Exploring the Potential of FlexSim 3D Simulation for Robotic Workstation Analysis

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Abstract **– Simulators play an important role in testing robotic workstations in production facilities, allowing real-world conditions to be simulated without risk to equipment and staff. They allow users to verify robot control algorithms, identify possible errors, and optimize production processes. By using simulators, companies can reduce prototyping costs and decrease downtime. In addition, it helps to improve safety in production and minimize training costs. The main aims of this research are to analyze and test the FlexSim software, which is a 3D simulator for visualizing and simulating scenarios in manufacturing workplaces. To test the program, a 3D model of a robotic workplace with conveyor belts and CNC machines was created. The simulated workplace was analysed using the analysis tools offered by the software. The results were obtained in the form of graphs, which makes it easier to visually identify downtime, weaknesses, and workstation efficiency. A comparative analysis of our chosen simulator and Tecnomatix Plant Simulation software was also carried out. These two advanced simulators are actively used at serial production plants to analyze and simulate innovative solutions at production locations. At the end of the article, the weaknesses of the two software programs are described, along with a comparative analysis in the form of a table.**

Keywords **– simulation, robotic workplace, manipulation, FlexSim, Tecnomatix Plant Simulation.**

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1. Introduction

In modern manufacturing systems, robots and material handling units efficiently manage and coordinate the flow of materials across distributed automated equipment. They bring two crucial advantages: the ability to create dynamic, mixed material flows, and the flexibility to adapt the system's interactions with its environment. [1] This flexibility stems from the reprogrammable nature and intelligence of modern robots, allowing adaptable, rather than fixed, material flows. Additionally, the demand for integrated and flexible systems from customers, competitors, and suppliers drives the development of this capability [2].

For effective robot design and usage, it is essential to develop an efficient motion planning algorithm by generating, simulating, evaluating, and optimizing robot trajectories in an off-line virtual CAD programming environment [3]. There are certain criteria for comparing and evaluating robot trajectories and trajectory planners [4]:

- Trajectories should be efficiently computed and executed.
- Trajectories should be predictable and precise, and should not degenerate in an unacceptable way near singularities.
- Position, velocity, and acceleration, and even the rate of change of acceleration, called jerk should be smooth functions of time.

- The trajectory planner should be able to efficiently determine whether the proposed trajectory requires the robot's end-effector to move to a point outside its workspace or move at a speed or acceleration that is physically impossible. Both of these situations can be controlled with a good model.

In this paper we have described and tested the FlexSim simulation software. Also, we have compared this software with the Tecnomatix Plant Simulation [5].

FlexSim simulation software is an object-oriented simulation tool for building models, creating visualizations, and simulating various manufacturing processes, logistics, handling, troubleshooting, and scenario testing. The main goal of the program in these contexts is to optimize and reduce operational costs. As for designing systems, it helps designers make rational decisions. The program allows the creation of a three-dimensional model of a real system, which can be analyzed in a shorter time and at much lower costs than the real system via suitable interface (Figure 1). FlexSim provides users with elegant visualization of processes in a 3D environment along with statistical analysis of the information.

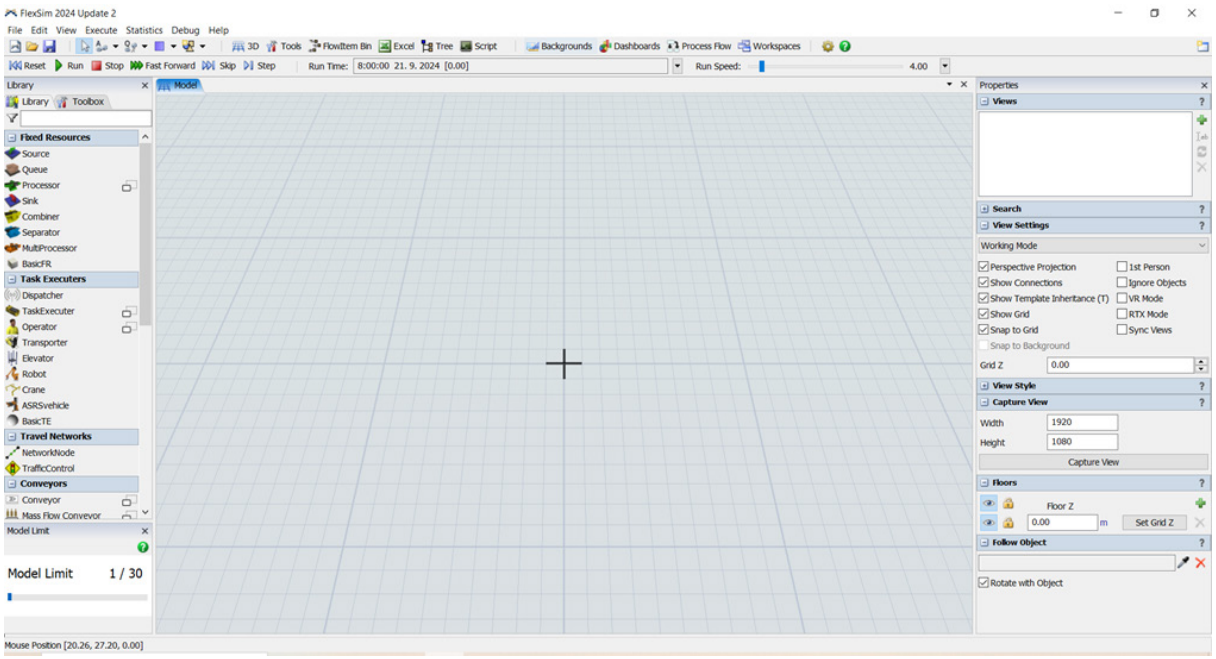

Figure 1. The FlexSim interface

The program falls into the category of discrete event simulation software. This means it is used for modeling systems that change their state at specific points in time due to characteristic events [6], [7]. The data processed in the program mostly involve physical products, but they can also include office work, customers, electronic messages, phone calls, and more. Individual items are processed and subsequently create process flows. Each point requires at least one (but possibly more) resources, such as an operator, tool, conveyor, machine, or vehicle. These resources can be either stationary or mobile.

FlexSim is a universal tool, which is why it is used in simulations across a wide range of industrial sectors.

Possible uses of the FlexSim simulation program [8], [9]:

- Improving machine utilization;
- Solving supply chain issues;
- Reducing wait times and queue lengths;
- Minimizing accident states;
- Determining the optimal production volume;
- Managing the logistics of materials, goods, products, and services;
- Demonstrating new system variants and possibilities;
- Analyzing new investment ideas;
- Reducing costs;
- Determining system throughput;
- Analyzing time settings;
- Solving problems related to material handling;
- Training operators;
- Analyzing daily operations.

The main system requirements are a 64-bit edition of Windows, a modern x64 Intel or AMD processor, 8 GB RAM or more, a GPU supporting OpenGL 3.1 or higher, 3 GB free. Here is a comparison of the two software programs:

Tecnomatix Plant Simulation:

- Architecture: Part of Siemens Tecnomatix portfolio, focusing on digital planning and manufacturing. It integrates with other Siemens tools like Teamcenter and NX.
- Accessibility: Targeted at large enterprises with complex needs. Available as a local or cloud solution within Siemens' digital factory ecosystem.
- Interface: The interface is feature-rich and offers numerous advanced tools and functions. However, it can be complex and challenging to learn.
- User Experience: Specialized training is often required, especially for new users. While the system is highly powerful and flexible, mastering it may take time due to its steep learning curve.
- Modelling: Tecnomatix Plant Simulation enables detailed and complex modelling of manufacturing and logistics processes. It offers robust tools for creating and analysing simulations, capable of handling intricate interactions and processes.
- Flexibility: It supports the creation of custom components and extensions through scripting and programming, allowing users to tailor the software to specific needs and expand its functionality.
- Simulation: Provides advanced simulation options, including the ability to model time and capacity constraints, interactions between different systems, and process optimization.
- Analysis: Offers a wide range of analysis options, including performance analysis, bottleneck identification, and optimization. It includes various tools for data analysis and result visualization.
- Integration: Strong integration with other Siemens tools, such as Teamcenter (PLM) and NX (CAD). Supports integration with additional industrial systems and ERP solutions.
- Extensibility: The ability to extend functionality using custom scripts and customizations, including the option to utilize Siemens APIs. Price: usually a higher price that reflects its robust capabilities and enterprise orientation. Prices are often customized and may include various levels of licenses and services.
- License: Various licensing options, including perpetual and subscription models. Licenses are often sold with added value in the form of training and support [10].

FlexSim:

- Architecture: An independent product focused on process simulation and analysis, compatible with various systems but not deeply integrated with enterprise solutions.
- Accessibility: Available as a desktop app and cloud version, accessible to a wide range of users, including small and medium-sized businesses.
- Interface: FlexSim features a modern and intuitive interface that allows quick model creation and editing. It has drag-and-drop functionality and visual tools that facilitate ease of use.
- Experience: It is considered user-friendly and quick to master, enabling a rapid onboarding process and effective use without the need for extensive training.
- Modelling: Allows quick model creation with predefined components and blocks that can be combined and customized. It is optimized for flexibility in modelling different types of processes.
- Flexibility: Supports visual and interactive modelling with the option to use predefined libraries and components, making the modelling process easier.
- Simulation: Excels in real-time visualization and interactive simulations. It is capable of simulating various processes and scenarios in real time.
- Analysis: Provides analytical tools for assessing performance and efficiency. It is optimized for quick and visual interpretation of results.
- Integration: Supports integration with various systems via APIs and export formats. However, integration with large enterprise solutions may be less comprehensive compared to Tecnomatix.
- Extensibility: Provides options for extension through plugins and custom scripts, but primarily focuses on visual customization and ease of use.
- Price: More affordable for a wide range of users, including small and medium-sized businesses. Offers various licensing models, including one-time and subscription licenses.
- License: Various licensing options, often with a simpler model for smaller companies and individual users.

In conclusion, it can be stated that Tecnomatix Plant Simulation is best suited for large enterprises with complex simulation and analysis needs, where deep integration with other industrial systems and detailed analysis are key. FlexSim is ideal for organizations seeking a flexible and user-friendly tool for simulation and analysis, with an emphasis on quick modelling and visualization. Both tools are strong in their own areas, and the final choice depends on the specific needs of organization, budget, and requirements for integration and usability.

2. Methodology Section

In this study, FlexSim software was used. A test model of a robotic workstation with conveyors and CNC machines was also created. The model contains two robots, the conveyors and two CNC machines. This program has a wide library of various objects and allows the inclusion of custom models in the assembly. Graphs were also generated to analyze the movements and efficiency of the robots. The main aim of the study is to compare two software programs and create identical robotic workplaces (Figure 2).

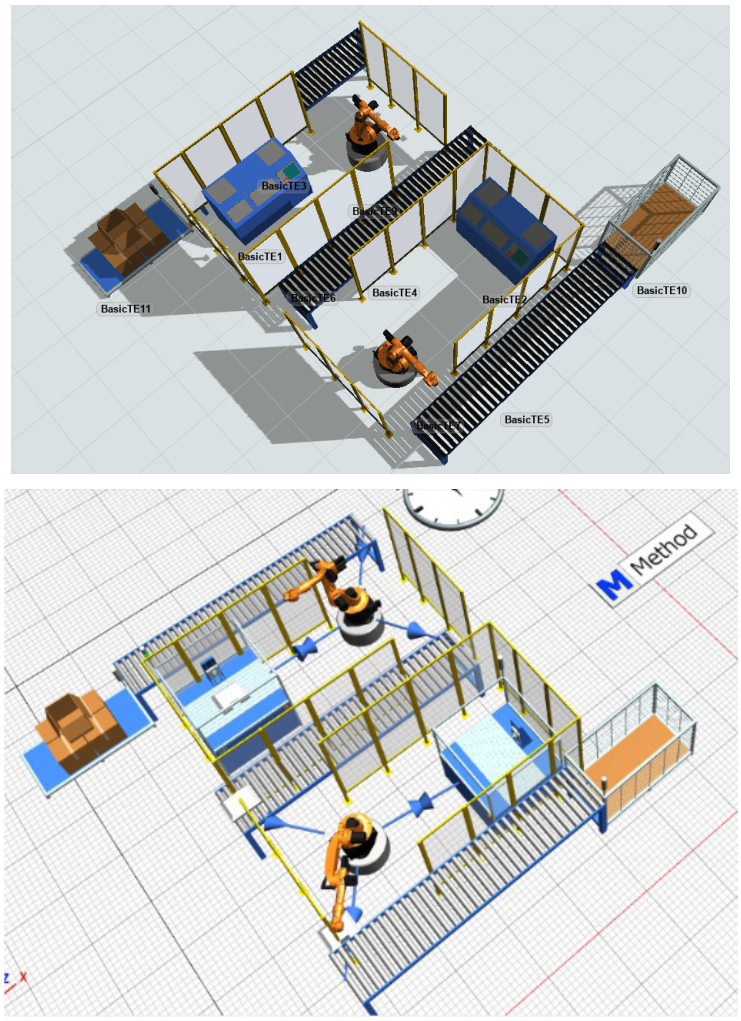

Figure 2. The created model in FlexSim software (on top) and model in Plant Simulation (down)

3. Results

This section shows the results in the form of a graphical visualization of the model. These graphs are useful in testing new experimental workstations, as well as analyzing old ones, in order to eliminate weaknesses and improve the productivity of the robotic workstation.

The efficiency graph is shown in Figure 3. This graph shows the number of tasks performed by robots and their employment as a percentage of their full-time employment. This graph is important for visualizing the occupancy of robots during tasks, as well as for visualizing the workload of robots.

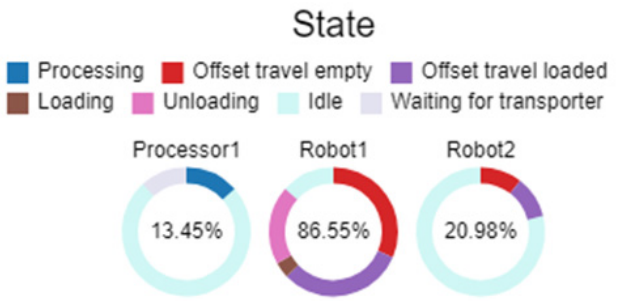

Figure 3. Efficiency graph

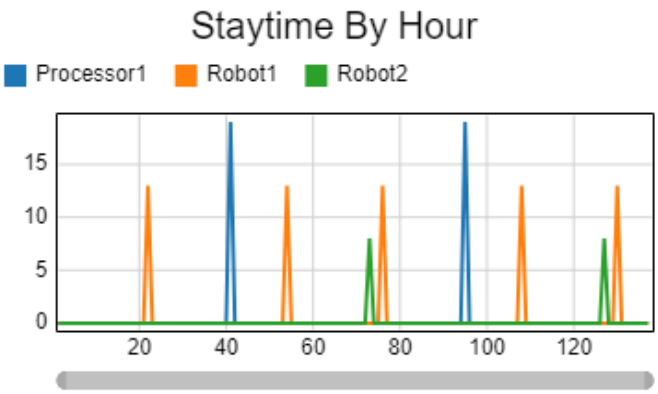

Figure 4. Staytime By Hour chart

Figure 4 demonstrates the stay time by hour chart. A "Staytime by Hour" chart in a robotic workplace typically shows the amount of time a robot or machine remains in a specific state or location within each hour.

This chart can track how long the robot spends in different activities such as working, idle, maintenance or downtime, setup/changeover. This chart helps analyze efficiency, bottlenecks, and optimization opportunities.

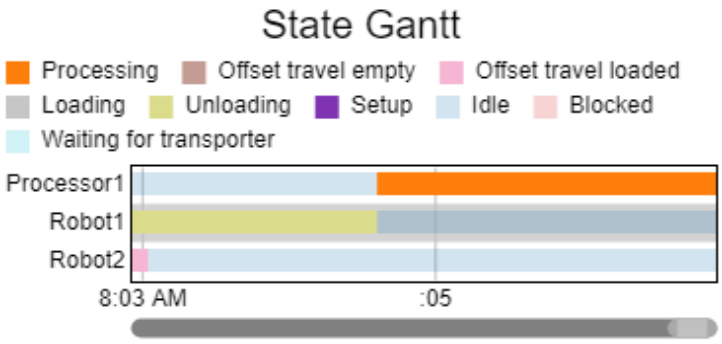

Figure 5. Gantt chart

Figure 5 shows Gannt chart which demonstrates the sequence of activities in material handling, as well as their duration. This chart helps determine the efficiency of the robots and also helps calculate their downtime during operations.

4. Discussion

During the realization of this study the FlexSim software was analyzed and compared with Tecnomatix Plant Simulation software.

After the analysis, the weaknesses of the software were identified, and a comparison table was prepared according to the criteria.

The comparison of the two software simulators is described in Table 1.

The main difference between the two software programs is that Tecnomatix Plant Simulation is more professional, as in turn FlexSim is more intuitive to use with easier visualization of the results.

Table 1. Comparison of Tecnomatix Plant Simulation and FlexSim software

Criterion	Tecnomatix Plant Simulation	FlexSim
Advantages		
Complexity of modelling	High ability to model complex and detailed systems	Flexible modelling with predefined components
Integration	Strong integration with other Siemens devices (Teamcenter, NX)	Possibility of integration with different systems and platforms
Analytical tools	Advanced analytical and optimization tools	Intuitive analytical tools with visualization stop
Extensibility	Extensibility via scripting and API	Possibility of extension and customization by means of accessories

The Tecnomatix Plant Simulation software's disadvantages are described in Table 2.

The main disadvantage of Tecnomatix Plant Simulation software is that it can be complex and difficult to learn. Extensive training and practice are required.

Table 2 Disadvantages of Tecnomatix Plant Simulation software

User interface	It can be complex and difficult to learn, requiring extensive training and practice.
Price	Higher price, often with customized licensing models, which can be costly for smaller companies
Complexity of implementation	Implementation can be complex and time-consuming, often requiring specialized support and configuration
Flexibility	It may be less flexible in adapting to very specific and unique processes outside of normal industrial standards
Technical support	Although powerful, it can be costly and not always quickly available for smaller users or new businesses
User interface	It can be complex and difficult to learn, requiring extensive training and practice.

Table 3 demonstrates the FlexSim software's disadvantages. The main FlexSim software's disadvantages are some limitations during the modelling very complex or detailed systems and when used in fast visualizations mode, the software may focus on reproducing visualizations, which can lead to analytical capability limits in very complex processes.

Table 3 Disadvantages of FlexSim software

Criterion	FlexSim
Complexity of modelling	May have limitations during the modelling very complex or detailed systems
Integration	May have limited integration with some enterprise systems compared to more integrated solutions like Tecnomatix
Functional expandability	May be less capable of advanced and specific functions or analyses compared to more robust tools
Licensing options	Price and licensing options can still be relatively high and not always suitable for very small companies or individual users
Visual subservience	Fast visualizations can cause to focus on the visual side, which can limit analytical abilities in very complex processes

5. Conclusion

This study was conducted to test the FlexSim software and compare the two 3D simulators, and the capabilities they offer for working with production workplace models. FlexSim simulator is intuitive software for modelling scenarios in production as well as testing innovations. In turn, Tecnomatix Plant Simulation also helps with these tasks. Both simulation software programs allow users not only to create and simulate innovations or old workplaces, but also to analyze their productivity and efficiency. FlexSim allows users to identify downtime on production lines, their occupancy, as well as the percentage of productivity utilization of devices and production equipment. The comparative analysis revealed both the strengths and weaknesses of the two 3D simulators. FlexSim is more intuitive software compared to Tecnomatix Plant Simulation, as the latter is more complex to use. Additionally, Tecnomatix Plant Simulation allows the generation of a greater number of analyses regarding the production workspace and is better suited for mass production environments, as it excels at analyzing many tasks without focusing on their visualization. FlexSim, in turn, is suitable for less task-intensive production workspaces and generates chart types such as: Staytime by Hour chart, efficiency graph and Gantt chart. This type of simulators is actively being implemented in production environments to reduce risks, as well as costs associated with testing, employee training, and analyzing proposed innovative changes in production workspaces before their implementation.

Acknowledgements

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References:

[1]. Arora, K. C., & Shinde, V. V. (2007). *Aspects of materials handling*. Firewall Media.

[2]. Stephens, M. P., & Meyers, F. E. (2013). *Manufacturing facilities design and material handling*. Purdue University Press.

[3]. Žlajpah, L. (2008). Simulation in robotics. *Mathematics and Computers in Simulation*, *79*(4), 879-897.

[4]. Huang, C. Y., & Nof, S. Y. (1999). Model of material handling and robotics. In *Modeling Manufacturing Systems: From Aggregate Planning to Real-Time Control*, 139-159. Berlin, Heidelberg: Springer Berlin Heidelberg.

[5]. Kopec, J., et al. (2021). Simulation processes in companies using PLM and Tecnomatix Plant Simulation software. *Acta Simulatio - International Scientific Journal about Simulation, 7*(3), 13-18.

[6]. Ononiwu, N., Macharia, M., & Al-Ali, M. Application of Discrete Event Simulation in Industrial Sectors: A Case Study. *International Journal of Advanced Engineering, Management and Science*, *2*(10), 239670.

[7]. Aliyu, R., Mokhtar, A., & Hussin, H. (2024, March). Research advances on the application of FLEXSIM in maintenance processes: A mini review. *AIP Conference Proceedings*, *2750*(1). AIP Publishing.

[8]. Kliment, M., et al. (2022). Use of the FlexSim simulation tool for creating simulation models. *Acta Simulatio*, *8*(1).

[9]. FlexSim. (n.d.). *Home page.* FlexSim. Retrieved from: http://www.flexsim.com/flexsim/ [accessed: 19 September 2024].

[10]. Siemens PLM Software. (2015). *Tecnomatix Plant Simulation – main information. Plant Simulation.* Siemens. Retrieved from: https://www.plm.automation.siemens.com/ru_ru/Images/7541_tcm802-4957.pdf [accessed: 20 September 2024].