Acta Tecnología - International Scientific Journal about Technologies
Volume: 11 2025 Issue: 2 Pages: 81-85 ISSN 2453-675X

https://doi.org/10.22306/atec.v11i2.279 Received: 31 Mar. 2025; Revised: 12 May 2025; Accepted: 03 June 2025

Application of digital twin using discrete event simulation in intralogistics processes

Magdalena Dobrzanska
Rzeszow University of Technology, Faculty of Management, Al. Powstancow Warszawy 10, 35-959 Rzeszow, Poland, EU, md@prz.edu.pl (corresponding author)
Pawel Dobrzanski
Rzeszow University of Technology, Faculty of Management, Al. Powstancow Warszawy 10, 35-959 Rzeszow, Poland, EU, pd@prz.edu.pl

Keywords: digital twin, discrete event simulation, AMR, intralogistics processes.
Abstract: As technology advances, companies are increasingly using technologies such as computer simulations and digital twins. These technologies enable monitoring, analyzing and optimizing the performance of processes in real time. They are also very useful in testing new ideas. This article presents the concept of using discrete event simulation as an integral part of the digital twin in the design and analysis of intralogistics processes. The authors propose using the Enterprise Dynamics discrete event simulator to create a digital twin of the AMR vehicle. For this purpose, they assessed the available technologies and the possibilities of their cooperation within the proposed digital twin.

1 Introduction

The Fourth Industrial Revolution has caused more and more companies to use modern technologies in their organization. This is due to the fact that companies require continuous improvement of their processes in order to ensure competitiveness, efficiency and adaptability. This trend is quite noticeable in the manufacturing industry. One of the most popular and increasingly widely used is the digital twin technology [1-4]. This technology is defined as a virtual representation of a real object, system or process. A digital twin is created using real-time data and simulation and modeling techniques. The purpose of their creation is to reproduce the behavior, characteristics and functioning of physical counterparts. They are used in the area of continuous improvement of production and intralogistics processes and increasing operational efficiency. There are a number of benefits associated with their use. These include the ability to predict exceptional situations, better risk management, the ability to monitor the process in real time and identify bottlenecks. The use of a digital twin (DT) also contributes to cost reduction and more complete achievement of sustainable goals. Another benefit of using a digital twin is the ability to effectively manage resources. Their monitoring contributes to making rational business decisions [5]. A digital twin also allows companies to introduce new products to the market earlier. A digital twin is therefore a tool that can support decision-making by providing full insight into real data and processes. In parallel with the growing interest in and application of digital twins in the industrial sector, computer simulations are used. One of the most popular simulation modeling methods used in the area of production processes is discrete event simulation (DES). The method is very useful in the analysis of structured workflows, optimization of resource allocation and identification of bottlenecks in the analyzed processes. This method is also used to create digital twins, becoming their integral part. DES tools take over the role of a digital twin, performing simulation software tasks on real-time data generated by IoT devices embedded in the physical twin [6,7].

The aim of the article is to propose a concept of using the DES tool as a digital twin in intralogistics processes.

The structure of the article is as follows. The introduction presents the characteristics of digital twins. The second chapter contains a review of the literature in the area of digital twins and discrete event simulation. It also presents examples of implementing digital twins in industry. The third chapter Methodology presents the proposed research methodology. In the next chapter, the authors propose a concept of using the DES simulator as an integral part of the digital twin. The whole article ends with a summary.

2 Literature review

Digital technologies enable precise monitoring and control of production and intralogistics processes, which contributes to their higher efficiency. Their use enables ongoing detection and elimination of potential irregularities. One of the increasingly commonly used tools are discrete event simulators and digital twins. Process modeling using discrete event simulation concerns processes in which all changes in the simulation model are represented by events that occur when specific conditions occur. Since discrete event simulation models are dynamic in nature, the current value of the simulated time should be tracked as the simulation progresses. It is also necessary to use a mechanism to shift the simulated time from one value to another. This results from the fact that time is subject to abrupt changes depending on the occurrence of discrete events [8-11]. There are many discrete event simulation tools available on the market. The most popular include: Arena, AnyLogic, Enterprise Dynamics, FlexSim, Simio, Plant Simulation, Simul8 [12]. In most cases, the software available on the market allows building models from ready-made objects, for which it is necessary to determine input parameters, relationships with other objects and the correctness of the process course. After building a simulation model, simulation experiments are carried out on it. The process taking place during the experiment is a reflection of the real process. Studying the process using simulation models allows for analyzing the characteristics of the process taking place during the simulation experiment and allows for determining the impact of input parameters on the behavior of the modeled process. During the process simulation, a larger number of experiments can be carried out using different values of input parameters. The obtained results, which are most often presented in the form of reports and graphs, are subject to further analysis and allow for selecting the optimal solution. The developed simulation model can also be subject to continuous modifications, and for the new versions of the model, subsequent simulation experiments can be carried out.

Simulation models in their basic form don't include automated data flows between the digital and physical worlds. In most cases, they use historical data [13]. They are characterized by varying degrees of staticity, because in some models, data can be manually updated. On the other hand, a digital twin has a close connection between the digital and physical worlds. Its characteristic feature is complete bidirectional data exchange (Figure 1).

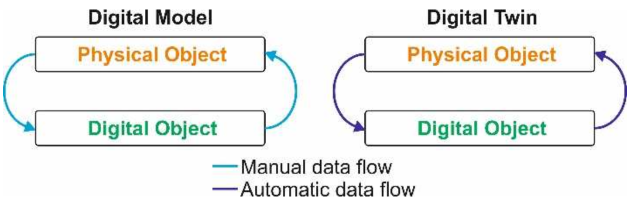

Figure 1 Data flow in the digital model and digital twin

Continuous two-way communication and data flow between the digital and physical worlds is possible thanks to the use of IoT sensors. These are devices used to collect and transmit data over the Internet using technologies such as wireless technology, big data, cloud computing. The authors of [6] note the strong connection between DES and DT. They pointed out that future research in this area should focus on solving the limitations and meeting the requirements for integrating DES with DT, and then on using DES and DT as a single technology.

Currently, some researchers have taken up the topic of the possibility of using discrete event simulators within the digital twin. One of such works is [14]. Its authors developed a DES system that uses online data to improve forecasts. The Flexsim software used by the authors, which allows real-time connections with servers, databases, and even PLC controllers. The object of the research was the production process and the conducted studies showed that DES provided more accurate forecasts of future performance and unforeseen problems in the near future compared to the forecasts of traditional DES using only historical data. An example of using the Flexsim discrete event simulator to implement a digital twin in a production environment is also presented in [15]. The authors of the work [16] proposed a digital twin solution based on a discrete event simulator and RFID technology. They tested the proposed solution on the example of warehouse management. The authors of the work [17] also dealt with the topic of integration of DES and DT technologies. In this case, the authors used Tecnomatix software. The digital model developed in this package was connected to the physical object using KEPServerEX and TSN technologies. The authors of [18] also presented a proposal to use DES technology in DT. Using the Simio software as an example, they tested the proposed solution for supporting decisions in the area of logistics processes taking place in the enterprise.

Based on the literature review, the authors decided to propose a concept of using the DES technology as an integral part of the digital twin in the design and analysis of intralogistics processes.

3 Methodology

The article proposes a concept of a digital twin based on discrete event simulation enabling the design and analysis of intralogistics processes. For this purpose, a conceptual design was developed, which is the first stage of the design process, which aims to develop general assumptions for the future solution. As part of the developed concept, a literature review was conducted and the current state of knowledge on the integrity of digital twins and discrete event simulators was assessed. Existing technological solutions were also reviewed. The scheme of the developed concept is presented in Figure 2.

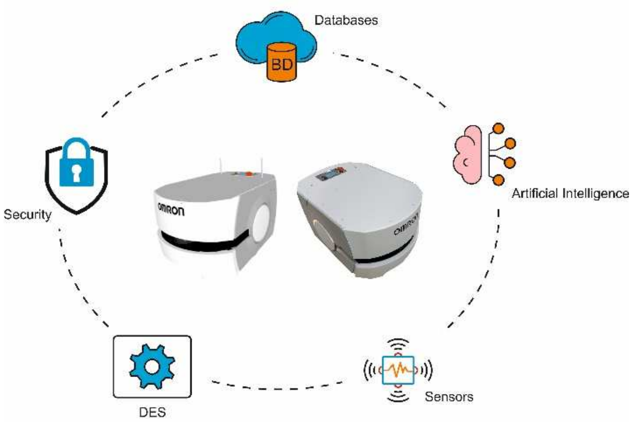

Figure 2 Concept of using a digital twin with a DES simulator in intralogistics processes

The assumptions of the proposed concept are presented in the next chapter using the example of an element of the intralogistics process.

4 The concept of a digital twin based on DES technology - results and discussion

In order to present the possibilities of using a digital twin in intralogistics processes, an example of using a digital twin using a DES simulator for the analysis and optimization of the operation of autonomous AMR vehicles was presented. Enterprise Dynamics software was proposed as a DES tool. This program can communicate (read and write) with any type of database. It is equipped with a set of lightweight database drivers that provide fast access to SQL database servers [19].

Omron has a built-in Advanced Robotics Command Language (ARCL) that enables the integration of a fleet of autonomous mobile robots (AMR) with an external system (automation, databases) and Integration Toolkit (ITK) an interface application that enables integration between the Fleet Manager system and the end-user client application, Manufacturing Execution System (MES), Enterprise Resource Planning (ERP), Warehouse Management System (WMS). In the case of the proposed concept, the ITK layer functionality is helpful, facilitating autonomous control of the AMR fleet using standard communication methods. The ITK layer enables real-time tracking of AMR data. For this purpose, it uses communication channels such as: RESTful Web Services, SQL with a PostgreSQL database, RabbitMQ [20].

The communication schema between the digital twin and the AMR vehicle is shown in Figure 3.

Figure 3 Communication schema between DT and AMR vehicle

Figure 4 shows a physical object - an AMR vehicle and its digital equivalent modeled in the ED software.

Figure 4 Physical object and its digital twin

To properly design a digital equivalent of an autonomous AMR vehicle, information about its parameters is necessary. The software allows the vehicle to be specified by defining its input parameters. Some of these parameters can be updated continuously thanks to the use of a digital twin. A set of such parameters is presented in Table 1.

Table 1 Matrix of length

Parameter	Description
Speed (m/s)	Maximum AMR speed
Acceleration (m/s²)	AMR Acceleration
Deceleration (m/s²)	AMR deceleration
Include deceleration	Slowing down at each turn according to the maximum permitted speed rule (m/s).
Min. angle (°)	Minimum turn angle for the maximum permitted speed (m/s) to be used.
Max. allowed speed (m/s)	Maximum allowed speed AMR
Load Time	Time required to load the goods
UnLoad Time	Time required to unload the goods
Load quantity	The amount of goods transported by a vehicle at one time
Battery capacity (Ah)	AMR vehicle battery capacity
Accl. Consumption (Ah)	Battery consumption for AMR acceleration
Decl. Consumption (Ah)	Battery consumption for AMR deceleration
Drive Consumption (Ah)	Battery consumption while driving AMR
Min. Capacity (%)	Minimum allowable capacity. If the battery capacity drops below this value, the AMR ends its task and goes to the Battery Charging Station for recharging.

Creating a digital equivalent and conducting simulation studies on it allows for the analysis of the intralogistics process and making appropriate decisions regarding the physical system. Enterprise Dynamics software provides two-way communication, therefore the output parameters resulting from the simulation experiments can be saved in an external database and become useful for the physical system.

Atom :	AMR						
		Average	St.Deviatior	LB (95%)	UB (95%)	Minimum	Maximum
Average task duration		28.07	0.11	27.10	29.04	28.00	28.15
Number of completed tasks		4213.50	27.58	3965.73	4461.27	4194.00	4233.00
Status Idle		0.10	0.01	0.05	0.15	0.10	0.11
Status Down		0.28	0.00	0.26	0.30	0.28	0.28
Status TravelFull		0.23	0.00	0.22	0.23	0.22	0.23
Status TravelEmpty		0.30	0.00	0.28	0.31	0.29	0.30
Status Load		0.05	0.00	0.05	0.05	0.05	0.05
Status Unload		0.05	0.00	0.05	0.05	0.05	0.05

Figure 5 Example set of output parameters for a digital AMR vehicle

Figure 5 shows an example set of output parameters for the digital AMR recorded during the simulation of its operation.

The use of a discrete event simulator to create a virtual model of the analyzed environment is known and presented by many authors [8-11]. Virtual models of intralogistic systems are created during the design of a physical system. However, many researchers note that relying solely on historical data as a reference for the analysis of various scenarios of the functioning of the intralogistic system obtained using the DES model is insufficient. Therefore, work is being carried out on the possibility of using DES in real time [14,16,17]. In such a case, the simulator should be fed with real-time data, which will increase the compliance of the Digital Twin with the real object. Therefore, the first stage is to master and improve the methods of communication between DT and the real object [1,17]. The proposed concept of using the DES simulator as an integral part of the Digital Twin concerns the area of intralogistics currently based mainly on autonomous systems. Therefore, the use of the proposed concept will provide support and effective decision-making in the analyzed systems. The virtual representation of the intralogistic system and two-way interaction in real time with the real world will certainly contribute to the conscious and timely management of the intralogistic system.

5 Conclusions

The article presents the concept of using a discrete event simulator as an integral part of a digital twin. The presented concept confirms the possibility of using DES technology as one of the main elements of a digital twin. The transition from the stage of a digital model, which is DES using historical data from a physical system, to a digital twin model requires a number of activities aimed at integrating discrete event simulators with many data sources in the analyzed process. In the case of intralogistics systems, in addition to information on parameters characterizing and influencing the operation of the means of transport involved in the functioning of the process, other information is also needed. These include, among others, the length of transport routes, places of picking up and putting down the load. Ensuring proper communication and data exchange between the virtual and physical models requires a direct connection with IoT sensors, servers or PLC controllers to ensure real-time communication. The presented possibilities of using DES as an integral part of a digital twin are subject to tests performed on a single element of the system, which is an AMR vehicle, in order to confirm the technical possibilities of using such a solution.

The presented work is the first stage of the planned research. The analysis of available technologies and the developed concept confirm the possibility of using DES as an integral part of the Digital Twin. In order to further develop research in this direction, it is necessary to carry out a real implementation of DES in DT. During real research, challenges resulting from the complexity of the proposed solution will certainly appear. The authors plan to test the proposed solution on an example intralogistics process.

References

[1] XIAOJUN, L., CHONGXIN, W., JIASHENG, H., ZHONGHUA, N., MUSHARAF, S., YUEHUI, Y., JINDAN, F.: Fusion method for digital twin model of a production line, *The International Journal of Advanced Manufacturing Technology*, Vol. 132, No. 11-12, pp. 1-23, 2024. http://doi:10.1007/s00170-024-13676-8

[2] DAVIES, O., MAKKATTIL, A., JIANG, C., FARSI, M.: A digital twin design for maintenance optimization,

Procedia CIRP, Vol. 109, pp. 395-400, 2022. https://doi.org/10.1016/j.procir.2022.05.268

[3] SOORI, M., AREZOO, B., DASTRES, R.: Digital twin for smart manufacturing, A review, *Sustainable Manufacturing and Service Economics 2*, Vol. 2, pp. 1-15, 2023. https://doi.org/10.1016/j.smse.2023.100017

[4] LANZINI, M., FERRETTI, I., ZANONI, S.: Towards the Implementation and Integration of a Digital Twin in a Discrete Manufacturing Context, *Processes*, Vol. 12, No. 11, 2384, pp. 1-14, 2024. https://doi.org/10.3390/pr12112384

[5] TREBUNA, P., PEKARCIKOVA, M., MATISCSAK, M.: Logistic-information system based on object-oriented approach, *Acta logistica*, Vol. 11, No. 4, pp. 537-547, 2024. https://doi.org/10.22306/al.v11i4.538

[6] AGALIANOS, K., PONIS, S.T., ARETOULAKI, E., PLAKAS, G., EFTHYMIOU, O.: Discrete Event Simulation and Digital Twins: Review and Challenges for Logistics, *Procedia Manufacturing*, Vol. 51, pp. 1636-1641, 2020. https://doi.org/10.1016/j.promfg.2020.10.228

[7] ZHU, Y., CHENG, J., LIU, Z., CHENG, Q., ZOU, X., XU, H., WANG, Y., TAO, F.: Production logistics digital twins: Research profiling, application, challenges and opportunities, *Robotics and Computer-Integrated Manufacturing*, Vol. 84, No. December, 102592, 2023. https://doi.org/10.1016/j.rcim.2023.102592

[8] DOBRZAŃSKA, M., DOBRZAŃSKI, P.: Simulation Model as an Element of Sustainable Autonomous Mobile Robot Fleet Management, *Energies*, Vol. 18, No. 8, 1894, pp. 1-18, 2025. https://doi.org/10.3390/en18081894

[9] CAMPOS, T.M.C., CARVALHO, M.S., OLIVEIRA, J.A., SILVA, P.V., MACHADO, T.: *Using discrete simulation to support internal logistics process design*, In: Proceedings of the 4th International Conference on Computers and Idustrial Engineering (CIE47), Lisbon, Portugal, pp. 11-13, October 2017.

[10] OLIVEIRA, A.V., PIMENTEL, C.M.O., GODINA, R., MATIAS, J.C.D.O., GARRIDO, S.M.P.: Improvement of the logistics flows in the receiving process of a warehouse, *Logistics*, Vol. 6, No. 1, 22, pp. 1-23, 2022. https://doi.org/10.3390/logistics6010022

[11] BEHÚNOVÁ, A., KNAPCIKOVÁ, L., BEHÚN, M.: Logistics Reengineering of Service Processes Through the Implementation of Software and Hardware of the Telephone Exchange in the Company, *TEM Journal-Technology Education Management Informatics*, Vol. 12, No. 3, pp. 1364-1369, 2023. https://doi.org/10.18421/TEM123-16

[12] NACIRI, L., GALLAB, M., SOULHI, A., MERZOUK, S., DI NARDO, M.: Modeling and simulation: A comparative and systematic statistical, *Procedia Computer Science*, Vol. 232, pp. 242-253, 2024. https://doi.org/10.1016/j.procs.2024.01.024

[13] WRIGHT, L., DAVIDSON, S.: How to tell the difference between a model and a digital twin, *Advanced Modeling and Simulation in Engineering Sciences*, Vol. 7, No. 13, pp. 1-13, 2020. https://doi.org/10.1186/s40323-020-00147-4

[14] EYRING, A., HOYT, N., TENNY, J., DOMIKE, R., HOVANSKI, Y.: Analysis of a closed-loop digital twin using discrete event simulation, *The International Journal of Advanced Manufacturing Technology*, Vol. 123, pp. 245-258, 2022. http://10.1007/s00170-022-10176-5

[15] MORABITO, L., IPPOLITO, M., PASTORE, E., ALFIERI, A., MONTAGNA, F.: A Discrete Event Simulation Based Approach for Digital Twin Implementation, *IFAC-PapersOnLine*, Vol. 54, No. 1, pp. 414-419, 2021. https://doi.org/10.1016/j.ifacol.2021.08.164.

[16] FÉLIX-CIGALAT, J.S., DOMINGO, R.: Towards a digital twin warehouse through the optimization of internal transport, *Applied Sciences*, Vol. 13, pp. 1-16, 2023. https://doi.org/10.3390/app13084652

[17] RIGÓ, L., FABIANOVÁ, J., LOKŠÍK, M., MIKUŠOVÁ, N.: Utilising digital twins to bolster the sustainability of logistics processes in Industry 4.0, *Sustainability*, Vol. 16, No. 6, 2575, pp. 1-15, 2024. https://doi.org/10.3390/su16062575

[18] COELHO, F., RELVAS, S., BARBOSA-P´OVOA, A.P.: Simulation-based decision support tool for in-house logistics: the basis for a digital twin, *Computers & Industrial Engineering*, Vol. 153, No. March, 107094, 2021. https://doi.org/10.1016/j.cie.2020.107094

[19] Incontrol, www.incontrolsim.com: ED Tutorials, [Online], Available: https://support.incontrolsim.com/en/ed-solution-areas.html [09 May 2025], 2025.

[20] Omron, https://www.omron.com/global/en: Models and specifications, [Online], Available: https://industrial.omron.pl/pl/products/ld-series#specifications_ordering_info [08 May 2025], 2025.

Review process

Single-blind peer review process.