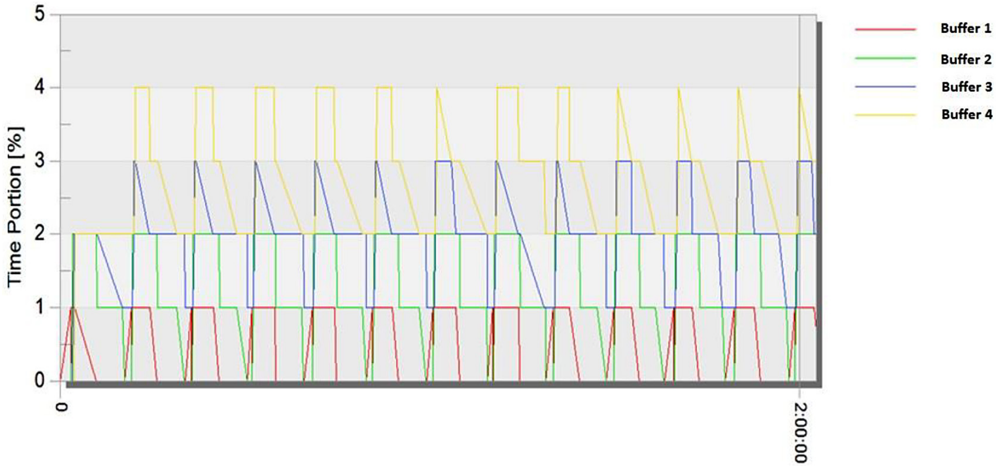

Figure 4. Analysis of component status in buffers 1, 2, 3, 4

because the given assembly site is underutilized, which causes errors in supply logistics.

Chart in Figure 5 shows that the status of additional buffers 5, 6, and 7 is constant from 3 to 7 components in each buffer. In this case, there is no longer any downtime on the line due to material shortages. Stocks in buffers 8, 9 and 10 (Figure 6) is sufficient from the point of view of the use of the assembly workplace. Inventory levels range from 5 to 9 components. A negative phenomenon is a greater accumulation of material in the buffers.

Buffers 11, 12, 13 and 14 (Figure 7) point to a demonstrable error in supply logistics. The number of components at each time moment ranges from 8 to 13. Again, there is an even greater increase in excess material in the buffers. The stock increases in the first hour, as the assembly site is not active at this time. Previous graphs of individual buffers show that more material accumulates in the buffers at each subsequent station. This accumulation is due to the fact that one AGV supplies all assembly stations from the beginning with the same amount of material. In the first hour, half of the workplaces do not use this material, which leads to its accumulation.

PROPOSAL FOR IMPROVEMENT

The analysis identified a bottleneck, which is the supply of individual buffers, which negatively reflected on the total number of gearboxes produced. To improve the current situation, a solution was proposed, which was based on providing an additional AGV set for supplying assembly workstations. This solution was designed due to the fact that the transport route is wide enough for the operation of two AGV sets at the same time (Figure 8). The benefit should be reflected in an improvement in the supply process and thus an increase in the number of gearboxes produced in one day.

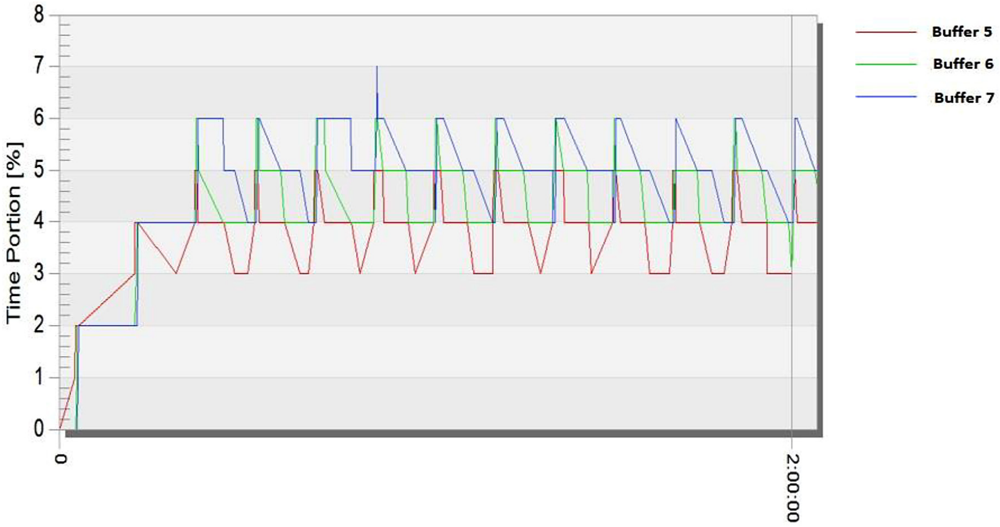

Figure 5. Analysis of component status in buffers 5, 6, 7

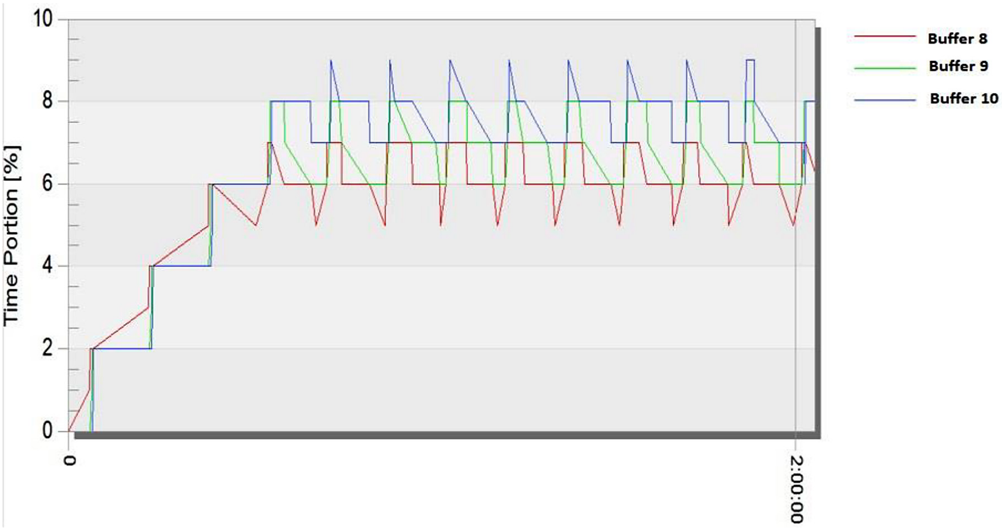

Figure 6. Analysis of component status in buffers 8, 9, 10

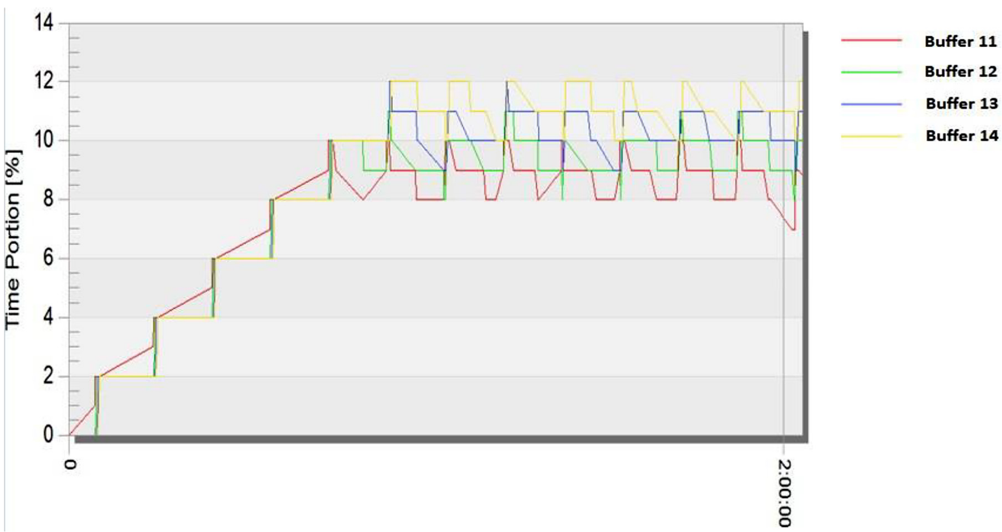

Figure 7. Analysis of component status in buffers 11, 12, 13, 14

Two AGV sets supply individual buffers in opposite directions. AGV_1 supplies the upper branch, buffers 1 to 7 (Figure 9). AGV_2 supplies the lower branch, which means buffers 8 to 14 (Figure 10). Both AGV sets supply individual assembly stations with 2 components per buffer at a time, because more components would only create excess material in them and fewer would mean material shortage. Therefore, 2 components are understood as the ideal amount.

The capacity of both AGV sets remained the same, namely 4 components per trolley. The distribution of components at two AGVs means that 4 trolleys can be used within one AGV set. Due to the fact that the trolleys are loaded simultaneously in the input warehouse, this loading time is saved. As a result, AGVs get to individual buffers sooner. The deployment of peripherals without automation was considered as part of the supply process solution design. By dividing the supply into two AGVs supplying different buffers, it improves supply logistics. The use of two sets of AGVs has resulted in the possibility of more accurate planning of the supply cycle.

Assembly station occupancy with two AGVs increased to 87% or up to 98% in one day (Fig. 11).

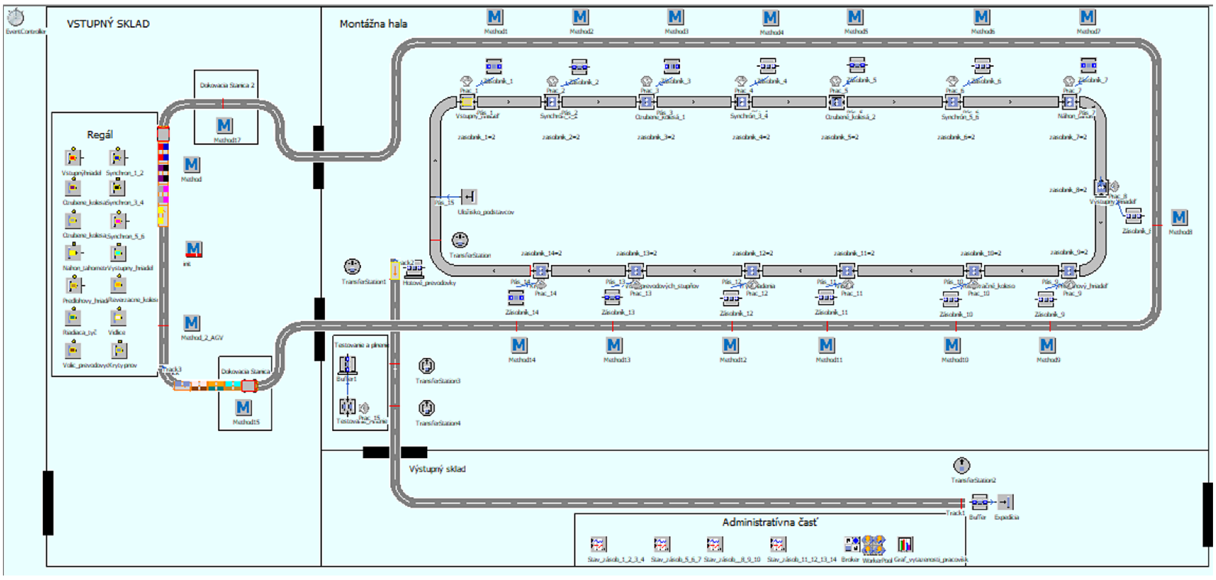

Figure 8. Simulation model of supplying the production process simultaneously with two sets of AGVs

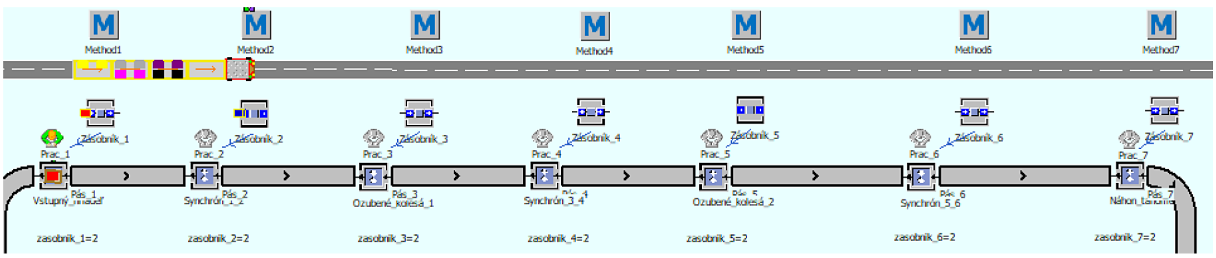

Figure 9. Upper supply branch using AGV_1

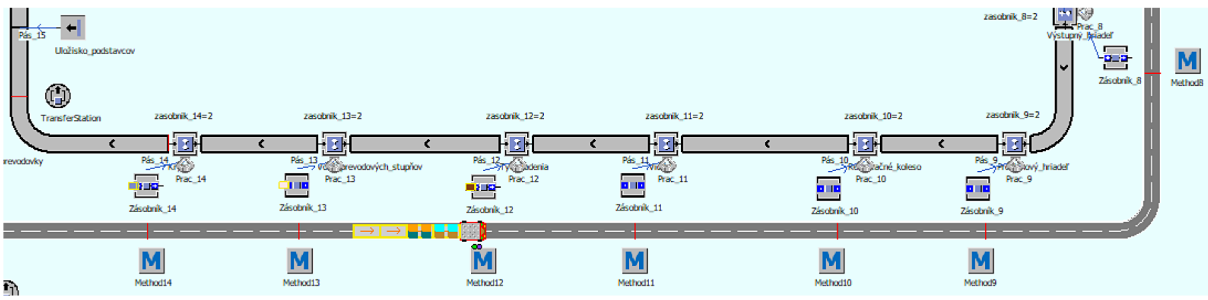

Figure 10. Lower supply branch using AGV_2

Simulation time: 1:00:00:00.0000

Current state

Cumulated Statistics of the Parts which the Drain Deleted

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Expedícia	Completed Gearbox	1:58:03.4967	272	11	25.32%	62.09%	12.58%	21.20%	

Simulation time: 1:00:00:00.0000

Improved proposal

Cumulated Statistics of the Parts which the Drain Deleted

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Expedícia	Completed Gearbox	2:05:11.9762	312	13	23.32%	62.61%	14.07%	19.94%	

Figure 11. Comparison of assembly process results before and after the implementation of the supply change

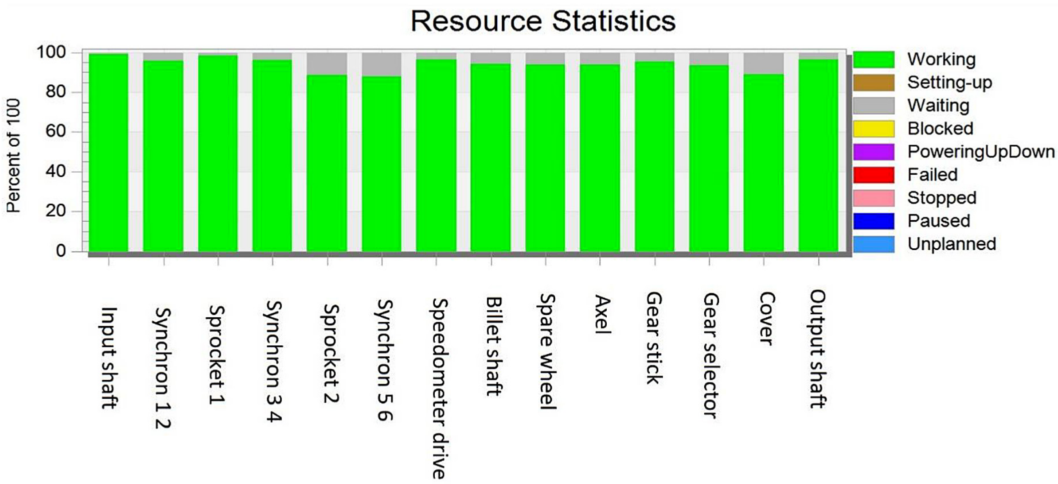

Figure 12. Occupancy of assembly stations in improved design

This utilizability is also linked to the number of finished gearboxes. In the improved design, the company can produce 312 finished gearboxes compared to the original 272. All production times on individual assembly lines remained the same (Fig. 12).

CONCLUSIONS

The current trend in industrial logistics focuses on adapting individual business processes to the requirements of production individualization, reduction of operating costs, increasing of production efficiency and service processes. In most cases, this is a complex issue. At the same time, its solution is always strongly individual with regard to the specific business environment. Nowadays, an effective solution to this issue cannot do without the use of computer simulation combined with supportive analytical approaches.

One of the most challenging areas in corporate logistics is the supply process, which includes, among other things, transport and handling. The correct set-up of the supply system must be carried out in accordance with the production of final products and services. At the same time, the supply must provide sufficient performance to achieve the utilization of individual production sites and processes with regard to their capacity and operating costs.

Solving the presented problem associated with increasing the efficiency of the automatic transmission assembly process, which is described in the framework of this paper, was performed in accordance with the above statements. By applying a simulation approach in combination with the Process FMEA method, a bottleneck within the assembly process was identified. This confirmed that the combination of these two approaches is suitable and effective for the needs of increasing the efficiency of today's modern logistics. The presented results demonstrate that this approach has brought an increase in the usability of assembly stations from the original level in the range of 75% to 85% to a new level of 87% up to 98% after modification based on the established facts. This is a significant improvement in the entire assembly process.

The presented approach can thus be generalized and applied to different types of logistics processes within a wide range of industrial areas. With its help, it is possible to detect bottlenecks of various types of logistics processes and subsequently look for options for their elimination.

The presented simulation model can be applied on a daily basis. It is a model that can be applied for production planning, verification of production plans as well as transport capacities of the transport system within intralogistics. After its modification, the above model can be transformed into an optimization model and can be used in the planning of picking and supply operations.

The simulation model can be used not only for supply process analysis. Other possible applications are in assembly line workflow optimization, production planning and transport units circulation analysis. At the same time, the simulation model can be used as part of the digital twin of the production process or as part of the digital factory and for the needs of production digitalization.

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