Use of modeling and simulation for training students: warehouse operations management

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Abstract: Efficient logistics requires skilled professionals for warehouse operations management. Conventional teaching methods often fail to bridge the gap between theoretical knowledge and practical expertise. Modeling and simulation (M&S) is becoming an important tool for training in different engineering disciplines due to its capability of providing a realistic and interactive environment. We study the impact of modeling and simulation on student training using AnyLogic software. The study analyzes the use of simulation modeling software to teach students how to optimize warehouse picking procedures. Starting from comprehensive literature on modeling and simulation and its impacts on learning and training, we employed two exercises for warehouse picking management. After gaining adequate knowledge of the software, the students experimented with different scenarios, assessed the influence of their decisions on key performance indicators (KPIs) such as picking time and efficiency, and developed their critical thinking, problem-solving, and decision-making abilities in a practical and interactive environment. Finally, we conclude the potential impact of modeling and simulation on enhancing students' learning and training in warehouse picking management.

Keywords: Modelling & Simulation, AnyLogic, Training, Warehouse operations management.

1. Introduction

Warehouses have become increasingly significant as e-commerce and customer demands have grown. The precise execution of the warehouse's picking and shipping process directly impacts the supply chain's right product in the correct amount (Richards, 2017 ; Hernandez, 2022). Order picking is a critical component of warehouse operations management, which accounts for over fifty percent of warehousing costs. Its operation is highly labor-intensive, involving a massive amount of human manual activities because inefficiency is directly related to higher expenses (Pham, 2019). In this regard, Warehouse operations management can be significantly improved by the collaboration of humans and robots. Human-robot collaboration is increasing to upgrade existing order-picking systems. Both dimensions of cooperation, humans following the robot or robots supplementing the humans, positively affect job satisfaction (Pasparakis, 2023). These collaborating robots are sometimes called cobots. Unlike traditional robots limited to safety zones, these robots share space with humans and work alongside them (Kakade, 2023).

Besides meeting higher demands, warehouse operations management faces other challenges due to the complexity of the workflow and varying levels of employees' competencies. These challenges include lost products and stock discrepancies requiring further training; however, it is costly because firms do not have an additional warehouse to train new employees, and displaced products must be returned to the initial spot after training (Yigitbas, 2020). Future employees can be trained in a virtual environment that mimics real-world systems to overcome this issue. Scientific research looks into the benefits of modeling and simulation to demonstrate complex scientific and technical topics, create interactive laboratories for practical training, tailor learning experiences, support professional growth for educators, and examine student learning and progress (Alam, 2023). Using simulation software and tools promotes a real-world understanding of complex structures. It allows learners to improve their learning by developing hands-on activities accurately designed by their teachers (Juan, 2017). Considering the complex nature of warehouse management and challenges in training, we incorporate the benefits of modeling and simulation in learning and training warehouse operations management. The study's target audience is engineering students (enrolled in bachelors and master's degree programs), i.e., future professionals involved in the decision-making of warehouse designs and operational management. Details of participating students have been mentioned in section 3.

In this paper, we analyze the impact of modeling and simulation for training engineering students in warehouse operations management. For this purpose, engineering students were given exercises to design a layout of the warehouse and the required number of robots under specific parameters. The students experimented with different scenarios, assessed the influence of their decisions on key performance indicators (KPIs) such as picking time and efficiency, and developed their critical thinking, problem-solving, and decision-making abilities in a practical and interactive environment. Prior to the study, students were adequately introduced to the simulation software Anylogic.

The remainder of the paper is organized as follows: section 1 includes an introduction, section 2 comprises the literature review, section 3 describes the method employed, section 4 comprises discussions, and section 5 consists of a conclusion.

2. Literature review

2.1 Warehouse operations management: challenges and importance of collaborative robots

Warehouses are an integral part of supply chain management and logistics; thus, they must adapt well to the increasing demands in the market. Technology giants are looking for more rapid and cost-effective ways to meet the logistics demand (Zhen and Li, 2022). Industrial organizations rely heavily on warehouse operations to ensure the smooth flow of inventory and products (Abidin, 2021). The warehouse's primary functions include fulfilling customer orders, protecting goods before transportation, providing short-term storage, and serving as a location for packaging and repacking. Before shipment, several warehousing facilities offer product inspection and repair services. The four main categories of warehouse operations are shipping, receiving, picking, and storing (Shah and Khanzode, 2017). In increasing demand, collaborative robots are increasingly installed in warehouses. Research highlights the benefits of utilizing human-robot collaboration for different tasks in warehouse operations management, including picking orders (Pasparakis, 2023).

Furthermore, warehouse operations management requires training due to evolving technologies (He, 2022 ; Yigitbas, 2020). The state-of-the-art approach highlights the benefits of employing collaborative robots and calls for further employee training for efficient warehouse operations management. However, this training requires more resources, such as a separate warehouse for training purposes Yigitbas, (2020), which is not affordable to most organizations. Literature highlights the significance of utilizing modeling and simulation to help this cause.

2.2 Simulation-based education: significance in training

Simulation-based education (SE) means using simulation software and tools to improve teaching and learning processes and enable a practical understanding of complex systems. The fundamental idea of simulation is the simplified representation of the real system in its simulation model, which describes just those properties of the real system that are relevant to our study (simulation) (Juan, 2017 ; Campos, 2020). Instead, a simulation can be considered a support tool that allows the experiment to examine the impact of its selections on the simulation model (Gola and Wiechetek, 2017). This will enable us to answer the question, "What happens if." The significant advantage of this technique is that it is feasible to pre-visualize the system's future behavior and realize the necessary adjustments in the real system based on its knowledge (Lau, 2022). Simulation is seen as a tool allowing interns to replace or expand their practical experience using an artificially developed environment. One of the primary benefits of simulation modeling systems is that the user does not have to worry about the model being executed as a series of executable statements. Thus, they build highly convenient computer environments in which you may create simulated parallel systems and research with them in an increasingly interactive way (Alam, 2022). The graphical environment resembles a real-world testing bench. Still, the user interacts with their images on the monitor rather than using heavy metal boxes, cables, and measuring equipment such as oscillographs and recorders. Furthermore, the user can examine and evaluate the simulation results within the experiment and, if required, take an active role in it (Magana and Silva Coutinho, 2017 ; Gaba, 2004). Many studies highlight the benefits of using modeling and simulation for training in different professional fields. Shah, (2022) performed a literature review on the current status of simulation-based training in healthcare. Modeling and simulation have also proved to be effective in students' learning. The study highlights the positive impacts of modeling and simulation on training students compared to traditional teaching methods (Bradley, 2020). Incorporating modeling and simulation into engineering curricula may have a pedagogical effect since it appears to create a more applied learning environment that encourages students to integrate numerous concepts and skills and complicated types of learning. The paper covers a variety of modeling and simulation approaches for students of computer science and engineering (Magana and Silva Coutinho, 2017). A survey of recent studies in SE is given in another research, emphasizing the fields of science, engineering, and management. Students with varying degrees, locations, and institutions can utilize simulation-based laboratories. Consequently, this facilitates the growth of multidisciplinary competencies, collaborative capabilities, and cross-cultural learning methodologies. Therefore, we may consider simulation education to be both a widely used and a resource that will continue to grow in popularity within current degree programs (Campos, 2020). So, the existing literature encourages modeling and simulation for education and training. Choosing appropriate modeling and simulation tools is itself an important task.

The literature highlights the usefulness of AnyLogic software for warehouse operations management. Anylogic is an easy-to-use simulation program that supports multiple methods. It allows us to integrate system dynamics, agent-based modeling, and process modeling into a single model entirely developed in Java (Kuklová and Přibyl, 2019). AnyLogic can present simulation models in both 2D and 3D, enhancing the visual representation of any ideas or concepts. Unlike linear optimization or table-based analytics, modeling allows observing an actual system's behavior over time with the necessary degree of detail. For instance, you may look up a warehouse's occupancy proportion on a specific day (Skafa, 2022). Focused on the analysis of its operation mode and the factors affecting the operation efficiency, obtains the existing problems of the Cainiao Station (warehouse in China) by using the modeling and simulation technology of Anylogic software and optimizes the spatial layout and operation mode of the Cainiao Station in combination with the field investigation and current simulation results (Chen and Chang, 2022). Many studies employed Anylogic software for warehouse operations management in different fields. The study Zhanbirov, (2023) employed AnyLogic software to build a simulation model of 114 blocks to study the impact of various parameters and volumetric planning solutions on the effectiveness of the warehouse' functioning. Another author proposed the AnyLogic simulation model as a practical approach to identifying and solving multi-grocery inventory problems for a modern warehouse (Vladimirovic, 2023). Mazurenko and Rusinov, (2022) used AnyLogic environment to create a digital copy of a coal terminal warehouse. Also, the software has been aiding in designing different trade-offs in the performance context, and identifying bottlenecks is crucial in warehouse operations management (Ferrari, 2021). The AnyLogic model has proven useful in determining the optimum truck fleet size. To aid decision-making, the simulation model has also been used to study the system's key performance metrics, including cycle times, resource consumption, and bottlenecks (Amjath, 2022).

Hence, the extensive literature review highlights the advantages of collaborative robots for warehouse operations management and emphasizes the need for further training to meet market demands. In this regard, our study analyzed the impact of modeling and simulation on learning and training future engineers. The following sections describe the study's methods and outcomes.

3. Materials and method

The participants of the study were engineering students at bachelor's and master's level of education enrolled in Operations management & Supply chain management courses respectively. The students were asked to design the warehouse shape to reach the desired target movements per hour. The required warehouse was intended to deliver medicine kits to the hospital. The warehouse's target audience was hospital patients. The means of delivery were automated robots. Such auto stores are flexible and are available 24/7. The overall attendance of the students' participation was eighty percent.

Students were equipped with adequate knowledge about the software and principles of warehouse management prior to this exercise. A detailed description of the desired parameters was provided which includes:

i. Design the actual shape of the warehouse meeting, which requires target movements per hour.

ii. Define an adequate number of robots to be used.

iii. Determine the number of charging stations and their positions.

iv. Define the loading and unloading portals.

v. Provide proof of their design using the Virtual Laboratory, available on the university cloud. Virtual lab interference is shown in Figure 1.

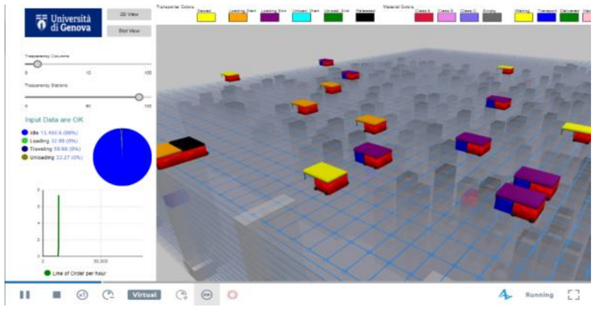


Figure 1. Virtual lab interface

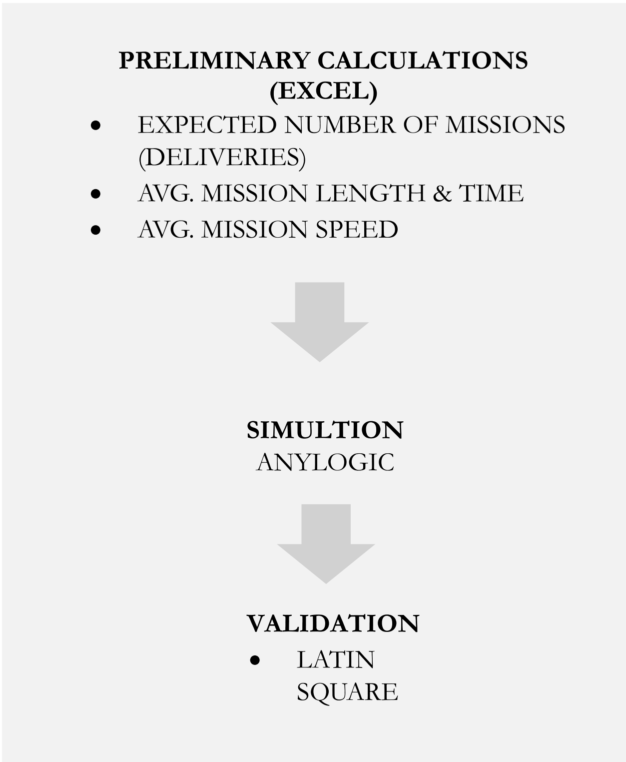


Figure 2. Exercise stages

The exercise had three stages, as shown in Figure 2. In the first stage, students made preliminary calculations for the mission, such as the expected number of deliveries, average speed, time, and length of the mission. These calculations were performed in an Excel file, as explained below. The bachelor level students were provided with excel calculations involved for the design of the warehouse whereas master's level students followed all the stages of the study at their own.

Students could enter several parameters in their design. Defining the layout is not very complex. In fact, it is based on a simple Excel file where each column represents one cell of the warehouse. In separate sheets, students could define an adequate number of robots per area and the specific schedule of the arriving picking orders. In Excel preliminary calculations, students used parameters that could directly affect the model, such as the number of robots, area size, and layout, as mentioned in Table 1. For the simulator, students had sensitive and informative parameters to provide valuable information about the simulated warehouse design. The second stage involved the simulation of the scenarios using Anylogic software. AnyLogic software has the ability to import excel files. Students could visualize their interplay's impact with different design parameters, such as changing the number of robots per area and order scheduling.

Table 1. Exercise parameters

EXCEL	**SIMULATOR**	
SENSITIVE	SENSITIVE	INFORMATIVE
N° AREAS	STACKING	ORDERS
AREAS	INITIAL	ITEMS
SIZE AND	SATURATION	% ORDERS
LAYOUT	HORIZONTOL	CELL
N°	SPEED	DIMENSIONS
ROBOTS		

The last stage was the validation of the model. For this stage, we used the Latin square technique as the simulation model was characterized by initial saturation, number of robots, and area. To identify the significance of each of these factors, the exercise delves into variation analysis using the ANOVA technique. This gave students insight into how a layout could be designed in multiple ways. For example, students could identify the required number of robots by controlling factors such as initial saturation and areas. Table 2 Enlists formulas used for ANOVA.

Table 2. ANOVA formulas

Variation Source	**Sum of squares**	**DoF**	**Mean square**	**F_o**
Treatment (initial saturation)	$\sum_{j=1}^{p} Y_j^2 - \frac{Y^2}{N}$	$p-1$	$\frac{SS_{treatmen}}{p-1}$	$\frac{MS_{treatment}}{MS_E}$
Rows(area)	$\sum_{i=1}^{p} \frac{Y_i^2}{p} - \frac{Y^2}{N}$	$p-1$	$\frac{SS_{rows}}{p-1}$	
Column (robot)	$\sum_{k=1}^{p} \frac{Y_k^2}{p} - \frac{Y^2}{N}$	$p-1$	$\frac{SS_{column}}{p-1}$	
Error	SS_E	$(p-1)(p-2)$	$\frac{SS_E}{(p-1)(p-2)}$	
Total	$\sum_{i,j,k} Y_{ijk}^2 - \frac{Y^2}{N}$			

For the analysis, participants used three initial saturation scenarios: 40%, 66%, and 76%, three robot scenarios: 1,2,3, and three scenarios for areas 6,12,18. Table 3 shows the results of the ANOVA analysis, where initial saturation is taken as the treatment factor. The results show that initial saturation is a non-significant factor, i.e., there is no difference in the outcome at all three initial saturation scenarios (40%, 66%, 76%).

Table 3. ANOVA solution

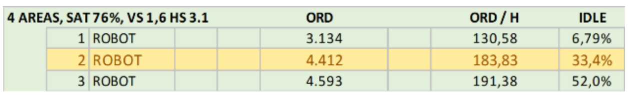
ANOVA	**Variation**	**Degree of freedom**	**Mean square**	**F_o**	F_{tab}
Rows(area)	387962.4931	2	193963.24655	104.2968842	5.4 > reject HO ,significant factor
Column (robot)	41309.00247	2	20654.50123	11.10519786	5.4 > reject HO ,significant factor
Treatment (initial saturation)	10338.0758	2	5169.0379	2.779209625	5.4 < cannot reject HO, non-significant factor
Error	3719.789867	2	1860		
Total		8			

H_O: no difference in mean — non-significant factor

H_A: difference in mean — significant factor

4. Discussion

This exercise is part of the regular training of bachelor's and master's level students. In the fall 2021 semester, more than 86 students joined the Virtual Lab. They produced 1940 simulations, an average of 22 different scenarios evaluated for each student. Figure 3. shows one of the generated scenarios.



4 AREAS, SAT 76%, VS 1,6 HS 3.1		ORD	ORD / H	IDLE
1	ROBOT	3.134	130,58	6,79%
2	ROBOT	4.412	183,83	33,4%
3	ROBOT	4.593	191,38	52,0%

Figure 3. Example scenario generated by participants.

The large number of scenarios for each student enhanced student learning by visualization of the impact of their interplay with various parameters. The impact of the study on student's learning and experience was evaluated by the report submitted by the participants. The evaluation criteria was structured in three sections and students learning has been categorized at three levels as explained below.

i. Level 1 : theoretical understanding of the participant has been considered satisfactorily if he was able to make correct preliminary calculations.

ii. Level 2 : if the results of simulations are consistent with the calculations? The cells (columns) or blocked or not?

iii. Level 3: overall report, if the student was able to justify the number of robots per unit area or adequate ?

Apart from delivered reports, students expressed keen interest in these exercises during the course with positive verbal feedback and suggestions. The students suggested more such exercises for this course as well as other courses. Interactive applications enhance students' learning as proved by many studies. According to a survey, 89% of students expressed satisfaction with their learning through interactive applications. 96% of students desired more interactive applications to increase their learning (Corral Abad, 2021). Higher attendance, i.e., 80% in our study, indicates students' interest in this course and exercises.

Furthermore, this study demonstrates the advantages of employing Anylogic for education, as stated by Skafa, (2022). AnyLogic can present simulation models in both 2D and 3D, which helps students better visualize their ideas and concepts. Modeling allows observing an actual system's behavior over time with the necessary degree of detail, which is impossible with linear optimization or table-based analytics. For instance, you may look up a warehouse's occupancy proportion on a specific day. The outcomes of the study agree with Alam, (2023) that using simulation in education is beneficial for students. It helps students gain more profound knowledge and clear concepts in their respective fields. Students are better prepared for their future careers by active learning and engagement. The benefits of simulation education are multi-dimensional; apart from simplified visualization of complex systems, the students can conduct virtual experiments to flourish their innovative and critical thinking abilities. The students learned how the system behaved under different scenarios, making them more familiar with the real-world contexts of warehouse operations management. Another crucial aspect of simulation education is collaboration, as students can collaborate with their fellows to generate different scenarios and find solutions to existing problems in warehouse operations management.

However, the use of simulation has some challenges that should be considered while using it for education and training. The simulation model should be a replica of the real-world system, which can be achieved by paying meticulous attention to input data and other parameters (Alam, 2021). After carefully considering these issues, simulation can be a powerful tool in education that can be applied for personalized learning experiences for each student, hands-on training, providing real-world context, and enhancing innovative and creative thinking skills (Skafa, 2022).

5. Conclusion

Increasing demands from online customers and e-commerce have challenged the efficiency of warehouse operations management. To meet this demand, the trend of using collaborative robots for warehouse order picking is increasing. Automatic storage and retrieval systems have many benefits over conventional warehouses, including 24/7 availability and power savings.

Using modeling and simulation has proved to be an effective approach for training future engineers in warehouse operations management. The course participants' free, direct feedback was encouraging. Future research may focus on developing metrics to assess the impact of Modeling and simulation on training and its comparison with conventional training methods.

References

Abidin, N., Ahmarofi, A.A., Gui, A., 2021. Designing the Re-layout Finished Goods Warehouse through the Simulation Method. Int. J. Ind. Manag. 10, 126–137. https://doi.org/10.15282/ijim.10.1.2021.6052

Alam, A., 2023. Leveraging the Power of 'Modeling and Computer Simulation' for Education: An Exploration of its Potential for Improved Learning Outcomes and Enhanced Student Engagement, in: 2023 International Conference on Device Intelligence, Computing and Communication Technologies, (DICCT). Presented at the 2023 International Conference on Device Intelligence, Computing and Communication Technologies, (DICCT), IEEE, Dehradun, India, pp. 445–450. https://doi.org/10.1109/DICCT56244.2023.10110159

Alam, A., 2022. Employing Adaptive Learning and Intelligent Tutoring Robots for Virtual Classrooms and Smart Campuses: Reforming Education in the Age of Artificial Intelligence, in: Shaw, R.N., Das, S., Piuri, V., Bianchini, M. (Eds.), Advanced Computing and Intelligent Technologies. Springer Nature, Singapore, pp. 395–406. https://doi.org/10.1007/978-981-19-2980-9_32

Alam, A., 2021. Should Robots Replace Teachers? Mobilisation of AI and Learning Analytics in Education, in: 2021 International Conference on Advances in Computing, Communication, and Control (ICAC3). Presented at the 2021 International Conference on Advances in Computing, Communication, and Control (ICAC3), pp. 1–12. https://doi.org/10.1109/ICAC353642.2021.9697300

Amjath, M., Kerbache, L., Elomri, A., Smith, J.M., 2022. Fleet Sizing of Heterogeneous Fleet of Trucks in a Material Handling System Using Anylogic Simulation Modelling, in: Proceedings of the International Conference on Industrial Engineering and Operations Management. Presented at the The 5th European

International Conference on Industrial Engineering and Operations Management, IEOM Society International, Rome, Europe, pp. 937–947. https://doi.org/10.46254/EU05.20220189

Bradley, K., Quinton, A., Aziz, A., 2020. Determining if simulation is effective for training in ultrasound: A narrative review. Sonography 7, 22–32. https://doi.org/10.1002/sono.12208

Campos, N., Nogal, M., Caliz, C., Juan, A.A., 2020. Simulation-based education involving online and on-campus models in different European universities. Int. J. Educ. Technol. High. Educ. 17, 8. https://doi.org/10.1186/s41239-020-0181-y

Chen, Q., Chang, X., 2022. Optimization and Simulation of operation flow of Cainiao Station based on Anylogic, in: EEI 2022; 4th International Conference on Electronic Engineering and Informatics. Presented at the EEI 2022; 4th International Conference on Electronic Engineering and Informatics, pp. 1–4.

Corral Abad, E., Gómez García, M.J., Diez-Jimenez, E., Moreno-Marcos, P.M., Castejón Sisamon, C., 2021. Improving the learning of engineering students with interactive teaching applications. Comput. Appl. Eng. Educ. 29, 1665–1674. https://doi.org/10.1002/cae.22415

Ferrari, A., Zenezini, G., Carlin, A., Rafele, C., 2021. An integrated simulation modelling approach for a warehouse 4.0. https://doi.org/10.21203/rs.3.rs-317679/v1

Gaba, D.M., 2004. The future vision of simulation in health care. BMJ Qual. Saf. 13, i2–i10. https://doi.org/10.1136/qshc.2004.009878

Gola, A., Wiechetek, Ł., 2017. Modelling and simulation of production flow in job-shop production system with enterprise dynamics software. Appl. Comput. Sci. 13, 87–97.

He, D., 2022. Teaching Practices of a Warehousing Management Curriculum based on Virtual Reality Simulation Technology. Int. J. Emerg. Technol. Learn. IJET 17, 96–109.

Hernandez, L.C., Jiménez G., H.S., Dantas, P.P.L., Cavalcante, C.A.V., 2022. Using multi-criteria decision making for selecting picking strategies. Oper. Res. 22, 3265–3290. https://doi.org/10.1007/s12351-020-00603-4

Juan, A.A., Loch, B., Daradoumis, T., Ventura, S., 2017. Games and simulation in higher education. Int. J. Educ. Technol. High. Educ. 14, 37. https://doi.org/10.1186/s41239-017-0075-9

Kakade, S., Patle, B., Umbarkar, A., 2023. Applications of collaborative robots in agile manufacturing: a review. Robot. Syst. Appl. 3, 59–83. https://doi.org/10.21595/rsa.2023.23238

KUKLOVÁ, J., PŘIBYL, O., 2019. Framework Model in Anylogic for Smart City Ring Road Management, in: 2019 Smart City Symposium Prague (SCSP). Presented at the 2019 Smart City Symposium Prague (SCSP), pp. 1–5. https://doi.org/10.1109/SCSP.2019.8805681

Lau, S., Trmcic, A., Martin, N.H., Wiedmann, M., Murphy, S.I., 2022. Development of a Monte Carlo simulation model to predict pasteurized fluid milk spoilage due to post-pasteurization contamination with gram-negative bacteria. J. Dairy Sci. 105, 1978–1998. https://doi.org/10.3168/jds.2021-21316

Magana, A.J., Silva Coutinho, G., 2017. Modeling and simulation practices for a computational thinking-enabled engineering workforce. Comput. Appl. Eng. Educ. 25, 62–78. https://doi.org/10.1002/cae.21779

Mazurenko, O.I., Rusinov, I.A., 2022. DISCRETE-EVENT SIMULATION MODELLING OF SEA COAL TERMINAL WAREHOUSE USING ANYLOGIC. Vestn. Gos. Univ. Morskogo Rechn. Flota Im. Admirala O Makarova 14, 181–198. https://doi.org/10.21821/2309-5180-2022-14-2-181-198

Pasparakis, A., De Vries, J., De Koster, R., 2023. Assessing the impact of human–robot collaborative order picking systems on warehouse workers. Int. J. Prod. Res. 61, 7776–7790. https://doi.org/10.1080/00207543.2023.2183343

Pham, H., Nguyen, D., Doan, C., Thai, Q., Nguyen, N., 2019. Warehouse operation optimization-simulation model, in: Proceedings of the 9th International Conference on Operations and Supply Chain Management (OSCM 2019). Institut Teknologi Sepuluh Nopember (ITS), Indonesia, pp. 1–8.

Richards, G., 2017. Warehouse Management: A Complete Guide to Improving Efficiency and Minimizing Costs in the Modern Warehouse. Kogan Page Publishers.

Shah, B., Khanzode, V., 2017. A comprehensive review of warehouse operational issues. Int. J. Logist. Syst. Manag. 26, 346–378. https://doi.org/10.1504/IJLSM.2017.081962

Shah, S., Aydin, A., Fisher, R., Ahmed, K., Froghi, S., Dasgupta, P., 2022. Current status of simulation-based training tools in general surgery: A systematic review. Int. J. Surg. Open 38, 100427. https://doi.org/10.1016/j.ijso.2021.100427

Skafa, E.I., Evseeva, E.G., Korolev, M.E., Скафа, Е.И., Евсеева, Е.Г., Королев, М.Е., 2022. Integration of Mathematical and Computer Simulation Modeling in Engineering Education. Интеграция математического и компьютерного имитационного моделирования в инженерном образовании. https://doi.org/10.17516/1997-1397-2022-15-4-413-430

Vladimirovic, S.G., 2023. Simulation methods of the analysis of management strategies for a multi-grocery warehouse.

Yigitbas, E., Jovanovikj, I., Scholand, J., Engels, G., 2020. VR Training for Warehouse Management, in:

Proceedings of the 26th ACM Symposium on Virtual Reality Software and Technology, VRST '20. Association for Computing Machinery, New York, NY, USA, pp. 1–3. https://doi.org/10.1145/3385956.3422106

Zhanbirov, G., Litvin, V., Taran, I., Izteleuova, M., Aliakbarkyzy, D., 2023. SUBSTANTIATION OF A REASONABLE NUMBER OF FORKLIFTS FOR A WAREHOUSE COMPLEX WITH FRONTAL RACKS IN AN ANYLOGIC ENVIRONMENT. | Transport Problems: an International Scientific Journal | EBSCOhost [WWW Document]. https://doi.org/10.20858/tp.2023.18.2.13

Zhen, L., Li, H., 2022. A literature review of smart warehouse operations management. Front. Eng. Manag. 9, 31–55. https://doi.org/10.1007/s42524-021-0178-9