A BIBLIOMETRIC RESEARCH OF THE SIMULATION USAGE IN LOGISTICS

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Abstract

The reality of the modern world is changing towards the usage of the latest technologies in everyday life. This could also be said about the improvement in the logistics field with the usage of Industry 4.0 tools and creating a more autonomous and transparent system that would create the possibility not only to see but also to forecast the logistics process. Many authors have already studied the influence of simulation on logistics processes. However, no attempt has been made so far to measure the topic from a bibliometric point of research. This study aims at covering this research gap and providing information for further research connected with this field. The research consists of a literature review, methodology, bibliometric study and conclusions. Bibliometric research includes the study of the publication year, author, journals and conference proceedings, key word co-occurrence and word cloud. In the process of literature review and bibliometric analysis, it was found that the usage of simulation in logistics has positive potential and several tendencies. The research was limited to the papers available in the English language only and could be further improved by adding other sources and/or comparisons. These findings could provide useful information for future publication and be used by practitioners to monitor tendencies.

Key words: simulation, logistics, Industry 4.0

1. INTRODUCTION

The contemporary competition in the business world put a great influence on the existing processes. The products become more varied, the demands become more personalized and the processes become faster. Each production system and each service are currently improving so that the cost of the final product would be decreased while the quality would remain or even become better. The economic fluctuation and difficulties in many countries motivate companies to reduce costs of the production to be able to survive the competition in the market.

Modern technologies and the introduction of new principles of industrial automation have a great influence on the processes and provide a profitable tool for improvement and development. This influence is connected with all the industrial processes and services connected with it, including logistics. As an inseparable part of any modern service and/or product logistics plays a crucial role in business success. Considering the fact that globalization is continuing to grow and products are now delivered worldwide, logistics influence the success of any enterprise greatly.

The logistics processes are currently estimated from the point of view of their correspondence to the new reality in the scopes of the so-called "Industry 4.0" paradigm, and improved methods and methodologies have already been offered by many scientists (Pareja Yale et al., 2020, Wang et al., 2022) many which highly rely on the simulation of logistics processes.

Despite the fact that the process simulation is currently getting a lot of attention from both practitioners and scientists as one of the main technologies used in the scopes of Industry 4.0, simulation has proved its successful influence on many business-related processes long before the notion of Industry 4.0 (or any related such as Smart factory, etc.) has been mentioned at Hannover fair in 2011 (Efimova & Briš, 2021). Thus, many papers have already been written discussing the influence of simulation on logistics and offering different simulation techniques for this field. However, to the best author's knowledge, so far there have not been any papers that evaluate the conjunction of simulation and logistics from the bibliometric point of view, however, there are some papers dealing with logistics in separate fields (Roy et al., 2021). At the same time, bibliometric research might provide useful information for scientists and future researchers.

In this paper, an attempt is made to respond to the research gap of the lack of bibliometric research and to measure the simulation usage in logistics from the bibliometric point of view. The research consists of the literature review, methodology discussion, bibliometric study, discussions and conclusions and provides useful information for future research in this field.

2. LITERATURE REVIEW

2.1. Simulation Usage in Logistics

With the growing speed and increasingly personalized customer demand (Efimova et al., 2021), the role of logistics is becoming more and more important. The development of technologies influences the logistics processes greatly. The introduction of RFID, sensors, Big Data analytics, Robotics etc. has a crucial impact on logistics processes. Moreover, as globalization continues to develop, new structures of marketing systems appear (Segetlija et al., 2011) and customers buy products from around the world, logistic processes require constant improvement so that the companies would be able to provide the required services and profits (Cudziło et al., 2018).

Simulation is a method of creating a computer model which allows working with probable dynamic situations (Vogal & Pecina, 2019). It is highly used for complex processes and is considered to be a powerful tool in situations of uncertainty

(Trauzettel, 2014). Simulation for logistics purposes has already been used for many years. The search in the SCOPUS database shows that the first paper that combines the words "Simulation" and "Logistics" in the name of the article was published in 1963 and was connected with space logistics, where computer-based mathematical models allowed engineers to use simulation to plan the activities (Richardson & Salas 1963). Since then simulation in logistics has been analyzed in many industries, surroundings and applications, the studies have covered different fields including industrial (Gyulai et al., 2020), healthcare (Roy et al., 2021), humanitarian (Pareja Yale et al., 2020) and others. Simulation appears to be a useful tool for solving many logistics problems by allowing one to analyze and assess the problem before it appears. Process automation, the usage of robots and RFID sensors, mobile technologies and other contemporary technologies are being evaluated as they possess tremendous potential for logistics processes optimization (Saini et al., 2021, Gyulai et al., 2020, Wei Wang & Shidong Fan, 2009, Paixão & Bernard Marlow, 2003). The focus currently is to create a flexible and automated system for transporting, where the simulation will play an important role.

Simulation in logistics has proved to have positive results for complex industrial processes as it allows one to verify new ideas without process interruption (Gyulai et al., 2020). Moreover, as the logistics processes are also complicated from the point of view of the cooperation between stakeholders (Becha et al., 2020), simulation of some processes might ease this communication. Here, simulation is one of the ways to "overcome logistics challenges" (Pareja Yale et al., 2020) as it serves "to bridge the gap between theory and practice" (Steenbergen & Mes, 2020). The development of computer technologies allows the simulation to be further developed (Vabek et al. 2021).

However, there still are many aspects that have not yet been fully investigated, such as transparency and standardization of simulation processes (Cai et al., 2022), some new techniques that require experiments, IT solutions for intelligent simulation (Wei & Sun, 2022) and much research still going on in simulation usage for logistics. At the same time, the amount of data on every simple topic is growing rapidly and sometimes it is complicated to keep a track of the data. To solve this problem bibliometric research is offered here in order to provide researchers and future authors with systemized information on the topic.

3. METHODOLOGY

The research topic was identified based on the literature review and bibliometric analysis was proposed to cover the research gap. Two source databases were used for the research WoS and SCOPUS as they usually generate major interest from academic and research communities. Both journal articles and conference papers were considered in this bibliometric research. The search was limited to the results available in English, thus it is important to note that the research could not provide a full-scale review. Moreover, the research considered only journal articles and proceedings papers, thus, book chapters, reviews and other similar documents were excluded from the search. Another important aspect is that the bibliometric analysis considered all the articles published till August 2022 (including August), but there were no limitations connected with the first publication time, and this is important to consider as another limitation for the given research. The process of selection of articles and conference proceedings for the paper is presented in Figure 1 and is also described further in more detail.

Figure 1. The search process and results



Source: own research

The process it consisted of several steps: first, the advanced search was used in both WoS and SCOPUS limited to "Simulation" AND "Logistics" in title names. The search resulted in 574 results from WoS and 1024 results from SCOPUS. After the exclusion of duplicates, the result was 1178. Then, only conference papers and articles written in English were left and the results became 1080 These results were further analyzed and the conclusion was drawn.

4. **RESULTS**

To begin with the bibliometric analysis all 1080 found articles were classified according to the source type. It was found that 363 journal articles were published and 717 conference papers. In some journals and conference proceedings, only a couple of articles (up to 3 for journals and up to 4 for proceedings papers) were published, other sources are mentioned in Table 1, where it could be seen that the most popular journal for this topic is "International Journal of Simulation Modelling" while the most popular conference is "Winter Simulation Conference" with 85 papers published there. Winter Simulation Conference which was in different places all around the world has received the biggest attention from researchers in this field. Thus, it might provide important feedback for researchers that Winter Simulation Conference is a shop floor for discussion and cooperation in this field.

Journal				Conference	
International	Journal	of			
Simulation Modelling			12	Winter Simulation Conference	85

Table 1. The number of articles and conference proceedings

		Simulation In Produktion Und	
Simulation		Logistk 2013	15
Sustainability (Switzerland)		Transportation Research Procedia	12
Computers and Industrial		•	
Engineering	7	Applied Mechanics and Materials	10
		Journal of Physics: Conference	
Journal of Simulation	7	Series	9
Journal of Statistical Computation			
and Simulation	6	Simulation Series	9
		Lecture Notes in Computer	
		Science (including subseries	
International Journal of Industrial		Lecture Notes in Artificial	
Engineering: Theory Applications		Intelligence and Lecture Notes in	
and Practice	5	Bioinformatics)	8
International Journal of			
Production Research	5	Advanced Materials Research	7
		ESM European Simulation and	
BMC Medical Research		Modelling Conference: Modelling	
Methodology	4	and Simulation	7
International Journal of		Lecture Notes in Electrical	
Simulation and Process Modelling		Engineering	7
Simulation Modelling Practice		The International Society for	
and Theory	4	Optical Engineering	7
		International Conference of	
		Chinese Logistics and	
		Transportation Professionals -	
		Logistics: The Emerging Frontiers	
		of Transportation and	
Statistics in Medicine	4	Development in China	7
		European Modeling and	
Applied Sciences (Switzerland)	3	Simulation Symposium, EMSS	6
Computational Intelligence and		Advances in Intelligent Systems	
Neuroscience	3	and Computing	6
		IFIP Advances in Information and	
Computers in Industry	3	Communication Technology	6
		International Conference on	
		Harbour, Maritime and	
Environmental Science and		Multimodal Logistics Modelling	
Pollution Research		and Simulation	6
	_	IOP Conference Series: Materials	
ICIC Express Letters		Science and Engineering	6
Journal of Coastal Research		Procedia Engineering	6
Journal of Convergence		European Conference on	
Information Technology	3	Modelling and Simulation, ECMS	6

		Summer Computer Simulation	
Open Engineering	3	Conference	6
		Int. Conference on Harbor,	
		Maritime and Multimodal	
		Logistics Modeling and	
		Simulation, HMS, Held at the	
		International Mediterranean and	
Polish Journal of Environmental		Latin American Modeling	
Studies	3	Multiconference	5
		ACM International Conference	
		Proceeding Series	5
		AIP Conference Proceedings	5
		Communications in Computer and	
		Information Science	5
		IFAC-PapersOnLine	5
		International Conference On	
		Industrial Engineering And	
		Engineering Management	5
		Simulation in industry	5

Source: own research

The author analysis demonstrated in Figure 2, illustrates that there are several authors that are the leaders in this field. As it could be seen the biggest number of publications have Wang Y., Neumann G and Straka M., authors that have 4 and less articles are not depicted here. At the same time, it was seen that there were many authors that have 2 or more publications – 260 authors (app. 24%), that could prove the sustainability of the mentioned topic.





Source: own research

The authors were also analyzed from the point of view of their cooperation on the topic. It was found that although the majority of papers were created by a group of authors, the cooperation between different groups is weak. For the analysis of author cooperation, a VOSviewer software was used and all the authors were included in the cooperation analysis. In Figure 3 only the authors that work in cooperation (there were 344 chosen by the program) are presented. As could be seen the cooperation between authors in this field is much higher in Asia and all these authors were divided into 29 clusters based on their cooperation. So, it is possible to say that although the cooperation between authors on the topic of Logistics and Simulation exists, it is low.

To better understand the correlation between the cooperation of authors and the number of published works, the same analysis for cooperation between authors was made in VOSviewer software. The minimum amount of published papers by an author was set to 5. All the authors have already been mentioned in Figure 2. As it Figure 4 depicts, the cooperation between authors who wrote the majority of papers is weak. Although there are several authors that work in cooperation, there are some authors that don't cooperate on this topic. The best cooperation was found to be between 5 groups of authors that are:

1st group: Liu L., Wang X. (cooperate with other teams), Wu Y. (cooperate with other teams), Yang B. (cooperate with other teams), Zhou L.;

2d group: Li L., Liu Y. (cooperate with other teams), Wang Y., Wu S.;

3d group: Chen Y. (cooperate with other teams), Li X. (cooperate with other teams), Liu X. (cooperate with other teams);

 4^{th} group: Liu M. (cooperate with other teams), Wang K. (cooperate with other teams);

 $5^{\rm th}$ group: Wang L. (cooperate with other teams), Zhang Z. (cooperate with other teams).





Source: own research (VOSviewer software was used)

Figure 4. Cooperation between authors who wrote more than 5 papers



Source: own research (VOSviewer software was used)

Considering the weak cooperation between authors an attempt was made to assess the cooperation between countries on this topic and it was found out that although their cooperation is not strong in some cases (as the parameters were set to 1 publication by a country), some countries have several connections on the topic. 15 clusters of cooperation were identified by the VOSviewer software where from 3 to 10 countries were cooperating (the clusters are shown in color). As could be seen in Figure 5, the leaders are China, the USA, Germany, and Italy.





Source: own research (VOSviewer software was used)

The constantly growing importance of the given topic could also be proven by the number of publications per year. As it could be seen in Figure 6, the number of publications rose from up to 10 till 2001 to above 40 starting from 2009. Although some fluctuations could be seen in different years, it is still obvious that in the last decade the topic connected with the usage of simulation and simulation tools for logistics and transportation remains important and gets high interest from researchers. As it could be seen, the highest amount of publications on this topic was made in 2009 when 84 papers on the topic were published. However, there is a decrease in the following years in the number of publications per year, the number is still high with 43 papers in 2020 and 69 in 2021. It is not yet possible to fully assess the year 2022 as the data for the research is gathered in August of 2022 and the year is still in progress, however, it is already seen that the combination of Logistics and Simulation remains critical, because up to date there have been 37 papers published already.



Figure 6. The number of publications per year

To better understand the tendencies in the field, a word cloud was created for the author key words. The word cloud was generated with the help of the word cloud generator at https://monkeylearn.com/word-cloud. As it could be seen from the word cloud (Figure 7) the most popular words, that are mentioned much more often than the others are "Simulation" and "Logistics". These words are closely followed by the following group of words that are also mentioned in many papers: Supplies chain, optimization, modeling, events, logistics systems events simulation. Other words that could be seen in the word cloud are also important for the research as they may provide new ideas and/or directions for future research and help authors to concentrate on something that has already been investigated by other authors. This could help to understand the general tendencies of the topic and identify the major focus of the researchers that have already published their works. This word cloud could also improve the search related to the study as it might provide some deeper insights on the general search topics.





Source: own research (with the help of word cloud generator at https://monkeylearn.com/word-cloud)

Following the construction of the word cloud, a map was constructed showing the connections between different keywords. For this purpose, a software program called VOSviewer was used. The minimum number of keyword occurrences was set to 7 to provide the visual information that can be analyzed. Thus, 44 keywords were chosen by the program. As could be seen in Figure 8, all the keywords can be classified into 8 clusters that are different in color and contains from 2 to 11 items per cluster. For a better understanding of the clusters and their compounds they are given below:

Cluster 1 (red) 11 items: container terminal, decision support system, discrete event simulation, flex sim, logistics center, logistics simulation, logistics system, modeling and simulation, production logistics system, simulation model, vehicle routing problem.

Cluster 2 (green) 7 items: modeling, optimization, petri nets, RFID, scheduling, simulation, transport.

Cluster 3 (blue) 7 items: discrete simulation, discrete-event simulation, logistics, modelling, production, simulation modelling, virtual reality.

Cluster 4 (yellow) 6 items: agent-based simulation, reverse logistics, simulation modelling, supply chain, sustainability, urban logistics.

Cluster 5 (purple) 5 items: cellular automata, logistics, logistic regression, monte carlo simulation, system dynamics.

Cluster 6 (light blue) 3 items: computer simulation, production logistics, witness.

Cluster 7 (orange) 3 items: arena, supply chain management, transportation.

Cluster 8 (brown) 2 items: city logistics, evaluation.

Figure 8. Key words co-occurrence



Source: own research with the usage of VOSviewer software.

The bibliometric research presented in this paper describes the general trend for the topic where Simulation and Logistics are combined. As it has already been stated the analysis has several limitations that should be considered.

5. CONCLUSION

The aim of this paper was to investigate the combination of Logistics and Simulation in order to identify future research perspectives based on bibliometric research. As the importance of simulation for logistics has already proven itself and the interest is still growing following the trends of process optimization and savings, the combination of the notions of Logistics and Simulation should also be measured in order to provide authors with the necessary information for future research.

The bibliometric research provided data on the existing situation and trends connected with Logistics and Simulation. It was found that the most popular venue for discussion related to the mentioned topic is Winter Simulation Conference, as it has the highest amount of all the works published in this field. Moreover, the number of papers published during the Winter Simulation Conference proceedings is incomparable to other sources connected with this topic. It was also noted that some authors specialize in this topic with the highest number of 9 publications per author and more than 20 % of all of the authors have several publications on the related topic. It was also assessed that the number of publications per year grew significantly in 2009 and remains high in the last decade, although with some slight fluctuations. This could also prove the stable interest in this topic. Considering all these trends it is possible to state that the interest in this field remains solid and future research in this field will continue to answer the research gaps connected with the fast development of modern technologies.

Further research in this field should consider the research limitations i.e. language of the research and type of document that was analyzed, moreover, possible analysis of the difference between countries and/or continents that could provide a better understanding of the focus of different parts of the world. As several research gaps were mentioned in the theoretical part of the research, such as data standardization for logistics processes, further development of technologies and their application, and influence on the simulation and optimization in logistics, these gaps can also be further investigated and assessed in the future. The lack of cooperation between authors and weak cooperation between countries that were identified in this research may also provide an impulse for future work, especially on the basis of comparison and sharing the experience.

Thus, the specialist, considering the implementation of Simulation for Logistics processes or researchers working in the field of Logistics and considering process simulation, should consider the results of the research as it proves the importance and efficiency of the application of simulation for logistics purposes.

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