LogForum

> Scientific Journal of Logistics <

2021, 17 (1), 59-69

http://doi.org/10.17270/J.LOG.2021.547

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

AUTOMATIC SIMULATION MODELLING OF WAREHOUSES

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ABSTRACT. **Background:** The goal of the paper is study on the possibility of using automation in simulation modeling of various types of warehouses, enabling quick verification of projects carried out in the area of storage. The paper outline the problem of simulation modeling of a complex storage system based on the concept of drawer racks designed by the company Zrembud located in Cieszyn, Poland. In order to properly evaluate the usefulness of the concept, the mechanism for modeling of both the drawer racking system and the highly popular row racking system was developed and adjusted to user without advanced simulations skills. The mechanism described in the paper is the part of the methodology of warehouse automatic simulation modeling.

Methods: Based on the structural analysis of rack types and the spatial relations of their components, modeling in the LogABS program was concluded. Modeling was performed in the DES (Discrete-Event System) environment. Data structures are necessary to automate the generation of warehouses. The engine code was written in C ++ programming language.

Results: The result of implementing the mechanism is the automatic generation of two storage systems, adapted to the user's requirements, in one simulation model. The first results of the analyzes for the generated structures determine the size of the storage area necessary to accommodate a certain number of storage units, as well as the level of complexity of the operation of both systems, which translates into the time of transport and loading activities.

Conclusions: The presented mechanism is the basis for the methodology of automatic simulation modeling of warehouses. It allows significant reduction in simulation models building duration, and thus a significant reduction in the time of projects consisting in verifying the concept of spatial arrangement in various projects related to the storage area. The proposed tool is innovative and useful for practitioners specializing in simulation modeling and specialists in warehouse design. Due to the organization and simplification of data structures, it can be implemented in various simulation modeling environments. Also after implementation, it can be used by people who do not have advanced simulation skills.

Key words: rapid warehouse design, automated simulation modeling, drawer racks, simulation, warehouse.

INTRODUCTION

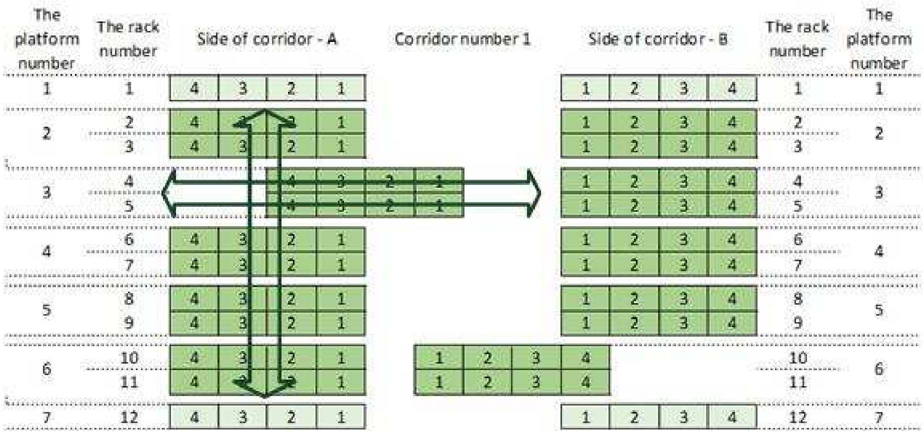
Nowadays, due to the limited amount of space, high cost of maintaining warehouses, limited access to a qualified workforce and high availability of outsourcing services related to the provision of commercial technical solutions, enterprises are exploring innovations in the field of storage. Due to the widespread automation, the cost of developing new solutions is constantly declining. The e-commerce industry became interesting phenomenon requiring efficient processing of a large number of orders for individual customers. The high volume of warehouse traffic is conducive to investing in semi or fully automated storage and picking systems.

One of such solutions is the innovative design of a semi-automatic storage system using racks placed on metal frames (called drawers). Such storage system is based on single or double sections of racks rotated 90 degrees relative to corridor. Each double rack (drawer) can move perpendicular to the transport corridor. The structure of the rack (the number of storage levels and the number

Citation: *Kluska K., 2021. Automatic simulation modelling of warehouses. LogForum 17 (1), 59-69, http://doi.org/10.17270/J.LOG.2021.547*

Received: 25.09.2020, Accepted: 12.11.2020, on-line: 12.01.2021.

of storage places on single level) can be freely modified depending on the users' requirements. The layout of the drawer rack warehouse is shown in Figure 1.



Source: own work

Fig. 1. The drawer rack system with directions of AGV movement

Figure 1 shows the arrangement of single and double racks in a drawer warehouse. The figure also indicates the platforms, racks and storage areas numbering. In the drawer racking system, single racks are placed at the ends of the rows of racks and do not need to be slid out - forklifts have permanent access to it. On the other hand, access to loads in double rack system is limited, so in order to get access to stored items, it is necessary to lift the platform (metal frame) with the racks and slide it out.

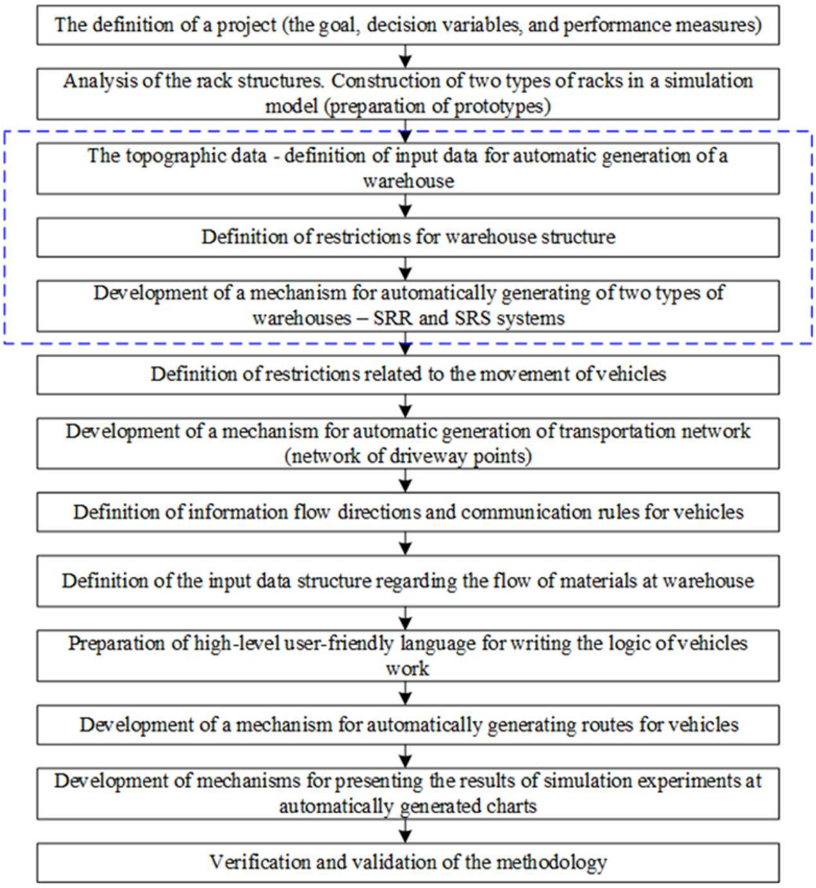
Source: https://zrembud.com.pl/nowe-systemy-regalowe/

Fig. 2. The prototype of drawer rack system

Moving the rack placed on a metal frame is feasible through the use of an automatic guided vehicle (AGV - called Transfer Unit in this case). It moves under the lowest shelving level (in directions marked by vertical arrow at Fig. 1) , and as a result it can reach any drawer, lift it, as well as slide it in and out when necessary (in directions marked by horizontal arrow at Fig. 1). The drawer-rack mechanism is described by Bartkowiak et al. [2019] in more detail. Researchers use data, ideas, rules and technical restrictions from the Zrembud company

The performance of the proposed solution is simulated and compared with the most standard systems, namely single depth row storage. The model is built in the Discrete Event System (DES) environment and uses the ABS simulation. The use of simulation results from the need to verify the designed system of AGV and forklifts management taking into account their communication and cooperation. The simulation allows to efficiently test the designed concepts related to both, the forklifts management and the implementation of safety restrictions. The preparation of a simulation model also allows observing the system in a virtual environment and refining the concept prior to its implementation. A particularly important stage in the design of the new shelving system is the development of a methodology for the automatic generation of drawer and traditional warehouses in order to compare such systems, and determine conditions when the SRS system has an advantage over the row racking system.

The stages of building the methodology of simulation modeling of storage systems are presented in Figure 3.



Source: own study

Fig. 3. The stages of building the methodology of automatic simulation modeling of storage systems

The implementation of the first two stages was the definition of the project and preparation of information and structures to build an automatic warehouse generation mechanism. The implementation of the steps marked in the diagram is the process of building the mechanism, which is the subject of this article. The next steps concern the definition of communication and cooperation rules between AGV and forklifts, and then the construction of a mechanism for automatic management of their work. The last stages of building the methodology include the development of mechanisms for generating charts (in order to analyze the results), as well as the process of its verification and validation.

The main goal of the paper is study on the possibility of using automation in simulation modeling of various types of warehouses, enabling quick verification of projects carried out in the area of storage.

The additional goals of the paper are:

- the presentation of automated drawer racks concept and its originality,
- basis for mechanism of automatic modeling of warehouse,
- presentation of implementation of described mechanism.

Main contribution is to develop the basis for the methodology for automatic building of simulation models of warehouses, that enables rapid warehouse design. Presented mechanism, as part of mentioned methodology, is dedicated to the user without advanced simulations skills and knowledge of simulation methods.

The paper is organized in five sections. Section 2 content the literature review about AS/RS systems and methods of assessment of warehouse performance. In section 3 authors describe the analysis of the rack structure - necessary step in building the mechanism for automatic generation of drawer rack system (SRS) and row racking system (SRR) in the warehouse. Section 4 describes mechanism for automatic generation of warehouses. Section 5 includes conclusions and further works.

LITERATURE REVIEW

The efforts of the companies to substitute manual picking with semi-or fully-automated systems are becoming increasingly popular. Designing new solutions related to the automation of picking processes is a great challenge due to the costs of developing and verifying such solutions. Kunc and Pawlewski [2019] provide the description of most popular non-automatic and semi-automatic solutions for warehousing.

In the existing facilities the amount of space is limited. It causes the developing of compact storage systems in order to improve the utilization of resources [Revillot-Narvaez et al. 2019]. Xu et al. [2019] describes how to designate the optimal size of a multi-deep AS/RS warehouse system. Tappia et al. [2019] provides analytical model that enables to measure the throughput times and order picking performance in integrated warehousing and picking systems. Hu et al. [2018] presents a hybrid algorithm for minimize the time of the retrieval and storage operation in AS/RS system.

The important research of De Koster et al [2008] contains the synthesis of approaches for optimal design of racks in a multi-deep compact automated storage and retrieval system (AS/RS). They consider several storage strategies, including the full-turnover-based storage, two class-based storage and the random storage.

This approaches allow transporting units manipulation in three-dimensional space along three reference axis X, Y, and Z. The movement is possible by implementing a mechanized devices to perform the repetitive tasks of loading, storage and unloading parts in racks.

Researchers use different methods to analyze the performance of fully and semi-automated warehouses. The most popular are dynamic simulation models. However, the study of AS/RS systems also adapts the static approaches.

The use of simulation involve the DES (discrete-event system) approach [Hrusecka et al. 2018], Petri nets [Gerini 2019], Agent-based approach [Ribino 2018], and others.

The static approaches includes travel-time models with empirical [Xu et al. 2020], statistical [Revillot-Narvaez et al. 2019] and continuous approaches.

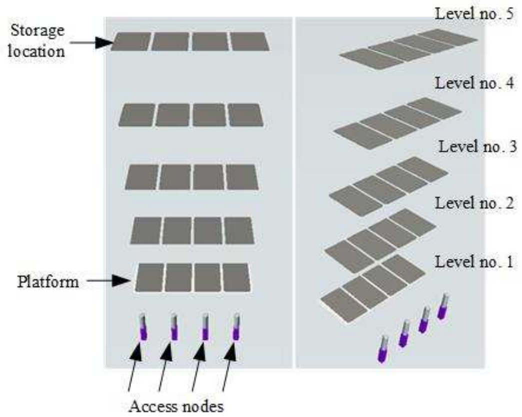
Nowadays researchers are searching opportunities to automatically build simulation models [Garrido and Saez, 2019, Burduk, Grzybowska, Safonyk, 2019, Indrajitsingha et al., 2019].

ANALYSIS OF THE RACK STRUCTURE

Creating a mechanism for automatic warehouse generation requires analysis of the rack structure and building racks in a simulation model (prototypes). It is the base to specify restrictions related to the structure of the rack and extract the parameters necessary for automatic generation of the warehouse.

In both systems, the rack consists of the platform (which is the basis of the structure), a group of storage places (shown as gray rectangles) and access nodes representing the stopping points for the forklifts (determining the distance of the forklifts from the rack when moving in the warehouse, as well as during manipulation).

In the case of the SRR system, the pallet places are arranged in a row on many levels relative to the rack floor, along the corridor. The SRR rack built in the simulation model is shown in Figure 4.

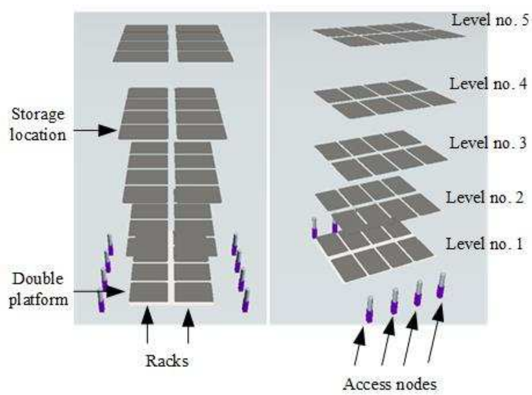


Source: own study with use LogABS simulation program

Fig. 4. The SRR rack built in the simulation model

Modeling a SRS rack requires consideration of both single (placed on the edge of each row of racks) and double (located in a row between the extreme racks) rack structures. Single racks are static racks, the structure of which do not differ from the traditional racks implemented in the SRR, except for the fact of placing them above the floor (placement of the rack on a metal frame) and the arrangement of these racks across (rotated 90 degrees) relative to the corridor.

A double rack (called drawer) consists of two racks placed on a platform. In the simulation model, a double shelf is a single, wide platform, on which two rows of storage places (two racks) are placed on many levels relative to the floor of the shelf, across the corridor. The double rack of the SRS system built in the simulation model is shown in Figure 5. On both sides of the drawer there are access nodes for the forklifts.



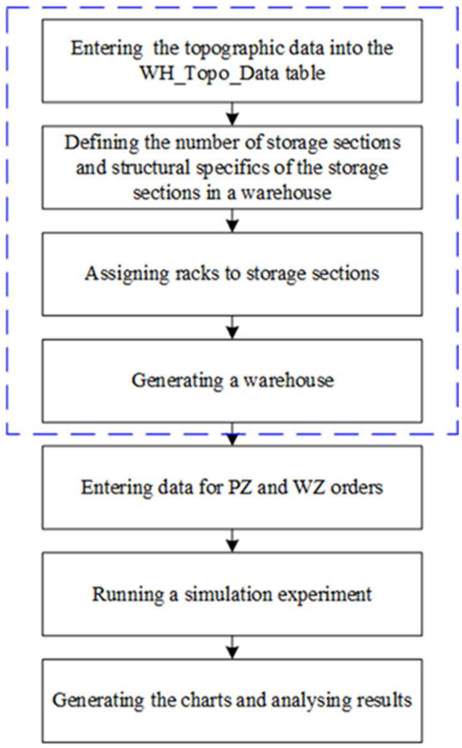
Source: own study with use LogABS simulation program

Fig. 5. The drawer rack built in the simulation model

At the current stage of mechanism development, the simulation model does not reflect the frame or metal structure of the rack. However, the distance between the base of the rack and the floor, the dimensions of the pallet places consistent with the size of the pallet and the distance between the pallets in the horizontal and vertical plane are modelled.

METHODOLOGY AND MECHANISM FOR THE AUTOMATIC GENERATION OF WAREHOUSE

The mechanism for automatic generation of warehouse structures described in this publication is part of the methodology for automatic building simulation models of storage systems shown in Figure 3. Automatic generation of a warehouse is a stage of this methodology, whose implementation is conditioned by the implementation of the steps indicated in Figure 6.



Source: own study

Fig. 6. The stages of methodology for automatically building simulation models of storage systems

The methodology also includes the definition of material flow data, automatic processing of this data, generation of forklifts and AGV executers operation routes, and the management of vehicles work taking into account spatial dependencies and communication. The methodology also includes generating graphs showing the results of simulation experiments. The implementation of these stages is related to the stages of methodology construction shown in Figure 3 and is the subject of other publications.

The use of the mechanism for automatic warehouse generation requires entering a number of data into the following tables:

- WH_Topo_Data - defines the most important data regarding the warehouse structure
- WH_SRS_Section_XXX and WH_SRR_Section_XXX, where XXX is the section identification number. These tables describe the specificity of the storage section, i.e. the types (determining the most important parameters) of the racks.
- WH_Assign_Sections_SRS and WH_Assign_Sections_SRR in which defined sections are assigned to the addresses in the warehouse (rack name).

The topographic data

The structure of the SRS and SRR storage systems is described in the WH_Topo_Data table. Structural data of SRS and SRS reference warehouses with an exemplary capacity of 3480 pallet places are presented in Figure 7.

	SRS	SRR
X coordinate of the first rack	80.78	83.89
Y coordinate of the first rack	35.90	-10
Numer of rows of racks	6	11
Number of racks in one row	12	12
The way of corridors generation	0	0
Corridor width	3.80	3.10
Width of a platform with a single rack (rack at the edge of row)	1.20	1.20
Width of a platform with a double rack	2.60	0
Width of AGV vehicle (Transfer Unit)	2.60	0
Length of platforms	3.60	3.60
Distances between racks	0.10	0.10
Distances between storage places on the Y axis	0.20	0.10
Distances between storage places on the X axis	0.08	0.08
Numer of forklifts	2	2
The maximum number of forklifts in a single corridor	1	2
The distance from rack (to load item)	1	1
The distance from rack (to wait for end of AGV movement)	3	0
The maximum hight of warehouse	8	10
Number of storage sections	2	2

Source: own study

Fig. 7. The view on the window with WH_Topo_Data table

The table is used to define the values of parameters regarding the structure of SRS (in the first column) and SRR (in the second column) warehouses. The first line specifies the X and Y coordinates of the first rack, i.e. the coordinates of the point from which the mechanism will start generating the entire warehouse. The next two lines define the number of rows of racks and the number of platforms (with racks) in one row of racks. The fifth row specifies how to generate rows of racks relative to the first corridor. The value 0 means that the first corridor has an even number of rows of racks (the racks are located on both sides of the corridor) while the value 1 means that the racks are placed only on one side of the corridor. The next row specifies the corridor width, i.e. the distance between the rows of racks. The next three parameters determine the width of the platforms with single and double racks, as well as the width of the AGV executer (also the station to which it is assigned). In the "Length of platforms" line, the user can specify the platform length, which mean width of the row of racks. In the next three lines the distance between racks next to each other and the distance between storage places (pallet places) in two reference axes must be specified. The next data concern the number of forklifts and restrictions on the capacity of the corridor (the number of forklifts that can remain in the corridor at the same time).

The next two lines specify the distances that the forklift must keep from the rack while waiting for the AGV end its movement and when loading from/ unloading to / the rack. These values directly influence the process of generating controlling markers at the right distance from the racks. Determining the maximum height of the warehouse is aimed at implementing additional functionality in the warehouse, i.e. enabling checking (after definition of the warehouse sections using the "Check Compliance" button - see Figure 8) whether the defined racks with the load will fit in the determined usable height. The last line allows to specify the number of storage sections (number of rack types).

Define the storage sections

The warehouse consists of sections. A section is a set of drawers with the same dimensions and structure. The number of sections is defined in the WH_Topo_Data table, and each section is defined in a separate table. Figure 8 shows the table defining the structure of an example section.

WH_SRS_Section_001 | Check Compliance | Help

	SRS
Width of a single storage place in X axis	0.80
Length of a single storage place in Y axis	1.20
The number of storage places within a single storage level	4
The number of storage levels	5
Height of platform	0.72
Height of L1	1.86
Height of L2	1.86
Height of L3	1.85
Height of L4	1.85
Height of L5	1.90

Source: own study

Fig. 8. The view on WH_SRS_Section_001 table filled with sample data

The WH_SRR_Section_XXX table (defining the structure of the section in the SRS warehouse) has the same structure as WH_SRR_Section_XXX table (defining the structure of the section in the SRR warehouse). The tables defining the sections are selected from the drop-down list at the top of the window. The user must complete all tables for the sections he has defined.

The first two lines of the table determine the size of a single storage place on the rack. All storage places within one rack have the same size. The next two lines define the number of storage levels on the rack and the number of storage places on single level. Then it is necessary to determine the height of the metal frame on which the rack stands. The following lines specify the height of the storage levels. Their number is adjusted depending on the defined number of levels.

Assign Sections to Platforms

After defining the section types for both kinds of warehouses, they should be assigned to the platforms (on which the racks stand) in the "Assign Sections to Platforms" window. The window is shown in Figure 9.

SRS

	AdrZR	AdrLogABS	Section
	1A_01	S1A_01	1
Row 2	1A_02	S1A_02	1
Row 3	1A_03	S1A_03	1
Row 4	1A_04	S1A_04	1
Row 5	1A_05	S1A_05	2
Row 6	1A_06	S1A_06	2
Row 7	1A_07	S1A_07	3
Row 8	1A_08	S1A_08	4
Row 9	1A_09	S1A_09	5
Row 10	1A_10	S1A_10	5
Row 11	1A_11	S1A_11	4

SRR

	AdrZR	AdrLogABS	Section
	1A_01	R1A_01	2
Row 2	1A_02	R1A_02	2
Row 3	1A_03	R1A_03	2
Row 4	1A_04	R1A_04	2
Row 5	1A_05	R1A_05	2
Row 6	1A_06	R1A_06	2
Row 7	1A_07	R1A_07	3
Row 8	1A_08	R1A_08	4
Row 9	1A_09	R1A_09	2
Row 10	1A_10	R1A_10	2
Row 11	1A_11	R1A_11	1

Source: own study

Fig. 9. The "Assign Sections to Platforms" window filled with sample data

The "Assign Sections to Platforms" window is divided into two parts. Both parts contain tables listing all rack addresses (platform names) in Zrembud (first column) and LogABS program (second column) notations.

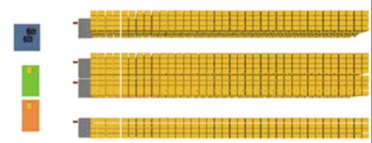
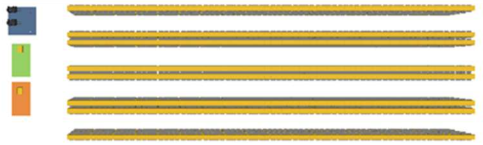
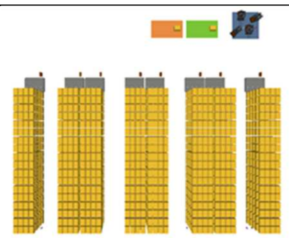
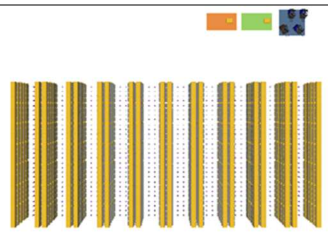
The first, left part of the window contains a list of shelves for the Drawer Storage System (SRS). The second part (right side of the window) contains a table with a list of shelves for the Single Depth Row Storage System (SRR).

In the third column of each table, the user can assign previously defined section type numbers to each rack in a warehouse. It should be remembered, however, that the section types for SRS and SRR have been defined separately, therefore the section type "1" will mean a different rack structure for the drawer storage system and for the row storage system. When entering values into the third table column on the left side of the window, use the section type numbers defined for the drawer storage system. Similarly, when entering values into the third table column on the right side of the window, use the section type numbers defined for the row storage system.

The automatic generation of warehouse

After filling up the tables, user can generate any type of warehouse by using the "Generate SRS" button (in order to generate the Drawer Storage System) or "Generate SRR" button (in order to generate the Row Storage System). After pressing the button, the warehouse in the simulation model will be generated automatically. The user can also delete the warehouse if it needs to be modified. The modification consists in correcting the data in the tables. Examples of generated warehouses are shown in Table 1. The most important parameters of warehouses is presented in Table 2.

Table 1. Simulation models of SRS and SRR systems

E.no.	SRS	SRR
1		
2		

Source: own work with use of LogABS program

Table 2. Parameters of generated SRS and SRR systems

	Experiment no. 1		Experiment no. 2	
Parameter	**SRS**	**SRR**	**SRS**	**SRR**
Number of rows of racks	4	8	8	20
Number of racks within a single row	19	18	10	7
Total width of storage area[m]	48	66	25	25,5
Total length of storage area [m]	22,5	22,5	44,86	56,6
Storage area [m^2]	1080	1485	1121,5	1433,3

Source: own work

Each warehouse has a capacity of 2880 loading units, the same dimensions of storage places, the same number of storage levels, he same number of locations at each level, and one dimension with the same or approximate value. The difference in the size of warehouses area is significant and amounts 27.3% and 22.3%.

CONCLUSIONS AND FURTHER RESEARCH

The result of the research described in the publication is a mechanism, which shows the ability to automatically generate warehouses of various types in the simulation environment. Presented mechanism enables the user without advanced simulation skills to generate a simulation model with two different types of storage systems. Operation of the tool requires only filling a few tables with information through simple, user-friendly interface. Generating the warehouse after filling in the tables takes several seconds. The user can also automatically delete the warehouse to correct the data in the tables and generate the warehouse again. This is an important stage in the methodology in automatic building simulation models of storage systems, which results in generated exemplary warehouses shown at figure 9.

Further development of the research includes the implementation of subsequent stages of the methodology in simulation technology, as well as the development of the methodology itself by developing a tool for determining the stock rotation for pallet places at SRS system and the allocation of indexes in the warehouse (assigning SKU to pallet places depending on their stock rotation). To increase the usability of the methodology, it is planned to expand the mechanism for automatic storage generation, which consists in extending the range of available storage systems with other types of racks. The methodology also assumes the definition and implementation of a number of variants for setting buffers for inbound and outbound materials, which also requires the development of an automatic warehouse generation mechanism. The most complex stage of methodology development is preparation of logic for management of AGV and forklifts movement. This logic has to involve many decision-making processes for proper handling orders related to warehouse stocking (PZ) and shipments (WZ), taking into account the rules of AGV's and trolleys movement and their cooperation. An important stage of the planned methodological evolution is the development of mechanisms enabling the implementation of resource and process cost accounting.

The initial results of simulation experiments show that the SRS system allows the storage of the same number of loading units in area smaller by over 22% compared to the SRR type warehouse. It does not change the fact that the complexity of the SRS system operation may result in a longer duration of internal transport orders.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

The research was conducted as part of the POIR.01.01.01-00-0373/17 project "Development of an automatic drawer shelf using modified 90 degree reverse row shelving systems dedicated to internal warehouse logistics", financed by the National Center for Science and Development, Poland.

REFERENCES

Bartkowiak T., Kunc T., Kluska K., Myszkowski A., Pabiszczak S., 2019. Novel approach to semi-automated warehouse for manufacturing: design and simulation, IOP Conference Series: Materials Science and Engineering, 591, 012040-1 - 012040-10, http://doi.org/10.1088/1757-899X/591/1/012040

Burduk A., Grzybowska K., Safonyk A., 2019. The use of a hybrid model of the expert system for assessing the possibility of manufacturing the assumed quantity of wire harnesses. LogForum 15(4), 459-473, http://doi.org/10.17270/J.LOG.2019.360

De Koster RMBM, Le-Duc T., Yugang Y., 2008. Optimal storage rack design for a 3-dimensional compact AS/RS, International Journal of Production Research, 46(6), 1495-1514, http://doi.org/10.1080/00207540600957795

Garrido J., Saez J., 2019. Integration of automatic generated simulation models, machine control projects and management tools to support whole life cycle of industrial digital twins, IFAC-PapersOnLine, 52(13), 1814-1819, http://doi.org/10.1016/j.ifacol.2019.11.465

Gerini C, Sciomachen A., 2019. Evaluation of the flow of goods at a warehouse logistic department by Petri Nets, Flexible Services and Manufacturing Journal, 31(2), 354-380, http://doi.org/10.1007/s10696-018-9312-3

Hrusecka D., Adla R., Krayem S., Pivnicka M., 2018. Event-B Model for Increasing the Efficiency of Warehouse Management, Polish Journal of Management Studies, 17(2), 63-74, http://doi.org/10.17512/pjms.2018.17.2.06

Hu HN., Li L., Lv ZJ., 2018. A Novel Hybrid Algorithm for Order Picking Optimization in Automated Warehouse, 2018 37TH Chinese Control Conference (CCC), 3216-3220, http://doi.org/10.23919/ChiCC.2018.8484006.

Indrajitsingha S.K. , Samanta P.N. , Raju L.K. , Misra U.K., 2019. Two-storage inventory model for deteriorating items with price dependent demand and shortages under partial backlogged in fuzzy approach. LogForum 15 (4), 487-499, http://doi.org/10.17270/J.LOG.2019.344

Pawlewski P., Kunc T., 2019. Using Agent Base Simulation to Model Operations in Semi-automated Warehouse, De La Prieta F. et al. (eds) Highlights of Practical Applications of Survivable Agents and Multi-Agent Systems. The PAAMS Collection. PAAMS 2019. Communications in Computer and Information Science, 1047, Springer, Cham. http://doi.org/10.1007/978-3-030-24299-2_5

Ribino P., Cossentino M., Lodato C., Lopes S., 2018. Agent-based simulation study for improving logistic warehouse performance, JOURNAL OF SIMULATION, 12(1), 23-41, http://doi.org/10.1057/s41273-017-0055-z

Revillot-Narvaez D., Perez-Galarce F., Alvarez-Miranda E., 2019. Optimising the storage assignment and order-picking for the compact drive-in storage system, International Journal Of Production Research, http://doi.org/10.1080/00207543.2019.1687951

Tappia E, Roy D., Melacini M., De Koster R., 2019. Integrated storage-order picking systems: Technology, performance models, and design insights, European Journal Of Operational Research, 274(3), 947-965, http://doi.org/10.1016/j.ejor.2018.10.048

Xu XH., Zhao XZ., Zou, BP., Gong YM., Wang HW., 2020. Travel time models for a three-dimensional compact AS/RS considering different I/O point policies, International Journal Of Production Research, 58(18), 5432-5455, http://doi.org/10.1080/00207543.2019.1659519

Xu XH., Zhao XZ., Zou BP., Li MZ., 2019. Optimal dimensions for multi-deep storage systems under class-based storage policies, Cluster Computing-The Journal Of Networks Software Tools And Applications, 22(3), 861-875, Special Issue: SI, http://doi.org/10.1007/s10586-018-2873-9

AUTOMATYCZNE MODELOWANIE SYMULACYJNE MAGAZYNÓW

STRESZCZENIE. Wstęp: W pracy przedstawiono problem modelowania symulacyjnego złożonego systemu magazynowania opartego o koncepcję regałów szufladowych zaprojektowaną przez firmę Zrembud posiadającą siedzibę w mieście Cieszyn w Polsce. Aby możliwa była ocena użyteczności koncepcji opracowano mechanizm do automatycznego modelowania zarówno systemu regałów szufladowych, jak i cieszącego się dużą popularnością systemu regałów rzędowych. Opisany w publikacji mechanizm jest częścią metodyki automatycznego modelowania symulacyjnego magazynów. Celem metodyki, a także zastosowania opisanego mechanizmu jest pełne zautomatyzowanie procesu modelowania symulacyjnego magazynów, prowadzące do minimalizacji czasu weryfikacji projektowanych koncepcji magazynów.

Metody: Na podstawie analizy struktury dwóch rodzajów regałów oraz relacji przestrzennych ich elementów składowych, odwzorowano je w modelu symulacyjnym. Opracowano struktury danych niezbędne do automatyzacji ich generowania. W artykule przedstawiono opracowany mechanizm automatycznego generowania dwóch rodzajów magazynów.

Wyniki: Wynikiem zastosowania mechanizmu jest automatyczne wygenerowanie dwóch systemów magazynowania, dostosowanych do wymagań użytkownika, w jednym modelu symulacyjnym. Pierwsze wyniki analiz dla wygenerowanych struktur określają wielkość obszaru magazynowania, niezbędnego do zmieszczenia określonej liczby jednostek transportowo-magazynowych, a także poziom złożoności obsługi obu systemów, przekładający się na czas realizacji czynności transportowych oraz ładunkowych.

Wnioski: Przedstawiony mechanizm stanowi podstawę metodyki automatycznego modelowania symulacyjnego magazynów. Pozwala on na znaczące skrócenie czasu budowania modeli symulacyjnych systemów magazynowania, a co za tym idzie znaczne skrócenie czasu projektów polegających na weryfikacji koncepcji zagospodarowania przestrzeni w rozmaitych projektach związanych z obszarem magazynowania. Proponowane narzędzie posiada duże znaczenie dla praktyków zajmujących się modelowaniem symulacyjnym oraz specjalistów projektujących magazyny. Dzięki uporządkowaniu oraz uproszczeniu struktur danych, może zostać ono wdrożone w różnych środowiskach modelowania symulacyjnego, a po wdrożeniu być stosowane przez osoby nieposiadające zaawansowanych umiejętności obsługi programów symulacyjnych.

Słowa kluczowe: modelowanie symulacyjne magazynu, automatyczne modelowanie symulacyjne, system regałów szufladowych, magazyn, symulacja

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