Advanced Logistic Systems – Theory and Practice, Vol. 19, No. 4 (2025), pp. 47-56.
https://doi.org/10.32971/als.2025.022

CREATING A DIGITAL TWIN FOR A PRODUCTION LOGISTICS MODEL SYSTEM USING DISCRETE EVENT SIMULATION

ISTVÁN MUNKÁCSI[1] – RÓBERT SKAPINYECZ[2]

Abstract: *The aim of the paper is to present the creation process of a digital twin based on discrete-event simulation for a production logistics model system. The given system is located in the Logistics 4.0 Laboratory of the Institute of Logistics of the University of Miskolc. It consists of an automated, PLC-controlled material handling system based on roller conveyors and turntables, which is supplemented by a gravity flow rack. It also has multiple locations along the conveyor track that could serve as storage or assembly stations. A real-scale model of the entire system was created with the aid of Siemens Tecnomatix Plant Simulation. In the developed model, proprietary methods control the transfer of raw materials, congestion management and the operation of the turntables. Based on the operation of the complete system, the simulation examines machine utilization, human resources and bottlenecks in the material flow. The results demonstrate the advantages of using discrete-event simulation based digital twins for the optimization of production logistics systems.*

Keywords: *simulation, digital twin, production logistics, material flow*

1. INTRODUCTION

The aim of the research presented in the article was to analyse the operation of the production logistics model system located in the Logistics 4.0 Laboratory of the Institute of Logistics of the University of Miskolc, to explore development opportunities, and to create a digital twin of the system using discrete event-driven simulation.

The actuality of the topic is given by the fact that although automation is increasingly widespread, a well-trained workforce is still indispensable. Due to the Lean approach, automation does not result in a reduction in the number of employees, but in the reallocation of resources. In addition, flexible manufacturing systems are gaining an increasingly important role, which are capable of producing multiple products and operating independent production lines, thus ensuring a high degree of flexibility. Therefore, the creation of digital twins for collaborative human-machine production systems has become increasingly important in the recent period. Besides, the further development of the laboratory could benefit greatly from the creation of such a digital twin as well.

The first part of the publication provides an overview of the tools of the logistics laboratory, the significance of simulation, and the industrial role of digital twins. The second part presents the model built in the Plant Simulation environment and the data that can be extracted from the different design versions of the system. The focus of the study is on the analysis of human resources and machine utilization, loss times, machine downtimes, material flow intensity and the detection of bottlenecks.

At the end of the publication, development proposals are formulated in order to make the model further expandable, more flexible and more efficient, so that the examined production system can operate with lower losses and in a more widely applicable manner. While the

[1]BSc logistics engineer student, University of Miskolc, Institute of Logistics, Hungary
istvan.munkacsi@student.uni-miskolc.hu
[2]associate professor, University of Miskolc, Institute of Logistics, Hungary
robert.skapinyecz@uni-miskolc.hu

main purpose of the model system is to support educational and research activities, nevertheless the proposed improvements can still aid in the further development of the laboratory to better fulfil these roles, while the creation of the digital twin can provide valuable insights from an industry perspective as well.

2. INTRODUCTION OF THE LOGISTICS 4.0 LABORATORY

The role of automation has been continuously increasing in the field of logistics and material handling in recent decades, and with the rise of Industry 4.0, it has now become indispensable. Modern logistics systems often require new approaches and integrated technological solutions [1]. The current laboratory system was developed in 2018, which is partly based on elements of previous laboratory versions. In addition, many of its components are based on industry standards or are custom-developed. In the following sub-chapters, the most important features of these subsystems are presented from an educational, research and development perspective [2, 3].

2.1. Main components of the laboratory

The core element of the logistics laboratory is an integrated material handling system, the main components of which are a PLC-controlled roller conveyor, a palletizing station and an automated storage system. The system also includes an automated guided vehicle (AGV) that completes the operation of the conveyor network [2]. The conveyor line forms the basic structure of the laboratory; it is modular in design, and each module has its own drive and control unit. The straight track sections consist of 2–4 meter elements equipped with optical sensors. These sensors monitor the transported goods, which can be stopped or allowed to continue depending on the traffic situation using pneumatic blocking units. The system is based on an electro-pneumatic operating principle, for which an industrial compressor provides the necessary compressed air [2]. The equipment also includes an RFID reader that can simultaneously identify up to a hundred chip-equipped products without physical contact.

2.2. Storage systems and related elements

Around the conveyor belt is a gravity flow rack consisting of inclined shelves and a manually operated refilling solution. This rack system represents the operation of manual workstations in an automated environment. An automatic high-bay storage system is located in the back of the laboratory. The shelving system is of industrial design, but the low height of the building required unique solutions. The storage system is operated by an automatic stacker, which identifies the storage locations with the help of pre-programmed controls and optical sensors, and carries out the storage and retrieval of goods. The stacker is directly connected to the conveyor belt system, so it can serve it in a fully automated manner [2].

2.3. Control and automation

The system is fully PLC-based, but each subsystem has its own control unit, allowing it to operate independently. The central control unit is complemented by a touch-screen interface that allows for both automatic and manual modes. Automated operation allows individual components to perform coordinated material handling tasks without human intervention. The system is supported by SCADA (Supervisory control and data acquisition) and MES (Manufacturing Execution System) solutions that provide higher-level monitoring and control functions [2].

3. THE ROLE OF SIMULATION TECHNOLOGIES IN INDUSTRIAL AUTOMATION

The design, optimization and operation of manufacturing and logistics systems are increasingly based on simulation technologies today. Simulation provides the opportunity to examine the operation of real systems in a virtual environment, which significantly reduces risks, costs and the time required. In parallel with the development of simulation methods, solutions such as digital twins and discrete-event simulation software have become available, which now form an integral part of industrial automation. These tools enable the preliminary modelling of complex systems, the analysis of their operation and the well-founded support of decisions.

3.1. Types of simulation methods

Simulation technologies use several approaches depending on the type of system we want to model. The most common types of simulation used in industrial environments are: Discrete-Event Simulation (DES): In this case, the state changes of the system are triggered by clearly distinguishable events, such as the arrival of a product on a conveyor belt. The method is particularly useful for modelling manufacturing and logistics processes, as it effectively handles material flow, machine utilization and workflow timing. Continuous Simulation: It is used to describe systems where state changes are continuous – for example, in the case of temperature, pressure or speed fluctuations. This approach is primarily suitable for modelling physical and technical processes. Agent-based simulation: System elements – such as machines, workers or robots – appear as independent decision-makers, and their behaviour and interaction with each other determine the operation of the system. This method is well suited for studying complex, decentralized systems. Hybrid simulation: A combination of the above methods, which allows for the simultaneous modelling of different types of processes. Choosing the right simulation method is essential for achieving accurate and reliable results. Discrete event-based simulation is the most common in industry, as it is well suited to the time-dependent, event-driven operation of manufacturing and logistics processes.

3.2. Introduction of the Tecnomatix Plant Simulation software

The Tecnomatix Plant Simulation software developed by Siemens is one of the most widely used tools for modelling and optimizing industrial processes. The program uses discrete-event simulation and allows detailed examination of production cells, production lines, plant halls, and logistics systems. Plant Simulation allows the creation of virtual factory models in which material flow, machine utilization, storage capacity, and bottlenecks can be analysed [4]. The object-oriented architecture of the software allows users to create their own elements or use objects from built-in libraries. The 2D and 3D visualization options make the created models easy to interpret not only from a functional but also from a visual perspective. Plant Simulation supports “what if” analyses, so that different scenarios can be tested before implementing the real system.

3.3. Digital twin – a new dimension of simulation

The concept of a digital twin is a virtual counterpart of a physical system that can simulate, analyse, and optimize its operation using real-time data. A digital twin is not a static model, but a dynamic, continuously updated representation that reflects the current state of physical assets. This enables predictive maintenance, performance enhancement, and rapid response to changing environmental conditions [5, 6].

4. PRESENTATION OF THE DEVELOPED SIMULATION MODEL

The model shown in Fig. 1 was created in Plant Simulation. Since the model was based on the Logistics 4.0 Laboratory of the Logistics Institute of the University of Miskolc, the dimensions correspond to the real dimensions of the objects in the laboratory. The following objects are shown in the image:

- 2 sources,
- 2 turntables,
- 6 roller conveyor tracks,
- 3 turners,
- 3 assembly stations,
- 1 station,
- 3 storages,
- 1 buffer,
- 1 worker group, and the necessary shift calendar and an organizer,
- 3 workplaces,
- 2 methods.

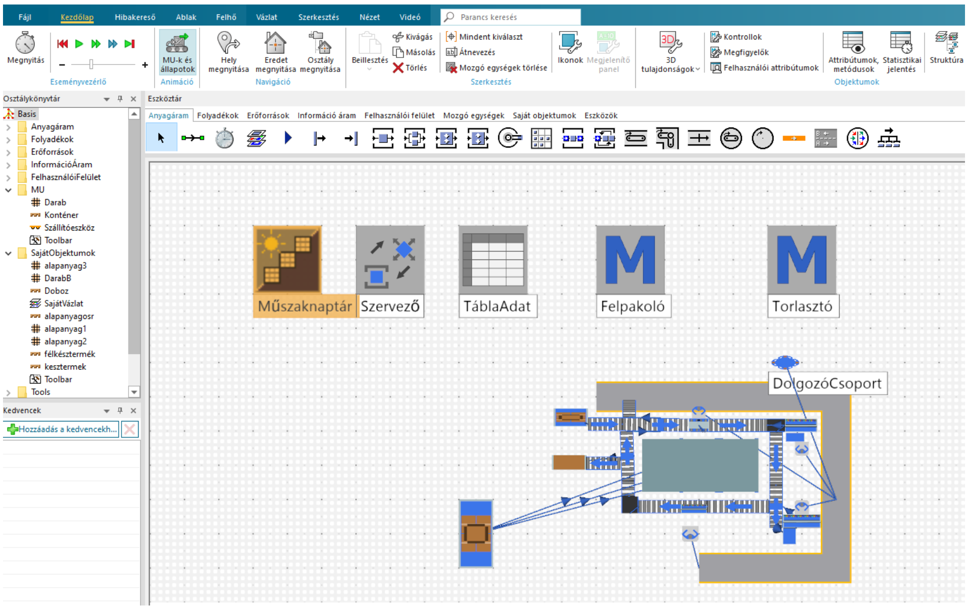

Figure 1. The model created in Plant Simulation

4.1. The operation of the model

The raw material pallet arrives through the “Source” point, while the other input (“Source1”) supplies the three supermarkets. The supermarkets contain the raw materials that provide the components needed for assembly. The raw materials arrive at the supermarkets based on orders; they are “raw material1”, “raw material2” and “raw material3”. These components are transferred by the operator at the “Station”. For the process to work, a method had to be written that specifies that the operator transfers the raw materials to a container called “raw material” when they arrive. When the method runs, the operator loads the raw materials into the container, which then proceeds to the assembly station. If the station is currently in production, a bottleneck occurs. A separate method had to be written to handle the bottleneck, since there is a translation unit in front of the assembly station. If the station is currently in production, a bottleneck occurs. A separate method had to be created to handle the bottleneck, as there is a turner unit in front of the assembly station. If any product remained on it, it caused an error in the simulation, and the raw material did not reach the assembly station. There is also a buffer in front of the assembly station, whose task is to ensure a circular flow of materials due to the prohibition of back and forth flow. The raw materials are assembled at the assembly station. From there, they are returned to the translation unit, and then continue to the inspection point, which is called “Assembly Station 2” in the simulation. From there, a semi-finished product leaves, passes quality control, and then leaves the station and exits the system as a finished product. The congestion handling method is responsible for ensuring that the flow of raw materials does not cause any disruption (Fig. 2). The method is called when the raw material pallet arrives at “Conveyor1”. In this case, it checks whether there is any processing in progress somewhere. If not, it simply lets the raw material continue. However, if an assembly operation is taking place at “Assembly Station1”, the method closes the conveyor, which the station only opens again when it is freed.

```
-- Description  : torlasztás
--
-- Parameters   : «parameters»
--
-- Return value : «result»
--
-- Called By    :Szállítoszallag1
--------------------------------------------
/*
Author  : Munkácsi István
Date    : 2025.09.19.

History :
____________________________________________
*/

if ?.StatNumOut >= 1
    ?.ExitLocked := true

    wait 20

    waituntil  .modellek.modell.Szerelőállomás1.empty = true

    ?.ExitLocked := false

    @.move
else
    @.move
end
```

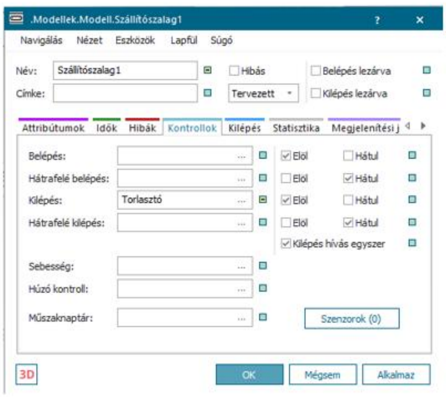

Figure 2. The method called “congestion” (“torlasztás” in Hungarian) and its application (in the method, “Szállítószalag1” stands for “Conveyor1” and “Szerelőállomás1” stands for “Assembly station 1”)

The method shown in Fig. 3 is responsible for the repacking of raw materials, which is called by “Station”. The task of the method is to reload three different raw materials required for production. These raw materials are stored in three different storages, which function as supermarkets. From there, the components required for each operation arrive.

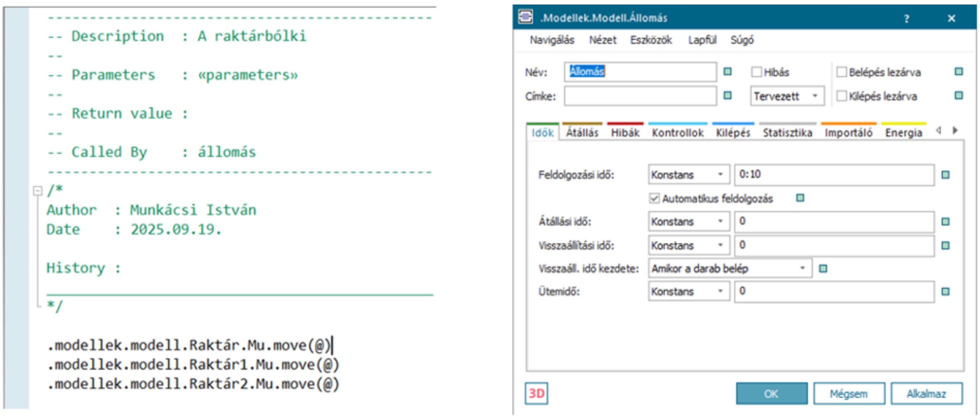

Figure 3. The method responsible for the transfer of the pallets and its application (in the method, "állomás" stands for "station" and "Raktár" stands for "storage")

The following figure (Fig. 4) shows the machine utilization. The figure clearly shows that at the "Station", the system is overloaded and blocked due to the intensive inflow of raw materials. The "Assembly Station1" and "Assembly Station 2" assembly stations receive the raw materials from the "Station", so its overload also affects the systems built on it.

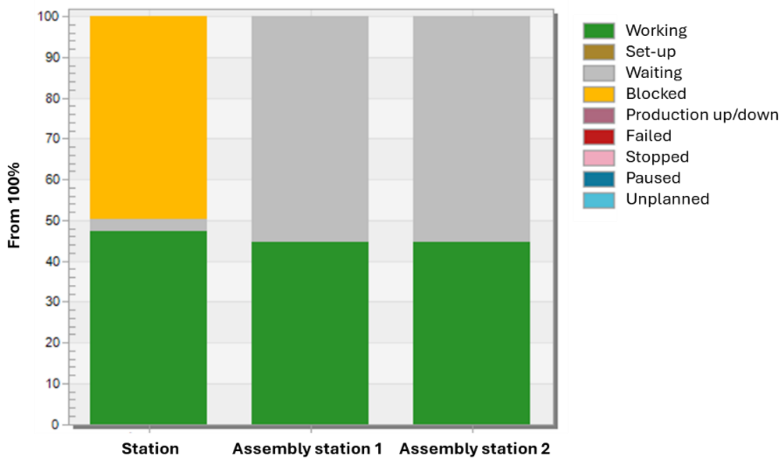

Figure 4. Resource utilization diagram of the machines

Fig. 5 shows the utilization of operators at the stations. From these data, we can conclude that the worker at the raw material inflow point ("Station") is the most utilized. At this point, the operator's utilization is 50%. The operator at the assembly stations is less utilized (45%). Coming to quality control (the station of the third operator), we get a value that is almost the same (~44%) as for the operator at the previous station.

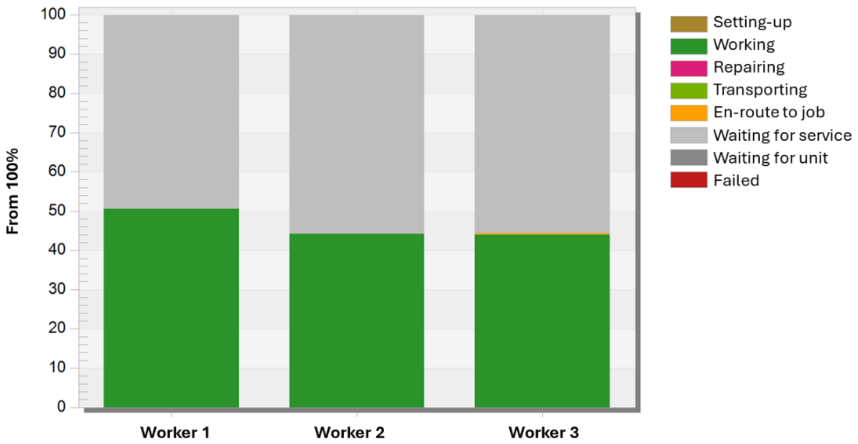

Figure 5. Utilization diagram of the operators

The Sankey diagram is used to determine the bottleneck of the material flow of products. Fig. 6 shows the application of the diagram for the modelled production system. It can be observed that the raw material accumulates a lot at the blockage part.

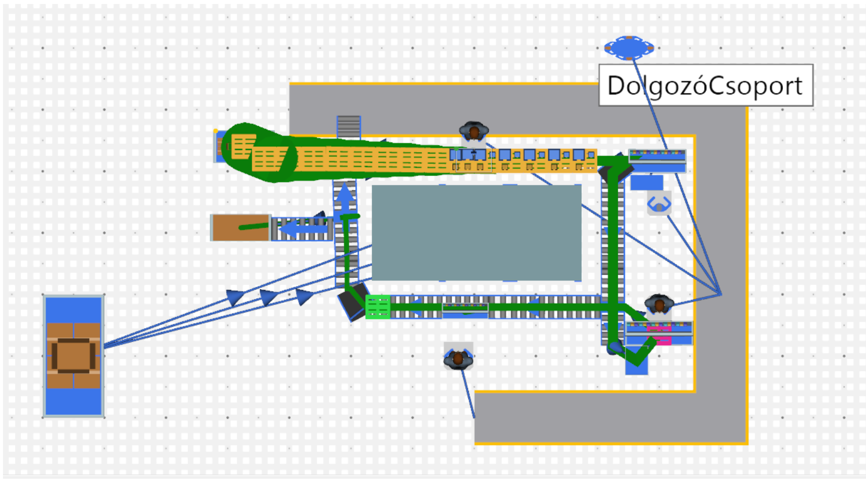

Figure 6. Sankey diagram in the model

5. PRESENTATION OF THE UPGRADED SIMULATION MODEL

The Sankey diagram for the upgraded model is shown in Fig. 7. The difference compared to the previous model is that a new assembly station was added for better productivity.

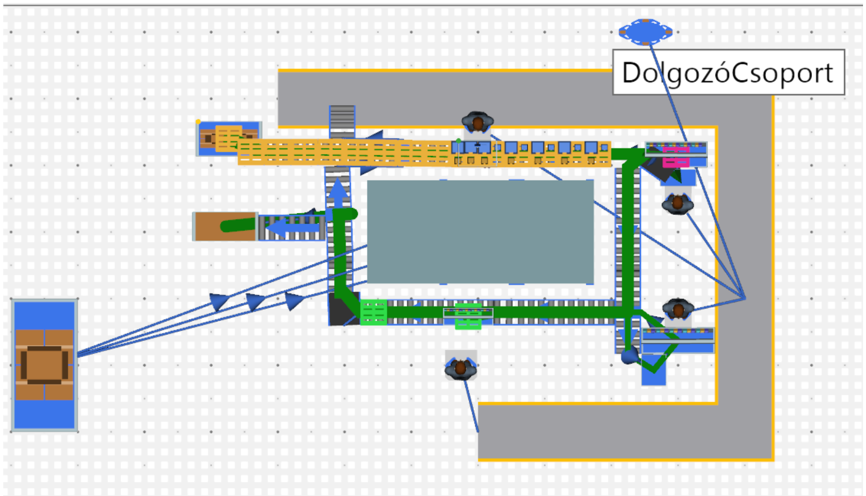

Figure 7. Sankey diagram in the upgraded model

In Fig. 8, the first station shows high blocking again. However, the utilization at the new assembly station (the last column in the diagram) is clearly higher. The utilization of "Assembly station 1" deteriorated, while the performance of "Assembly station 2" (quality assurance) remained unchanged.

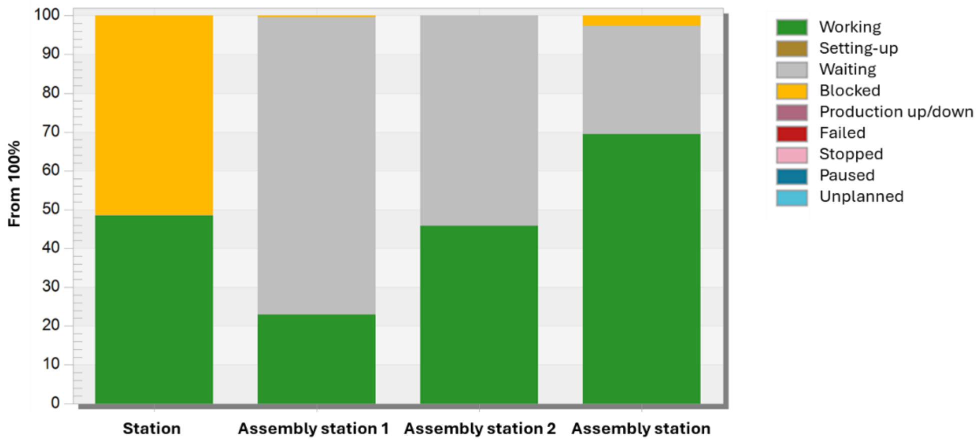

Figure 8. Machine utilization in the upgraded model

Fig. 9 shows the operator utilization in the upgraded model. "Worker 2" works at the assembly station. This is a newly created station. This station has the best utilization in the model. "Worker 1" has the second best utilization. This worker works at the station called "Station". "Worker 3" works at "Assembly Station 1". His performance has deteriorated compared to the previous one. "Worker 4" has no change in performance compared to the previous model. This worker works at "Assembly station 2", in quality assurance.

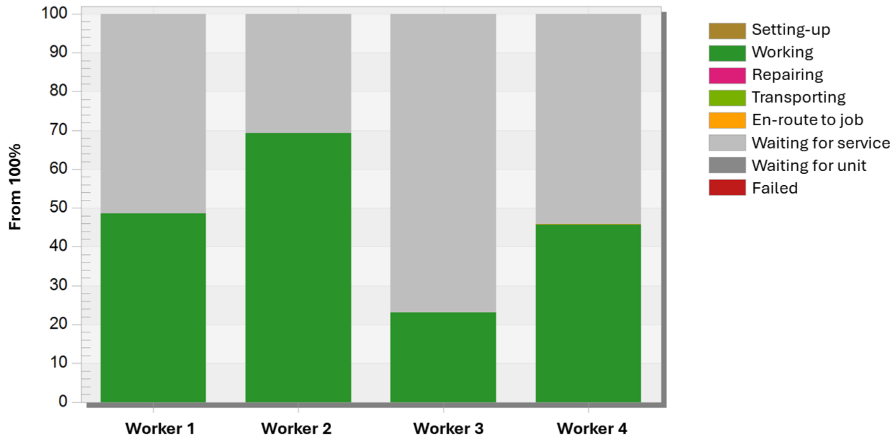

Figure 9. Utilization of the operators in the upgraded model

As the comparison of the two models showed, while the productivity clearly increased through the introduction of a new station in the upgraded model, the accumulation of the raw materials at the blockage point still remained. This can be addressed with the implementation of additional improvements, which will be mentioned in the conclusions.

4. CONCLUSIONS

In the frame of the research, a digital twin of the Logistics 4.0 Laboratory located at the Logistics Institute of the University of Miskolc was created using the Plant Simulation software. The model includes sources, assembly stations, roller conveyor tracks, storages and turntables. It also includes employee resources and the methods required for their operation in order to represent the complete functionality of a production logistics model system.

During the simulation, material flow processes, congestion management, employee and machine utilization, and potential bottlenecks were examined. Based on the analysis of the Sankey diagram, significant material accumulation can be observed at the congestion section, which is one of the main performance limiting points of the system. Machine utilization was low at several stations, especially at the assembly and quality control points, which indicates efficiency problems.

Operator utilization also showed differences: adequate values were reported at the raw material loading point, while lower values were reported at the assembly and control points. Based on these results, future development proposals for the model system include merging work processes to better utilize resources, as well as parallel operation of assembly stations, which can achieve significant time savings and increased efficiency. As the system in question is a model system oriented for research and education, therefore the main aim of the proposed upgrades is to further improve the capabilities of the laboratory in supporting the mentioned activities. Besides, the digital twin developed in the frame of the research could be directly connected with the real system in the future through a proper interface, which could open up entirely new research directions.

References

[1] Illés, B., Tamás, P., Dobos, P. & Skapinyecz, R. (2017). New challenges for quality assurance of manufacturing processes in industry 4.0. *Solid State Phenomena*, **261**, 481-486. https://doi.org/10.4028/www.scientific.net/SSP.261.481

[2] Károly, M., Veres, P. & Skapinyecz, R. (2019). A Miskolci Egyetem Logisztikai Intézetébe telepített high-tech logisztikai laboratórium bemutatása. *Multidiszciplináris Tudományok: a Miskolci Egyetem közleménye,* **9**(1), 73-80. https://doi.org/10.35925/j.multi.2019.1.10

[3] Miskolci Egyetem: *Lean folyamatfejlesztő specialista szakirányú továbbképzés (in English: Lean process development specialist training)*. Retrieved from https://www.uni-miskolc.hu/kepzesek/szakiranyu-tovabbkepzes/Lean-folyamatfejleszto-specialista/ (last accessed: 10.12.2025)

[4] Siemens: *Plant Simulation*. Retrieved from https://plm.sw.siemens.com/en-US/tecnomatix/plant-simulation-software/ (last accessed: 10.12.2025)

[5] Siemens: *Outperform your competition with a comprehensive Digital Twin* Retrieved from https://www.siemens.com/global/en/products/automation/topic-areas/digital-enterprise/digital-twin.html (last accessed: 10.12.2025)

[6] Matyi, H. & Tamás, P. (2021). Application of Digital Twin technology in the development of logistics process. *Advanced Logistic Systems - Theory and Practice*, **15**(1), 12-19. https://doi.org/10.32971/als.2021.002