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Intralogistics in Digital World – Different Mode and Means of Transport in Internal Processes

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Abstract:

Purpose: *The main goal of this article is to show intralogistics modeling in the digital world, focusing on aspects of changing means of transport and impact of these changes on transportation organization. The author used a 3D simulation technologies to show the effects of organizational changes in intralogistics (different means of transport and different transport organization). Moreover, the author wants to show that methods from external transport (supply chain) can be easily transferred to the intralogistics level. During the bibliographic analysis, it was noticed that the topic discussed is new, and additionally, when analyzing the mode of transport in intralogistics, there are no articles in the searched literature database, what can be defined as a research gap. Which additionally indicates the need for and sense of such an article.*
Design/Methodology/Approach: *For the purpose of this article the literature review and bibliometric analysis were made (quantitive approach). Thanks to them, a research gap was defined. The author draws attention to the fact that methods from the supply chain can be transferred into internal logistics. Internal transport within a given enterprise is a transport network in micro terms. The author at this research focus on aspects of impact of changing means of transport to the mode of transport. For showing the influence of it, author decided to use simulation technology (quantitive approach).*
Findings: *Two simulation models were designed and built to show the implementation of intralogistics processes using different means of transport. For both of them, the activities performed by transportation employees were analyzed, as well as the distance covered. For both cases, the method of organizing transport routes was analyzed, in relation to the models known in external transport (supply chain) for the organization of transport orders. This allowed for the possibility of transferring the method from SC to intralogistics to be shown.*
Practical Implications: *The application of computer simulations in the area of intralogistics described in this article, with particular emphasis on the impact of organizational and technological changes on the analyzed process, can be used in practice in the area of internal transport. Showing the impact of changing the organization of transport from forklifts to transport using logistic trains can serve as a starting point for further test scenarios for enterprises. The use of computer simulations has great potential due to the possibility of testing changes and their impact on the process in the virtual world, which reduces risk, costs, and negative impact on the environment.*
Originality/Value: *Article combine all aspects in one research: computer simulations, intralogistics and transport modes, what fill up the research gap. The author presents that*

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the mode of transport defined in the literature in the context of external transport can be easily transferred to the intralogistics level. For a more practical aspect, the author analyzes and presents these modes on simulation models. Moreover, based on these computer models, the impact of changing the means of transport into an intralogistics system was defined.

Keywords: *Intralogistics, internal logistics, internal transport, mode of transport, computer simulation, digital world.*

JEL Codes: *R4, L91.*

Paper Type: *Research article.*

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1. Introduction

Logistics is a very important element of the economy - it connects all its sectors by enabling the exchange of goods on a global scale. Topics and scientific areas related to logistics are wide - from the supply chain, through warehousing, to internal transport. Adding to this, aspects of economics, sustainability, and Industry 4.0 make up a huge range of topics involved in one area – logistics.

Ongoing changes in the environment and technologies pose constant challenges for enterprises regarding fast reaction to changes in the market and opportunities in the business world (Saniuk *et al.*, 2014). Moreover growing public awareness poses challenges for enterprises in terms of effective and sustainable development.

In the context of sustainable development, three dimensions should be taken into account simultaneously: economic, natural and social (Souza and Alves, 2018). It is important for companies to focus on all aspects in parallel - then it can be talk about the sustainable development. To put it simply: it is important how we plan, what technologies we use and what impact the decisions we make have on the society around us.

Intralogistics, as a part of logistics, is also subject to rules that concern a holistic view of the issue. It is difficult to talk about the sustainable development of the logistics area by an enterprise without taking into account the internal transport area. Rapidly developing technologies (such as 3D simulations, virtual reality, and augmented reality) and technical solutions (autonomous vehicles, logistics trains) currently enable companies to analyze various development scenarios, including in a virtual system, which translates into better management of available inventories.

In this article, the author presents an example of an intralogistics system for a conceptual area using modern 3D simulation technologies. The author decided to show two options for internal transport in the company: a popular option (transport only with forklifts) and a mixed version (forklifts and logistics trains). For both models, results for operations in the production/assembly zone are presented to show the lack of downtime caused by intralogistics, and informations about the distance traveled by employees carrying out transport operations.

Additionally, the author paying attention to the aspect of using various technical solutions (different means of transport), also raises the issue of how to plan transport routes in relation to transport models in logistics, such as the shuttle, shuttle-continuous, radial, circumferential and relay model. The author uses simulation technologies to show specific results for individual solutions. At the same time, author draws attention to the fact that intralogistics uses solutions from external transport (supply chains), such as route planning depending on various factors (type of goods, location of shipping and receiving places).

Internal transport within a given enterprise is a transport network in micro terms. By combining all the above-mentioned elements: intralogistics, computer simulation, transport models and sustainable development, the author places herself in the research gap (which is shown in the bibliometric analysis). There are no articles analyzing all these elements at the same time.

The main goal of this article is to show modeling of intralogistics in digital (simulation) world. Author by using simulation program shows result of changing organization in intralogistics (different means of transport and different mode of transport).

2. Literature Review

It is worth noting that the term intralogistics is a relatively young term, but this area has always existed as an indispensable element of the organization of transport processes. Technological development, including process automation and changes in the demographic structure of humanity (aging society, low population growth) all together result in the search for improvements in further areas, including internal transport.

It is known that if the transport process in the company is not completed on time, it will cause delays in further stages of the implementation of the main processes in the company - in a production company, lack of deliveries of materials to the production line or failure to collect the product from the line means stopping production, which equates to resulting from the failure to achieve the company's basic goal - production for the purpose of making money. Logistics and production are two separate departments in the company, but they must cooperate and complement each other.

In order to illustrate the relationships between the issues discussed, the author quotes selected definitions for the following concepts in a defined order: logistics, intralogistics, aspect of sustainability in logistics/intralogistics and topic of transport mode.

The basic term in the analyzed context is logistics. Referring to literature sources, logistics is:

- "It is a complex science which improves the quality of business processes and which enables a company to react to demands of a market as well as of a customer faster" (Pečený *et al.,* 2020).
- "… it entails different activities such as planning, production, purchasing, transportation, warehousing, loading and unloading, handling, packaging, processing, distribution, control, information processing and traceability. These activities in the right proportion are necessary to achieve the basic goal of logistics which is reflected in the effective flow of goods / services / people / information, at the right time with the right equipment / devices / competent personel, in the right place, all in adequate quality and the right quantity in order to satisfy customers. Logistics should also strive to be cost-effective and environmentally friendly" (Kukovič *et al.,* 2014).
- "the goal of traditional logistics is to coordinate various types of resources and flows (including informational, material, human, financial, etc.) to satisfy all participants in the logistics subsystem at minimal cost" (Kutsenko *et al.,* 2022).

Second topic is intralogistics. Intralogistics is a relatively young term, which was defined in 2011 by the Intralogistics Forum Verband Deutscher Maschinen- und Anlagenbau (VDMA) as (Hompel and Heidenblut, 2008): "The organization, control, implementation and optimization of the internal flow of materials, the flow of information and the handling of goods in industry, retail and public facilities."

Intralogistics can be meant as micro logistics - every aspect of logistics is conducted but on a smaller scale - in the context of the area of one company/factory, within the four walls. Other definition of intralogistics is: "Intralogistics focuses on the flow of materials within the factory and thus includes the supply of materials to the individual production processes or their operating resources" (Meißner and Massalski, 2020). A broad literature review in the field of intralogistics and the digital twin concept is presented in (Kosacka-Olejnik *et al.,* 2021).

Next important area is aspect of sustainability in logistics and intralogistics. "Sustainability outcomes encompass the adoption of environmentally and socially responsible practices as well as the achievement of environmental, social or economic performance" (Hoffa-Dabrowska and Grzybowska, 2020). In the context of logistics it can be said that "sustainable logistics is aimed more at coordinating various types of resources and flows (including information, material, human, financial, etc.) to satisfy all participants in the logistics subsystem while achieving sustainability between economy, environment and society" (Kutsenko *et al.*, 2020).

Sustainability is an important and popular topic in logistics, which is confirmed by a large number of articles (Zagloel *et al.*, 2024), (Liu *et al.*, 2018), (García-Arca *et al.*, 2020), (Kayikci, 2018), (Zowada, 2020), (Matusiewicz, 2022), (Jayarathna *et al.*, 2023). It can also be found also articles about sustainability in logistics education (Lukman, 2021). In the context of intralogistics and sustainability, there are much fewer articles, as the author showed further in the bibliometric analysis section below. Examples of articles describing the topic of intralogistics and sustainability (Fusko *et al.*, 2019), (Scholz *et al.*, 2018), (Loske *et al.*, 2021).

A very important element from the point of view of this article is the issue of transport models used in logistics. The logistics industry uses various transport models, depending on needs, requirements and conditions. Choosing a transport model is a complex transport process that must take into account factors such as: demand, supply, available transport infrastructure, available means of transport, the ability to flexibly adapt to the prevailing and changing conditions, as well as following development and ecological trends (cargonite.pl/news/modele-transportowe-wykorzystywane-w-logistyce-rodzaje).

Transport process management covers a number of issues: from the choice of means of transport and the selection of the route, to attempts to consolidate loads in order to reduce business costs, as well as for the sake of pro-ecological activities. Five basic models are defined for the organization of transport orders (Stajniak *et al.*, 2008):

- shuttle model – the means of transport runs regularly between two points (loading and unloading), waiting for a specific activity at both points;
- shuttle-continuous model – the means of transport runs regularly between two points (loading and unloading), but does not wait at these places, but after reaching them, picks up a loaded or empty semi-trailer, trailer, container, body interchangeably and goes to the next place;
- radial model – the means of transport transports cargo from one loading point to many unloading places; after unloading at a given point, the means of transport returns to the loading place, where it is reloaded and transports the goods to other collection points;
- circumferential model – the means of transport is loaded at one point and then delivers the goods to subsequent unloading points without returning to the loading point in between;
- relay model – in this model, transport is organized from the loading point to the final unloading point using reloading points. Typically, the goods are delivered to the reloading point in a larger batch (using 33-pallet means of transport, trains or ships), and then reloaded onto smaller means of transport and delivered to the customer.

These models are the basis for building more complex systems within the supply chain. None of these models is a universal model that will fit every job. Depending on the specification of the transport order, the model should be adjusted or the order should be divided and different models should be used at its specific stages - combining different transport models in order to complete the transport order. In the practical part of the article, the author will demonstrate the use of the discussed transport models in intralogistics, as well as their mixing within one case.

3. Research Methodology

In order to examine the researchers' interest in the topic of intralogistics in the digital world, with particular emphasis on the use of different modes and means of transport in internal transport, a bibliometric analysis was conducted. The analysis was made at the beginning of the 2024 year. Bibliometric analysis was the first step to recognizing the topic of interest by scientists. During research a research gap was defined in the context of computer simulation, transport mode, and intralogistics. The bibliometric analysis is presented at chapter 4.

In the second step author decided to use the simulation for doing some experiments and to show the results of them in the described topic. The idea was to show something usuful, not only a description of the idea of what and how to do it. The author decided to build two simulation models in order to show the existing transport models in the intralogistics area, as well as to show the impact of changing the organization of internal transport (change of transport means) on the implemented process. Two models were built:

1. including transport only using forklifts,
2. including transport using forklifts and logistics trains (milk-run).

In both cases discussed, the main goal is to ensure the availability of raw materials and empty containers in the production area, so that the operator at the station does not wait for materials or a free place to put the finished product. At the same time, from the research point of view, it was important to analyze the distance traveled by logistics employees. The description of simulation models is presented at chapter 5. Based on that model the influence of change means of transport for others is showing, and resulting from this change of mode transport also. This models show intralogistics processes.

The simulation models were built by using LogABS software (logabs.com/). The simulation models present a simple production system consisting of 4 assembly stations:

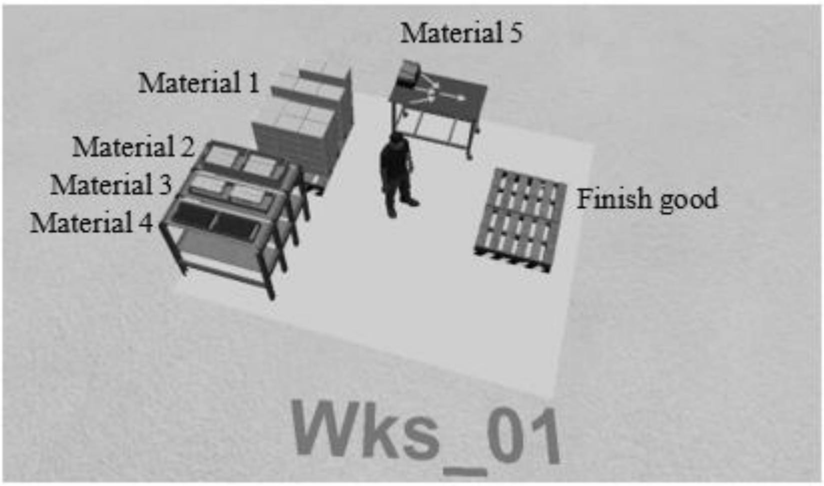
- station 1 (Wks_01) and 2 (Wks_02) assemble a product consisting of a total of 16 elements, the production time is 60 seconds,

- assembly station 3 (Wks_03) and 4 (Wks_04) assemble a product consisting of a total of 30 elements (the same as stations 1-2, but in a different quantity), due to greater complexity, the production cycle is 120 seconds.

The layout of containers with parts at the station is shown at figure 1. At all stations, the materials needed for assembly are located in appropriate containers at the station: material 1 is on the pallet, materials 2-5 are in containers, and empty pallets for finish good. In both simulation model, in every assembly station for containers with parts number 2-4 have been designed shelves. When designing the logistics processes, it was assumed that there would be 2 containers at the station. The use of two containers, in accordance with the principles of Lean (kanban), allows the use of one container while the other needs to be replaced. This allows the containers to be operated freely without interrupting production.

For this purpose, the shelf for parts number 2-4 consists of two levels (the upper one contains filled containers), and on the lower one the operator will place empty containers, which will be taken away by a logistics employee when the materials are replenished at the station. The replacement of containers has been designed to take place on the outside of the station, so as not to interfere with the assembly worker area during the replacement.

Figure 1. *Layout of the Assembly Station*



Source: *Based on screenshoot from used simulation software.*

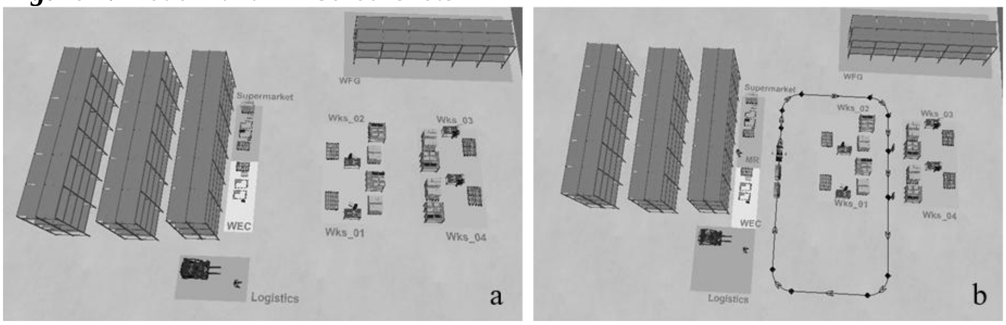
Designing models take into account the warehouse area and transport issues. The warehouse area featured:

- Supermarket with prepared containers needed for assembly,
- WEC (warehouse empty containers) - storage area for empty containers returning from the assembly area,

- WFG (warehouse finish goods) - a finished products warehouse where pallets with finished products are delivered from each of the four assembly stations.

In addition, there is a station called Logistics, in which there is a warehouseman equipped with a forklift, who is responsible for delivering containers, pallets with materials or empty ones to the assembly stations and collecting the pallet with finished products and taking it to the finished products warehouse. Figure 2a shows a screenshot of model 1 with all the described elements, figure 2b shows a screenshot of model 2 with all the described elements.

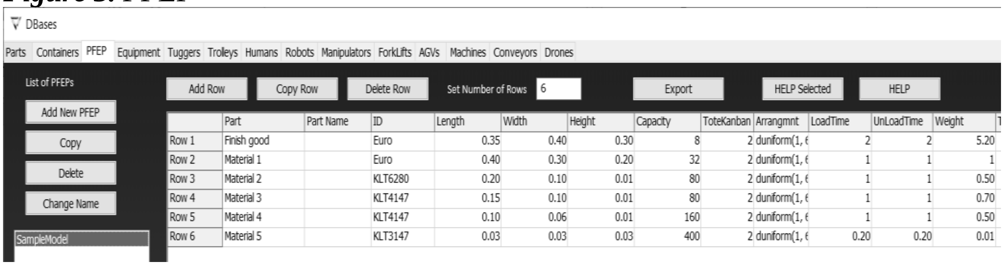
Figure 2. *Model 1and 2 – Screenshots*



Source: *Screenshoots from used simulation software.*

In the case of model 2, in which internal transport was reorganized - the delivery of containers with parts and the removal of empty containers (i.e. for materials 2-5) for all four assembly stations is carried out using a logistics train. The separate station was added for the logistics train and its operator. In addition, the route for the logistics train is designated. Operating stops for assembly stations have been designed to simultaneously service two stations (1 and 3, 2 and 4, respectively).

Figure 3. *PFEP*



	Part	Part Name	ID	Length	Width	Height	Capacity	ToteKanban	Arrangmnt	LoadTime	UnLoadTime	Weight	T
Row 1	Finish good		Euro	0.35	0.40	0.30	8	2	duniform(1,	2	2	5.20	
Row 2	Material 1		Euro	0.40	0.30	0.20	32	2	duniform(1,	1	1	1	
Row 3	Material 2		KLT6280	0.20	0.10	0.01	80	2	duniform(1,	1	1	0.50	
Row 4	Material 3		KLT4147	0.15	0.10	0.01	80	2	duniform(1,	1	1	0.70	
Row 5	Material 4		KLT4147	0.10	0.06	0.01	160	2	duniform(1,	1	1	0.50	
Row 6	Material 5		KLT3147	0.03	0.03	0.03	400	2	duniform(1,	0.20	0.20	0.01	

Source: *Screenshoot from used simulation software.*

From the point of view of building a simulation model in the used software, a very important element is PFEP (Plan for every part), in which information about each material, raw material, semi-finished product, and finished product participating in the implementation of the modeled process are defined. For each of these elements, modeller must specify a transport container and the number of elements in this container and many other information. It is a kind of mini database. During building the models, modeller can use a ready-made library of containers available on the market. For models described in this article, pallets and three different KLT containers (different dimensions) were selected. The defined PFEP for the described models is presented in Figure 3.

4. Research Results

It was decided to carry out the bibliometric analysis from general to specific - i.e. from the broadest concept (logistics) to the most narrowed area (aspect: transport mode, intralogistic*, sustain*, computer simulation). It is intended to show the level of interest in given issues, including very specific ones. Articles available in the Web of Science database (accessed from the Clarivate Analytics server) at the beginning of 2024 were analyzed. Results are presented by information from Web of Science Analyze Results.

The author deliberately searched the database in terms of the occurrence of specific concepts in the entire area. The author did not intentionally narrow the searching. This was intended to show general interest in a specific topic, while narrowing down issues related to the area described in this article. The results are summarized in Table 1 and Figures 4-6.

Table 1. *Number od articles and year of first article for chosen topics*

No.	Searching word	Number of articles	Year of first article
1.	logistic*	725823	1909
2.	intralogistic*	317	2005
3.	logistic* + sustain*	35543	1974
4.	intralogistic* + sustain*	24	2016
5.	logistic* + simulation*	24536	1958
6.	intralogistic* + simulation*	73	2005
7.	logistic* + computer simulation*	3923	1971
8.	intralogistic* + computer simulation*	15	2008
9.	logistic* + sustain* + computer simulation*	199	1992
10.	intralogistic* + sustain*+ computer simulation*	1	2019
11.	transport mode + logistic*	2683	1977
12.	transport mode + intralogistic*	3	2022
13.	transport mode + logistic* + sustain*	620	1997
14.	transport mode + intralogistic* + sustain*	1	2022
15.	transport mode + logistic* + computer simulation*	22	1998

16.	transport mode + intralogistic* + computer simulation*	0	-
17.	transport mode + logistic* + sustain* + computer simulation*	3	2015
18.	transport mode + intralogistic* + sustain* + computer simulation*	0	-

Source: *Own study, based on bibliometric analysis from Web of Science database (accessed from the Clarivate Analytics server).*

On the first step the analyzes was made for term “logistic*”, then “intralogistic*”, after that for both of them it was searched also about “sustain*”, “simulation*” and “computer simulation*”. From the point of view of this article, it was also considered important to check the literature on the issue of "transport mode" in the area of logistics and intralogistics and also aspect of “computer simulation*” and “sustain*”.

In this area, searching the database only for simulations was omitted, because the area of interest from the point of view of the article is computer simulation of the intralogistics area. When conducting a bibliometric analysis, the author decided to focus on several important areas from the point of view of this article: logistics, intralogistics and transport models in these areas. For each of them, various variants in the area of sustainable development or computer simulation were also analyzed.

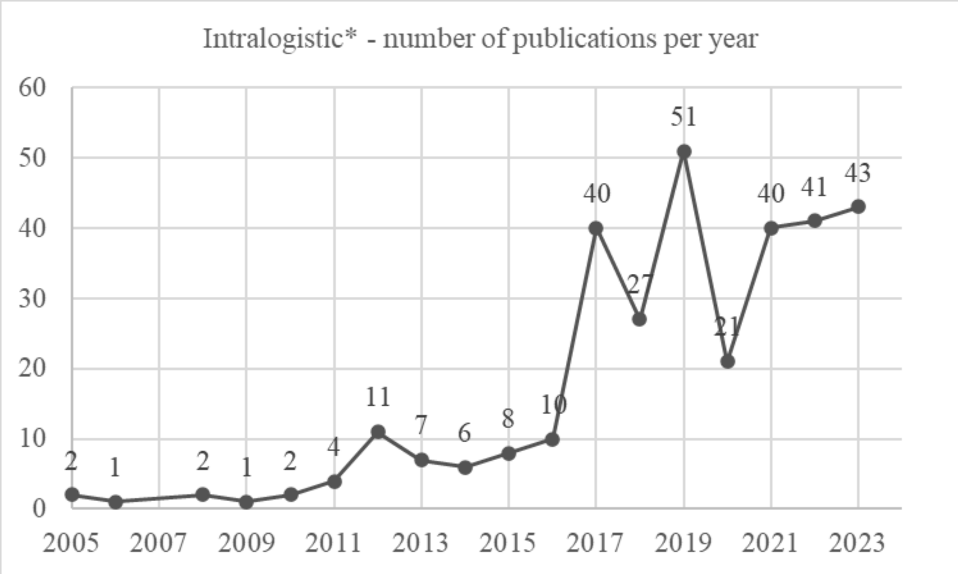
Analyzing the data presented in Table 1, it can be noticed when a trend appeared in these areas. The year of publication of the first article clearly indicates the order of the researched areas, and the total number of articles indicates the popularity of the topic. Searching the database in terms of the main topics of this article, i.e. intralogistics, transport models, computer simulation and sustainable development, no article was found in the searched database.

Moreover, only one article was found regarding transport models, intralogistics and sustainable development. This indicates a research gap. Due to the focus on the area of intralogistics, it was decided to show the growing publication trend for this issue in Figure 4-6. In Figure 4 author present number of publications for intralogistics from 2005. The same was made for aspect of intralogistic and sustainability topic (Figure 5) and for intralogistic and computer simulation (Figure 6).

The obtained results clearly show that the topic of intralogistics is a new research area. There has been a noticeable increase in scientists' interest in intralogistics since 2017 (Figure 4).

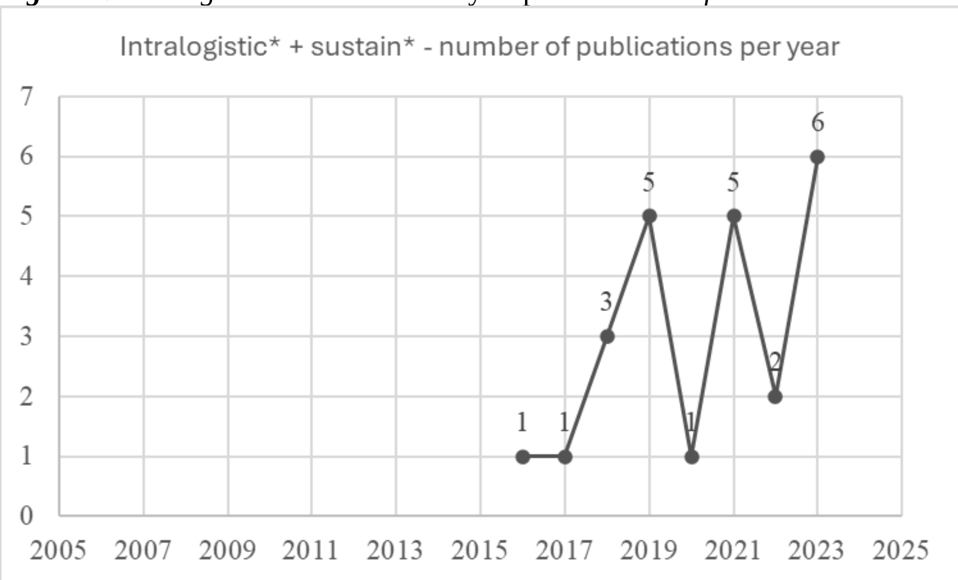
Moreover, topic of sustainability in intralogistics starts nearly this year (Figure 5). In Figure 6 the author shows the use of computer simulation in the area of intralogistics. It can be noticed a small number of articles on this topic.

Figure 4. *Intralogistic – Number of Publications Per Year*



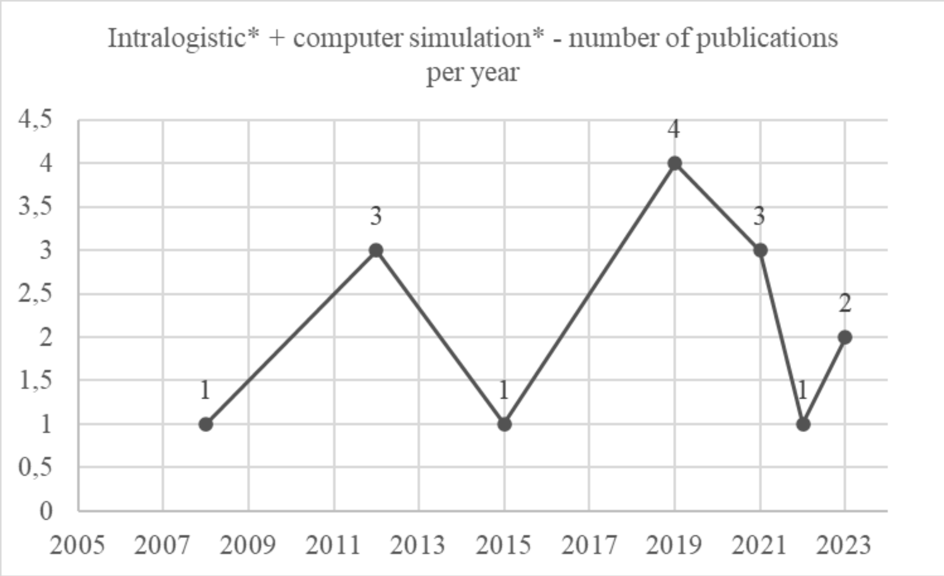
Source: *Own study.*

Figure 5. *Intralogistic* and Sustainability Topic – *Number of Publications Per Year*



Source: *Own study.*

Figure 6. *Intralogistic and Computer Simulation – Number of Publications Per Year*



Source: *Own study.*

5. Discusion

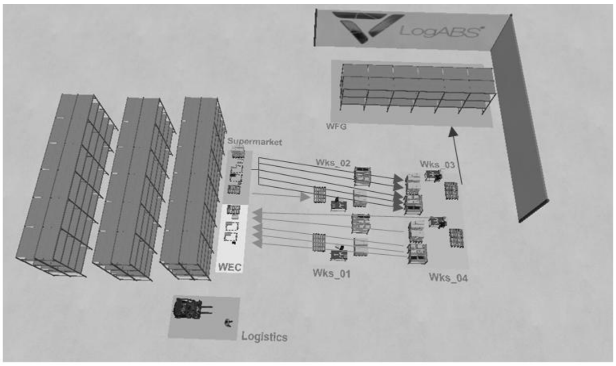
5.1 Simulations – Flows and Modes of Transport

According to the topic of the article, the author focuses on the area of intralogistics, which means paying special attention to the transport area. As a result of the author's work is a presentation of material flow and transport organization in simulation models. In order to approximate the flow of materials in both models, the flows were drawn on the layout corresponding to a given model (model 1 - Figure 7, model 2 - Figure 9).

The author decided not only to analyze the material flow and transportation organization in theoretical considerations, but also decided to build simulation models and show the influence of changes on the process, and system. In the case of model 1, the materials are transported by the operator using a forklift. The material flow at model 1 is presented at Figure 7.

In model 1, the necessary container with material or an empty pallet is pick-up from the Supermarket and then delivered to the appropriate location in a given station. From here, an empty pallet is taken and taken to the WEC. In the case of a finished product, the empty pallet is taken from the Supermarket, a full pallet is taken from the assembly station and transported to the WFG. In Figure 7, the arrows are directed to different assembly stations for better readability and to show the side from which the container is replaced.

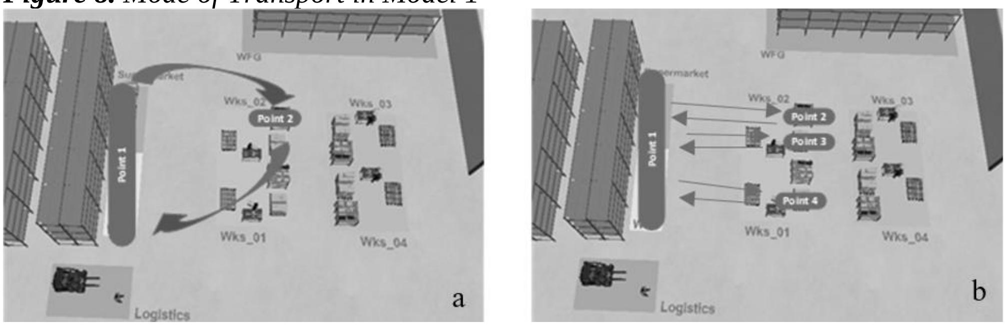
Figure 7. *Model 1 – Material Flow*



Source: *Own study based on screenshoot from used simulation software.*

Figure 8 shows the mode of transport in model 1. Referring to transport models, transport in this situation from the point of view from one transportation order, initially looks like the organization of individual transport orders - load, deliver, return (shuttle model) but with some with some extension - taking into account the circulation of empty containers (Figure 8a) – at point 1 the full container is loaded, then transported to the point 2, here is unload, and the empty container is loaded and transported to the point 1 where is unload.

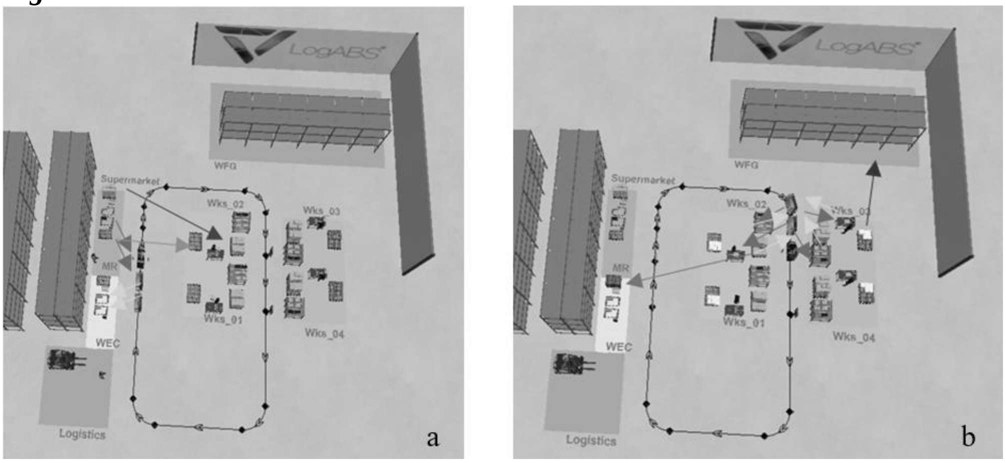
Figure 8. *Mode of Transport in Model 1*



Source: *Own study based on screenshoot from used simulation software.*

From the point of view of several orders coming from various locations in the assembly area and recognizing specially separated areas of the warehouse (Supermarket and WEC) as one common area (just warehouse), the organization of transport in this model can be compared to the radial model in which one means of transport serves several unloading points (locations at the assembly station) each time returning to the loading point (warehouse), with the difference that due to the turnover of empty containers from the assembly stations, the means of transport does not return empty (Figure 8b).

Figure 9. *Model 2 – Material Flow*



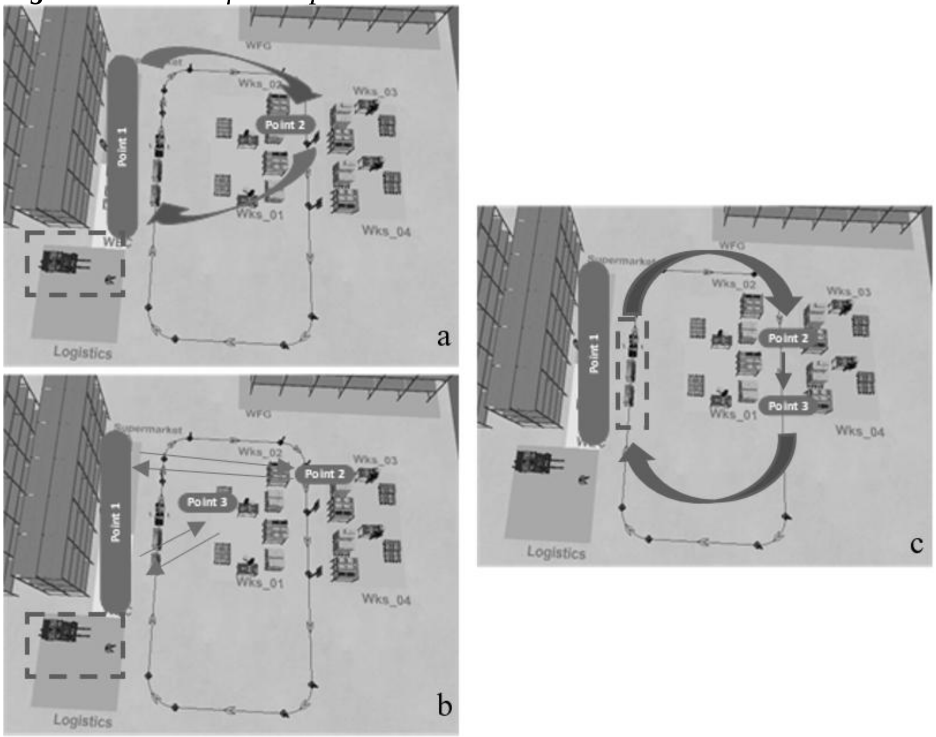
Source: *Own study based on screenshoot from used simulation software.*

In the case of model 2, according to Figure 9, the materials are transported by the operator using a forklift (9a) and by the logistic train (milk run) (9b). Materials on pallets are transported by forklift, materials in containers are transported by milk-run. For material 1, full pallet is loading from Supermarket and then delivered to the location in station. From here, empty pallet is taken and transported to the WEC.

The container for materials 2-5, which are transported by milk-run, are loaded from Supermarket into trolley, then after moving, unload from trolley to the location. At the same transportation cycle the empty containers from locations are loaded into trolleys and transported to the WEC. In the case of a finished product, empty pallet is taken from Supermarket, a full pallet is taken from the assembly station and transported to the WFG by forklift. Analyzing the transports carried out in model 2 in relation to the transport models, it can be concluded that in the case of deliveries made by the operator using a forklift, we are again dealing (as in model 1) with a shuttle model (Figure 10a), and from a broader perspective, with a radial model (Figure 10b) – it look the same like in model 1.

The situation changes when using a means of transport such as a logistics train. The idea behind organizing transport using logistics trains is to simultaneously transport many containers to various delivery locations along a specific route, while collecting interchangeable containers (empty/full) from the serviced locations. Transport is organized according to the circumferential model (Figure 10c). The use of container transport using logistic trains resulted in a change in the transport models used - the circumferential model appeared. In model 2, transport using forklifts was not completely eliminated, because in practice, materials transported on a pallet are often transported using forklifts or AGVs, usually on a single-pallet basis.

Figure 10. *Mode of Transport in Model 2*



Source: *Own study based on screenshoot from used simulation software.*

Therefore, transport in this model remains the most common practice in the area of internal transport. Not all transports are worth consolidating, for example, due to the frequency of pallet deliveries with a given material. The change in the means of transport in model 2 influenced the occurrence of a new transport model. When changing the means of transport, transport should be organized appropriately. In the case of logistics trains, it is actually talking about the consolidation of cargo transport within internal transport.

Modelling transport using a logistics train, it is necessary to plan a route and a driving schedule for a given logistics train. The existing demands and available transport infrastructure (routes, trains and logistic wagons) should be analyzed. In model 2, the route was designed to enable reaching the serviced locations, as well as the Supermarket and the WEC.

After analyzing the demand, it was determined that the logistics train could consist of two wagons, so it was decided to use shelf wagons. The demand for containers was determined using the built-in Solver tool in the used software and then manually combined into given transport routes. Figure 11 presents the specific need to replace containers with materials 2-5 in the designed model.

Figure 11. *List of Requirement of Replacing Containers*

ID_Request	Time	P_xx	Container	Adres	Content
1	3387.87	4	KLT4147	Wks_03	1
2	3387.87	4	KLT4147	Wks_04	1
3	3759.56	4	KLT4147	Wks_02	1
4	3763.98	4	KLT4147	Wks_01	1
5	4280.31	5	KLT3147	Wks_03	1
6	4280.31	5	KLT3147	Wks_04	1
7	4724.29	5	KLT3147	Wks_02	1
8	4730.03	5	KLT3147	Wks_01	1
9	6922.07	2	KLT6280	Wks_03	1
10	6922.07	2	KLT6280	Wks_04	1
11	6924.99	3	KLT4147	Wks_03	1
12	6924.99	3	KLT4147	Wks_04	1
13	6933.99	4	KLT4147	Wks_03	1
14	6933.99	4	KLT4147	Wks_04	1
15	7595.21	2	KLT6280	Wks_02	1
16	7597.13	3	KLT4147	Wks_02	1
17	7602.14	4	KLT4147	Wks_02	1
18	7605.12	2	KLT6280	Wks_01	1
19	7606.12	3	KLT4147	Wks_01	1
20	7610.98	4	KLT4147	Wks_01	1
21	8712.96	5	KLT3147	Wks_03	1
22	8712.96	5	KLT3147	Wks_04	1
23	9527.50	5	KLT3147	Wks_02	1
24	9538.79	5	KLT3147	Wks_01	1
25	10480.11	4	KLT4147	Wks_03	1
26	10480.11	4	KLT4147	Wks_04	1
27	11444.71	4	KLT4147	Wks_02	1
28	11457.99	4	KLT4147	Wks_01	1

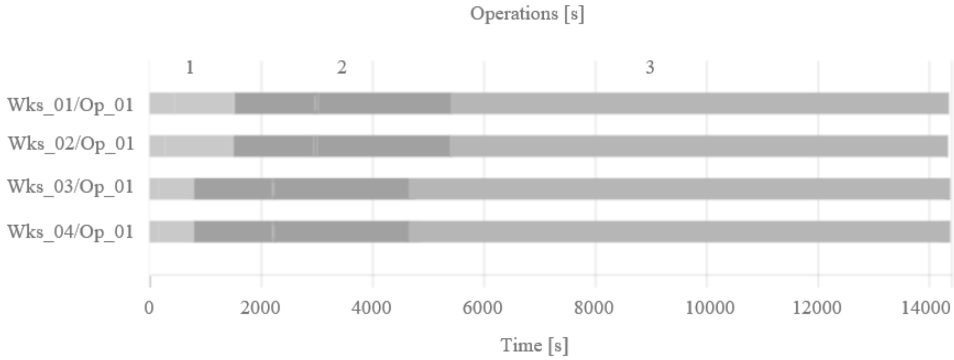
Source: *Own study.*

After receiving from Solver specific demands: when (Time), where (P_xx and Adres), type of container (Container) and how much (Content), the information were analyzed and combined into groups so that one train transport route would deliver the necessary items at the required time, i.e. before the next container was empty. Five train transport routes were defined: first route, which include row 1-4 in Figure 11, second route - row 5-8 in Figure 11, third route - row 9-20 in Figure 11, fourth route - row 21-24 in Figure 11, fifth route - row 25-28 in Figure 11. Each train routes are marked different colour in Figure 11.

5.2 Computer Simulations – Analytical Results

The described models present a relatively simple situation in the production (assembly) area, therefore it was decided to analyze a short period of time - 4 hours. Analyzing both built models, the first important factor is to check whether production (assembly) took place without downtime resulting from the lack of materials, the availability of which is responsible for logistics.

Figure 12. *Operations – Report for Model 1*

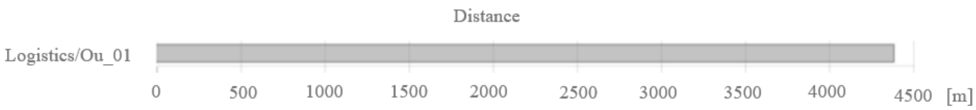


Source: *Result from used simulation software.*

For this purpose, an aggregated operation chart was generated in the software, where the share of individual activities can be traced. For model 1, the share of individual activities is shown in Figure 12. For model 2 the results are the same, so they are not presented. In Figure 12 presented with defined numbers are: 1 – transport activities, 2 – loading and unloading activities and 3 – assembly activities are presented at charts. At graph there is no waiting operations, what is desirable in this situation.

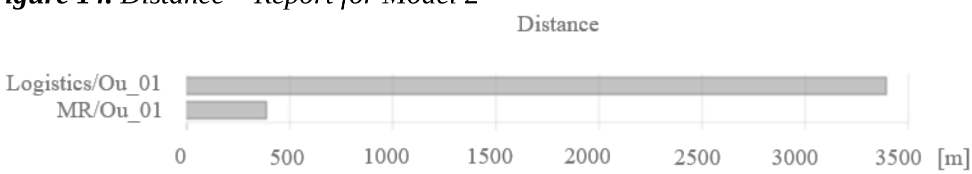
The second important indicator from the point of view of logistics is the distance covered by logistics operators. On this basis, further calculations regarding internal transport costs could be made. In the case of model 1, there is one logistics employee using a forklift at work, in the case of model 2 - two (one using a forklift and the other being a logistics train operator). The distance covered in meters is shown in figure 13 for model 1, in figure 14 for model 2.

Figure 13. *Distance – Report for Model 1*



Source: *Based on result from simulation software.*

Figure 14. *Distance – Report for Model 2*



Source: *RBased on result from simulation software.*

Analyzing the results regarding distance, in model 1 the people responsible for transport covered 4.39 km, and in model 2 - 3.79 km. The reduction in distance is not spectacular, but it should be remembered that only 4 hours of work were analyzed, and if converted into 3-shift work, 5 days a week, this is already 18 km. Transports performed by an employee using a forklift, who is responsible for the turnover of materials transported on pallets, have a very large share in these statistics. The frequency of their replacement is high - this is an element that should be analyzed in more detail in further consideration of the designed system.

6. Limitation of the Study

Two models for intralogistics presented in the article are simple models - they contain a simple and small arrangement of positions. Expanding it to a larger one would yield different results. It can be concluded that in the case of expanding the models, changing the transport organization from single deliveries to deliveries in the train version would result in a greater reduction in the distances covered by transport, due to the greater possibility of consolidating deliveries.

In the case of considering a change in the organization of transport in the enterprise, additional aspects should be taken into account, e.g. the cost of purchasing logistics trains. Savings resulting only from a shorter distance covered by internal transport employees is not sufficient to make such strategic decisions. However, the possibility of testing different variants in a virtual environment should be considered a cost-effective and sustainable solution (no erroneous changes introduced in the real environment and then corrected).

7. Conclusions

The development of technologies, including computer simulations, enables their increasingly wider use in practice. Thanks to the available tools, it is possible to accurately reproduce processes in the virtual world and then test various variants of changes on a computer model, and not on a living organism such as a production system.

The current trend of building digital twins encourages enterprises to take a broader look at the use of digital technologies - there is a noticeable increase in business in the trend of building digital twins for the entire enterprise in order to test variants across the entire system. The simultaneous increase in automation in business, as well as the development of VR and AR technologies, forces software suppliers to constantly develop, also in this area, so that the simulation model can take into account all the necessary elements.

Used 3D software enables the construction of digital twins of factories, taking into account modern intralogistics means (logistics trains, AGV) and the ability to view the created model in VR. The development described is also driven by scientific development - the search for new organizational models, new technological solutions and others. In that article, the author showed a simple model taking into account the production (assembly) area and intralogistics – intralogistics in the digital world.

Two simulation models were built and described, presenting various models of internal transport organization. The differences consisted in the use of different means of transport, which translates into a different organization of transport tasks. In this work, the author also showed the modes of transport occurring in both models, depending on the proposed method of transport. The described modes of transport are mainly described in the context of external transport - the supply chain (transport between one company and another).

However, it should be realized that the mode of transport defined in the literature can be easily transferred to the intralogistics level, because here the same transport takes place between one point and another, only the distances are different. In the case of internal transport, attention should be paid to the fact that these transport models are often combined and intertwined in order to complete the entire order. In the presented simple model, where transport is carried out using forklifts, there are actually two transport models - the shuttle model and the radial model. In the case of the logistic train model, the use of the logistic train results in the occurrence of a circumferential model.

The use of a logistics train to transport containers of materials actually means consolidation of loads and transport orders. Cargo consolidation has a positive impact on the discussed area of the company, such as:

- reduced traffic in the production area (fewer individual transports performed),
- increased safety in the production area due to reduced traffic in this area,
- lower energy consumption to deliver materials to points due to covering a shorter distance,
- less environmental pollution due to lower energy consumption.

It is worth to mention that use of logistics trains has a positive impact on the aspect of sustainable. It can be and should be considering in three dimensions: economic, natural and social. In economic terms it means - smaller distance covered for transport, which translates into lower transport costs, in natural terms - less environmental pollution and in social terms - higher labor comfort, greater safety.

Intralogistics in the digital world, in simulation models, made it possible to present the different options (organizational, technological) in this area. By building a simulation model and making changes in the virtual world, it is possible to test many options and choose the best. In described example changing the way of organizing internal transport, resulted in a reduction of the distance covered by logistics. It can be said that computer simulations contribute to sustainable development. Testing potential changes in a virtual model certainly has a smaller impact on the environment than in the case of testing on a living organism.

The research described allows for their further development. An aspect that definitely needs to be developed is to conduct an analysis of the costs of changing the means of transport vs. the impact of this change on the environment and society. A full long-term analysis of the effects of changing transport should be made, including cost calculations. During this calculation, it should look at the aspects of sustainable development; currently, the cost factor is not the only element that determines whether or not to implement a given solution.

The next possible step is to analyze the implementation of intralogistics processes using autonomous vehicles (autonomous logistics trains or AGVs). For this purpose, it would be worth establishing cooperation with a supplier of such solutions to parameterize the designed system in accordance with real data and to show specific business solutions.

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