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Subject review
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Logistics 4.0: Challenges, Opportunities and Threats

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Abstract: Climate change, the main accelerator of which has been consumerism and the industry driving it, soon will force companies to make changes that will intensify their activities in the natural environment. The Covid-19 pandemic, Due to their specificity, has disrupted global supply chains on an unprecedented scale. In addition, the progress of the analysis supported by the assumptions and tools of Industry 4.0 (I4.0) opens unlimited development opportunities. These changes also have a significant impact on Logistics, making the concept of Logistics 4.0 (L4.0) increasingly popular. The scope of defining L4.0 varies from the use of individual I4.0 tools to the presentation of complex models. This paper presents a literature review using the STAR method on the L4.0 concept to identify the scope of its determinants and possible perspectives for the development of logistics in the context of I4.0 and the challenges mentioned.

Keywords: Industry 4.0; Logistics 4.0; STAR

1 INTRODUCTION

The subject of L4.0 is a consequence of the emergence of the concept of I4.0, which was presented in 2011 as a strategic initiative of the German government in terms of the development of the sphere of high technologies and industrialization. It can be assumed that it is therefore a logical continuation of expanding the I4.0 concept to include other functional areas of the company.

The very concept of I4.0 often occurs in parallel with the term the 4th Industrial Revolution (4IR). It significantly changes the existing paradigms in the field of innovation, which by combining technologies blurs the boundaries between the physical, biological, and digital worlds [1]. Visible growth in collecting and storing data about everyone and everything, their processing, supported by ubiquitous telecommunications processes, opens new development opportunities not only for industry, but also for societies [2].

Federico (et al.) indicated 21 new technologies, which they defined as the I4.0 technological lever and included: Internet of Things (IoT), Smart Products (SP), Smart Machines (SM), Cyber-Security & Blockchain (CSB), Artificial Intelligence (AI), Automation (At), Big Data Analytics (BDA), Cloud Technologies (CT), Machine to Machine Communication (M2M), Radio Frequency Identification (RFID), Sensors Technologies (ST), Digitalization (Dt), Robotics (Rb), Omni Channel (OC), Optimization Systems (OS), Business Intelligence (BI), 3D-Printing (3Dp), Mobile Apps (MA), Enterprise Resources Planning (ERP), Augmented Reality (AR) and Nanotechnology (Nt). Roblek (et al.) under 4.0 also pointed to the technologies Internet of Services (IoS), Cyber-Physical Systems (CPS), Human to Human (H2H) and Human to Machine (H2M) communication via the Internet, Integrated Customer Relationship Management (ICRM) – CRM and social media (SocM) [3]. Zheng (et al.) added, Additive Manufacturing (AM), Virtual Reality (VR), Simulation and Modeling (S&M) and Visualization Technology (VT) combined with 3D-Printing (3-DP) [4]. Extending this issue with Autonomic Vehicles (AV) or the increasingly developing drone technology, it can be said that technologically the world has become ready to change the existing paradigms in the sphere of managing functional areas of the organization, including logistics.

The presented I4.0 technologies show great application potential. However, it should be noted that their application possibilities are currently limited only by the technological imperfection of 3-DP and the operating paradigms applicable in enterprises, based mainly on the second and third industrial revolution. Perhaps the third decade of the 21st century is the moment when you can question the existing, selected laws of industry functioning in favor of the opportunities created by I4.0 technologies.

2 MATERIAL AND METHODS

In the era of such a significant digitization of literature, scientific and research work has been greatly facilitated in terms of access to scientific publications. Virtually anywhere in the world where there is access to the Internet, a researcher can browse and analyze many publications. And it is this number of publications that is often a big problem. It involves the proper selection and analysis of large collections of publications, which would be impossible in the aspect of a traditional literature review. A valuable method that makes it possible to solve this problem is a literature review.

There are many types and models of literature review. Booth, Sutton and Papaioannou [5] proposed, for example, the SALSA (Search, Appraisal, Synthesis, Analysis) model, which can take various forms depending on the types of literature review.

Table 1 Selection of the type of literature review [5]

SALSA Stages	STAR	SYSTEMATIC
SEARCH	Comprehensive research of recent literature	Exhausting
APPRAISAL	Lack	Possible
SYNTHESIS	Narrative or tabular	Narrative or tabular
ANALYSIS	Current state of knowledge, indications for future research, as well as their limitations	Current state of knowledge, practical recommendations

From the point of view of the topic of the discussed issue, as well as the research questions, both the State-of-The-Art review and the Systematic search and review approach can be applied here (Tab. 1).

In the article, it was decided to use the STAR research method, as it corresponds to the subject of the issue and the purpose of the presented work. The STAR method allows for a review of the latest, at the same time setting further research directions [6].

While reviewing the literature using the STAR method, the primary research scheme proposed by Cooper was used, consisting of the following steps:

- Formulating the research problem.
- Data collection:
- Selection of databases in which publications will be searched.
- Specify keywords and search restrictions.
- Identification of the collection of publications.
- Selection of publications within a separate set [7].
- Data evaluation.
- Analysis and interpretation.
- Presentation of the results.

The research problem was formulated using five basic research questions presented below.

1) How many publications are currently available that have the term L4.0 in the title?
2) In what scientific areas is the concept of L4.0 defined?
3) How is the concept of L4.0 defined?
4) What general models of L4.0 appear in the analyzed literature?
5) What challenges, opportunities and threats are faced by L4.0?

To answer the first four research questions, a literature review using the STAR method, the theoretical basis of which was described above. The answer to the fifth research question will be an original analysis and interpretation resulting from the STAR literature review.

The second stage was data collection. Among the deliberately selected databases in which the search for publications was started, there were two most popular bibliometric and abstract databases, i.e., Scopus (SCPS) and Web of Science (WoS). As part of the database search process, the following criteria were formulated:

- The word "Logistics 4.0" should appear in the title of the publication.
- The time horizon of the searched databases was 8 years (since 2015, when the first publications with keywords according to the Scopus and Web of Science databases began to appear).
- Type of sources: scientific journals, electronic books, proceedings papers.
- The publication language is English.
- Publications had full access under Open Access, Full Text Finder, or Full Text Open Access.

The collected database of publications made it possible to proceed to the next stages, i.e., data evaluation, analysis, and interpretation, which will be presented in the next chapter.

3 RESULTS

The evaluation and analysis of the collected data was carried out in terms of the criteria listed in Chapter 2. Then, an additional data evaluation and analysis sheet was created, the task of which was to indicate quantitatively the titles containing the key word in the analyzed databases, separately for publications in scientific journals and books, and for publications published under Proceedings Papers. The total number of publications identified in bibliometric and abstract databases is presented in Tab. 2.

Table 2 Number of publications in scientific journals and books containing the word "Logistics 4.0" from 2015 to 2022

	2015	2016	2017	2018	2019	2020	2021	2022	Total
WoS	1	0	1	1	5	8	11	20	47
SCPS	0	0	1	0	4	13	19	25	62

Table 3 Scope of publications in scientific journals and books containing the word "Logistics 4.0" from 2015 to 2022

SCPS			WoS
Engineering	28	39	Engineering Industrial, Manufacturing, Electrical Electronic, Multidisciplinary, Mechanical, Chemical, Civil, Environmental
Business, Management and Accounting	23	26	Management, Business, Operation Research Management Science
Computer Science	17	9	Computer Science Information Systems, Artificial Intelligence, Interdisciplinary Application, Theory and Methods, Telecommunications
Environmental Science	8	27	Environmental Sciences, Studies, Green Sustainable Science Technology,
Decision Sciences	10	1	Statistics Probability
Social Sciences	10	1	Psychology Applied,
Economics, Econometrics and Finance	7	1	Economics
Materials Science	7	0	Materials Science Multidisciplinary,
Physics and Astronomy	6	5	Physics Applied,
Energy	5	0	No Similar
No Similar	0	3	Transportation, Transportation Science Technology,
No Similar	0	7	Chemistry Multidisciplinary, Analytical,
No Similar	0	4	Others Instruments Instrumentation, Ergonomics, Mathematics,

Another element of the research was to specify the thematic scope of the discussed publications. For this purpose, not fully compatible scope from the analyzed databases were used, e.g., in the SCPS database there was the thematic scope of Engineering, while in the WoS database the thematic scope of Engineering was additionally defined, e.g., Engineering Industrial or Engineering Manufacturing. In this way, related thematic SCPS were assigned, also showing those areas that had no equivalents, e.g., Energy.

This meant that in the SCPS database, there was a publication that was classified in the Energy thematic scope, while in the WoS database, there was no such publication. In a similar way, thematic areas related to Transportation, Chemistry, Ergonomic or Mathematics appeared in the WoS database, the equivalents of which could not be found in the Scopus database.

It should also be noted that each of the titles could be assigned to several thematic areas, therefore the data presented in Tab. 2 do not coincide quantitatively with the data presented in Tab. 3. The results of literature research also show that the largest number of titles containing a keyword appear in the areas (in the case of the WoS database, the cut-off point of 80/20 appears here - the Pareto principle) and Environmental Science (in the case of the SCPS database, the distribution is slightly more linear, and the areas of Decision Science, Social Science or Economics should be added). The thematic scope of publications in scientific journals and books with the title "Logistics 4.0" is presented in Tab. 3.

Table 4 Number of publications in proceedings papers containing the word "Logistics 4.0" from 2015 to 2022

	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
WoS	1	1	4	7	25	17	5	12	1	73
SCPS	0	1	1	5	17	12	7	10	2	55

Table 5 Scope of publications in proceedings papers containing the word "Logistics 4.0" from 2015-2022

SCPS			WoS
Engineering	30	48	Engineering Manufacturing, Industrial, Electrical Electronic, Civil, Multidisciplinary,
Computer Science	30	46	Computer Science Artificial Intelligence, Interdisciplinary Applications, Theory and Methods, Software Engineering, Information Systems, Telecommunications and Cybernetics
Business, Management and Accounting	19	30	Operation Research Management Science, Business, Management,
Decision Sciences	20	1	Statistics Probability
Social Sciences	2	10	Education Educational Research, Education Scientific Disciplines, Social Science Interdisciplinary
Environmental Science	5	7	Environmental Sciences, Studies, Green Sustainable Science Technology,
Economics, Econometrics and Finance	0	1	Economics
Materials Science	1	0	No Similar
Physics and Astronomy	2	0	No Similar
Energy	1	0	No Similar
No Similar	0	5	Transportation Science Technology, Transportation,
No Similar	0	3	Chemistry Multidisciplinary, Analytical,
No Similar	0	7	Automation Control Systems, Robotics
Other Mathematics, Medicine, Earth, and Planetary Science	13	2	Others Ergonomics

In the case of publications included in Proceeding papers, a slightly higher number of publications was identified in the case of the WoS database and a slightly smaller number of publications in the case of the SCPS database.

As in the case of the first group of publications, the most important subject areas include Engineering, Computer Science, Decision Science, Business and Management (and the names assigned to them from the Web of Science database), which is shown in Tab. 5.

Due to the optimization of the volume of the presented publication, in the next part of the work it was decided to use only publications available as scientific articles and available books – proceeding's papers were rejected. In total, we managed to gain access to 52 publications, of which 16 titles were repeated in both databases. This means that a total of 36 publications were included in the analysis. In the SCPS database, 4 unique titles were identified in the WoS database, similarly, in the WoS database, 16 unique titles were identified in the SCPS database.

The next step in implementing the research goals set before the article was a critical review of the collected articles in terms of defining the concept of Logistics 4.0.

From the conducted analysis, it was proposed to identify the following contexts for defining logistics 4.0:

I. Using Industry 4.0 tools in logistics.
II. Logistics 4.0 and the issue of managing organizations and economic aspects.
III. Creating new Logistics 4.0 models or definitional and conceptual assumptions for these models (Fig. 1).

As can be seen from Fig. 1, the largest number of titles of publications with L4.0 in the title refer to the economic management context, approx. 42%. In second place are publications that draw attention to the use of I4.0 tools in various areas and logistics processes. Articles focusing on conceptual-definitional and model aspects are only in third place.

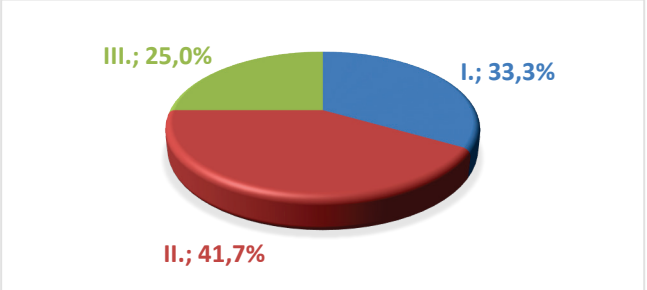

Figure 1 Definition contexts of the concept Logistics 4.0

The first context of defining logistics referred to the use of single or multiple I4.0 tools in logistics, logistics concepts, processes, logistics phases. Publications related to:

A. Single or multiple I4.0 tools used in logistics, e.g., blockchain.
B. I4.0 tools in the context of existing logistics concepts (Lean, Agile, LeAgile, Resilient, Green, Total Logistics Management, and others).

C. Use of I4.0 tools in specific logistics processes (e.g., transport, packaging, storage, order processing, inventory management).
D. The use of I4.0 tools in specific logistics phases (procurement, production, distribution, returns and disposal) – Fig. 2.

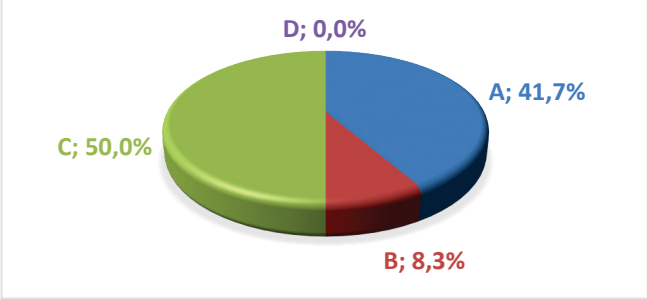

Figure 2 Context of defining logistics relating to the use of single or multiple I4.0 tools in logistics, logistics concepts, processes, logistics phases.

Fig. 2 shows that the largest number of analyzed publications relate to the use of single or multiple I4.0 tools in general logistics. Attention is drawn here to the technology used and its possibilities of application in logistics [8, 9] or very specific areas of it [10, 11] rather than to specific logistics processes [12] or logistics phases.

The second analyzed group consisted of articles relating to the broadly understood spheres of management and economics. Publications related to:

E. Management of functional areas of the organization in the context of the use of individual I4.0 tools - including, for example, social capital, outsourcing.
F. Absorption of knowledge and innovation.
G. Economic issues, current socio-economic trends e.g., sustainability and circular economy, and the use of I4.0 tools in specific industries – Fig. 3.

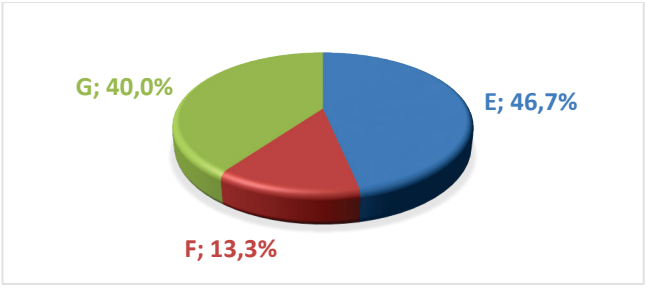

Figure 3 Context of defining logistics articles relating to the broadly understood spheres of management and economics.

As can be seen from Fig. 3, the largest number of publications in this group, i.e., about 47%, is occupied by publications relating to the spheres of organization management, e.g., social capital [13]. The next group consists of articles with the word L4.0 in the title referring to economic issues, economic and social trends, and specific industries [14] - 40%. The smallest group are publications on the absorption of knowledge and innovation, e.g. [15].

The third analyzed group of publication titles were those that referred to model and definitional contexts. In this way, works related to:

H. Models of Logistics 4.0.
I. Logistics 4.0 measurement models.
J. Logistics 4.0 maturity models.
K. Definition of Logistics 4.0 – Fig. 4.

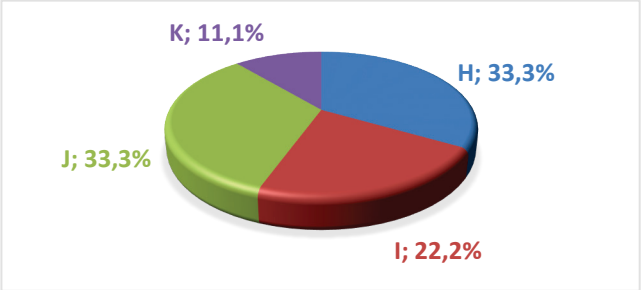

Figure 4 Context of defining logistics articles relating to model and definitional contexts.

The largest number of publications containing the L4.0 keywords applies equally to the general L4.0 models [16] and the L4.0 maturity models [17] – over 66% in total. L4.0 measurement models [18] and definitional issues [19] account for approximately 22% and 11%, respectively.

The literature review shows that the very concept of Logistics 4.0, in most cases, means issues of logistics management using selected I4.0 tools. Models whose aim would be to capture the entire L4.0 system, understood as a deliberately designed and organized cyber-physical system that implements broadly understood logistics issues, appear much less frequently.

To answer the fifth research question, three articles (from the searched group of publications containing the keyword Logistics 4.0 in the title) referring to the issue of the model approach to L4.0 were analyzed in detail.

The first of them by Strandhagen (et al.) [20] rightly combines the issue of logistics, the assumptions of I4.0 and the issue of sustainable development. It indicates eight basic trends in Logistics 4.0, which the authors include:

- Individualization.
- Servitization.
- Accessibility.
- Autonomy.
- Global network.
- Digitalization.
- Green logistics/circular economy.
- Sharing economy/collaboration.

Winkelhouse and Grosse [21], in turn, distinguish three basic elements within the L4.0 conceptual framework, i.e.:

- Technological blocks containing I4.0 technologies and digital transformation technologies.
- External changes related to the change of paradigms of mass production to mass personalization and individualization of products,
- Shortening of product life cycles,
- Issues of sustainable development and globalization.

As part of the inductive refinement of the L4.0 framework, they divide technological blocks into three basic stages related to information, i.e.: generation, handling and

use, in which selected technologies or I4.0 tools are used (e.g., IoT, CPS, CT, SocM) or Mobile Systems (MS). In turn, external changes were also divided into three groups, but slightly different: customer, market, and environment. On this basis, the L4.0 model, based on the existing paradigms of time, quality, cost, implements in individual phases and logistics processes, with the involvement of social capital based on socio-technical interactions, knowledge, and resources as well as system operators and administrators, as well as technological blocks - activities aimed at to cope with external changes [22].

The issues of sustainable development in the L4.0 model were also discussed by Bag's (et al.) [23]. They divided the L4.0 capabilities into technological, organizational, and environmental capabilities, and on this basis, they attempted to assess the company's performance. They have shown in their research that the impact of technological and environmental capabilities is stronger than the impact of organizational capabilities. Building L4.0 resources should focus more on dynamic technological and environmental capabilities rather than on organizational capabilities. Thus, the pressure of managers on the above-mentioned areas allows you to develop the capabilities of L4.0, and thus improve the agility, flexibility, and responsiveness of the organization [24].

In addition to the critical literature review presented in the paper, it is worth noting that Federico (et al.) [25] presented the theoretical structure of the Supply Chain 4.0 concept (SC4.0), which in a way refers to the theoretical constructs of the L4.0 models. They distinguished four basic pillars of SC4.0, which included leadership and social capital, technological levers based on I4.0 solutions, SC4.0 considering the concept of End to End (E2E) and defining measurements and requirements for processes. All this should contribute to the strategic results regarding the agility, flexibility or responsiveness of the organization mentioned by Bag's (et al.).

As you can see, the presented models have many common features, such as the use of I4.0 tools or the proper use of human capital. It seems, however, that they omit at least a few key elements that may pose serious challenges for enterprises wishing to follow the assumptions of the L4.0 concept, which will be discussed in the next chapter.

4 DISCUSSIONS

The presented answers to the first four research questions allow to indicate the current trends in the development of logistics and supply chains. The answer to the fifth research question requires a critical analysis of the publication in the context of the challenges, opportunities and threats that face the assumptions of the L4.0 concept.

When analyzing the collected literature, it should be noted that it seems to omit several key aspects that can be categorized in two areas: geo-political-social and technological. These issues, at the beginning of the third decade of the 21st century, are clearly felt from the point of view of practical aspects of logistics and supply chains in the world. What's more, these phenomena have not occurred on such a scale in recent decades, which is why they deserve attention even more. Geo-political and social issues include:

- The ongoing Covid19 pandemic, which certainly changes its face over time, thus hindering the predictability of economic phenomena.
- The ongoing conflict in Ukraine and other armed conflicts destabilizing global supply chains.
- Natural disasters and dynamic weather changes resulting from the deteriorating condition of the natural environment.
- The issue of the I-Gen (Internet Generation) society entering adulthood, which is very different from the previous X, Y and Z generations [26], the development of Society 5.0 (S 5.0) and Evergetics [27].

When it comes to technological aspects, the basic elements include:

- Considering the consequences of the introduction of 3-DP for logistics and supply chains.
- Legal regulations regarding the functioning of SF and its technology, their taxation, etc.
- The issue of access to AI – ChatGPT.
- Critical analysis of the use of thinking robots (perhaps also sentient robots due to artificial intelligence - which was brilliantly touched upon by Nobel Prize winner Ishiguro in his novel Klara and The Sun [28]).

As you can see, in addition to the opportunities presented by the development of civilization, including IV IR, there are several challenges and threats that should already be the subject of scientific research. In the realm of Geo-political and social issues, these include, for example:

- The presentation of business models no longer based on global supply chains (which was strongly verified by Covid).
- Exploring mediating conditions in areas of the world that are permanently threatened by armed conflicts, with a view to avoiding them, and building models for the functioning of economies in such crises,
- Identification of factors that allow for the simultaneous implementation sustainable development and the circular economy goals with existing business models.
- Social changes resulting from the large-scale use of information technology (IT) by people, profoundly changing the perception of knowledge, creativity, but also the very behavior of the I-Gen and younger generations in the context of, for example, education or the labour market.
- The conditions for the implementation of production and logistics activities under conditions of severely limited resources, turbulent climate change and high product personalization.

In the technological area, these include, for example:

- The use of additive manufacturing (e.g., 3-DP) on a mass scale, which may lead to changes in existing paradigms in the areas of logistics, production and quality stemming resulting from of the 2nd IR and 3rd IR.

- The use of IoT or the Internet of Everything (IoE) technologies, which will soon replace a large part of the processes at the interface of human-machine communication with M2M communication.
- The impact of augmented and virtual reality on human perception and the brain, especially when tools such as augmented reality glasses are used, for example, for logistics processes.
- The security of bigdata, which is set to increase through widespread digitalization, and the potential risks posed by criminal activity in the bigdata sphere.
- The effects of the application of AI, which through the aggregation of knowledge can generate ideas and projects hitherto unheard of (the question is also whether they are also safe for humans).

There are many areas where science and practice meet in the case of L4.0. The available technologies, allow fundamentally change the current industrial, economic, or social reality. However, these changes are too slow for the increasing number of challenges that are emerging, because they require a fresh, new perspective. An approach that in many cases will have to break away from existing laws, assumptions, and industrial paradigms in favor of completely new, often revolutionary solutions.

5 CONCLUSIONS

The presented review of the literature using the STAR method allowed to answer the research questions by indicating both the subject of publications related to the L4.0 issues and to indicate the existing achievements in this field. The main fields of knowledge in which the concept of L4.0 is situated were defined, and publications were selected in terms of definitional contexts. Finally, the L4.0 models presented in the analyzed publications are briefly discussed. Space was also left for further research of publications appearing as part of the Proceedings Papers.

Areas that have not yet been included in the literature analysis described have been indicated. This is probably due to the unlimited possibilities offered by the I4.0 concept and the need to have multidisciplinary knowledge that would enable an attempt to build this type of comprehensive models - logistics of the future – L4.0.

In such disciplines as economics or management sciences, it is very difficult to clearly indicate what an opportunity is, what a threat is, and what an opportunity for development is, because in general a given issue has its multi-contextual nature. Therefore, the presented article should be the beginning of a discussion on the modification of the existing production, logistics or quality paradigms towards the future development of I4.0, based on which logistics and supply chains would develop. Development that would be sustainable at the same time, caring primarily for the planet and the well-being of people.

It is also important to note the limitations of the research. The first limitation is the fact of selecting articles that only contained the word Logistics 4.0 in the title. Certainly, research containing the word Logistics 4.0 not only in the title, but also in the keywords and in the abstracts would have been much more detailed. The second limitation was the fact that only bibliometric-abstract databases such as WoS and SCPS were searched. This may in some ways leave out articles or conference proceedings that are not included in these databases. A third limitation is the incompatibility of the subject areas of the two databases, which significantly hinders the research.

Further research directions will develop in expanding the scope of keywords (e.g., Logistics 4.0, L4.0, Supply Chain 4, Supply Chain Management 4.0, etc.) and the scope of searches (title, keywords and abstract). In further research, it is also planned to extend the searched databases to identify comprehensive models that consider the characteristics of I4.0 in supply chains and logistics processes.

6 REFERENCES

[1] Kodama, F. (2018). Learning Mode and strategic Concept for the 4th Industrial Revolution. *Journal of Open Innovation: Technology, Market, and Complexity, 32*(4), p. 1. https://doi.org/10.3390/joitmc4030032

[2] French, A. M., Jain, H., Larsen, K. R, Risius, M., & Shim, J. P. (2021). The 4th Industrial Revolution Powered by the Integration of AI, Blockchain, and 5G. *Communication of the Association for Information Systems, 49*(10), p. 267. https://doi.org/10.17705/1CAIS.04910

[3] Roblek, V., Mesko, M., & Krapez, A. (2016). A Complex View of Industry 4.0. *SageOpen, 6*(2), 1-3. https://doi.org/10.1177/2158244016653987

[4] Zheng, T., Ardolino, M., Bacchetti, A., & Perona, M. (2021). The applications of Industry 4.0 technologies in manufacturing context: a systematic literature review. *International Journal of Production Research, 59*(6), 1923-1924. https://doi.org/10.1080/00207543.2020.1824085

[5] Booth, A., Sutton, A., & Papaioannou, D. (2012). *Systematic approaches to a successful literature review*. Los Angeles: Sage, 24-26.

[6] Wondimu, N. A., Visser, U., & Buche, C. (2022). Interactive Machine Learning: A State-of-the-Art Review. https://arxiv.org/abs/2207.06196. https://doi.org/10.48550/arXiv.2207.06196

[7] Rowley, J. & Slack, F. (2004). Conducting a Literature Review. *Management Research News, 27*(6). https://doi.org/10.1108/01409170410784185

[8] Kim, E., Kim, Y., & Park, J. (2022). The Necessity of Introducing Autonomous Trucks in Logistics 4.0. *Sustainability, 14*, 3978. https://doi.org/10.3390/su14073978

[9] Tubis, A. & Poturaj, H. (2021). Challenges in the implementation of autonomous robots in the process of feeding materials on the production line as part of Logistics 4.0. *LogForum, 17*(3), 411-432. https://doi.org/10.17270/J.LOG.2021.611

[10] Chen, Y-T., Sun, E., Chang, M-F., & Lin, Y-B. (2021). Pragmatic real-time logistics management with traffic IoT infrastructure: Big data predictive analytics of freight travel time for Logistics 4.0. *International Journal of Production Economics, 238*, 108157. https://doi.org/10.1016/j.ijpe.2021.108157

[11] Di Nardo, M., Clericuzio, M., Murino, T., & Sepe, Ch. (2020). An Economic Order Quantity Stochastic Dynamic Optimization Model in a Logistic 4.0 Environment. *Sustainability, 12*, 4075. https://doi.org/10.3390/su12104075

[12] Perotti, S., Bastidas Santacruz, R. F., Bremer, P., & Beer, J. E. (2022). Logistics 4.0 in warehousing: a conceptual framework of influencing factors, benefits and barriers. *The International Journal of Logistics Management, 33*(5), 193-220. https://doi.org/10.1108/IJLM-02-2022-0068
[13] Lagorio, A., Cimini, C., Pirola, F., & Pinto, R. (2021). A taxonomy of technologies for human-centered logistics 4.0. *Applied Sciences, 11*(20). https://doi.org/10.3390/app11209661
[14] Zoubek, M., Simon, M., & Poor, P. (2022). Overall Readiness of Logistics 4.0: A Comparative Study of Automotive, Manufacturing, and Electronics Industries in the West Bohemian Region (Czech Republic). *Applied Science, 12*(11). https://doi.org/10.3390/app12157789
[15] Stachowiak, A., Adamczak, M., Hadas, L, Domański, R., & Cyplik, P. (2019). Knowledge Absorption Capacity as a Factor for Increasing Logistics 4.0 Maturity. *Applied Sciences, 9*(24). https://doi.org/10.3390/app9245365
[16] Strandhagen, J., Vallandingham, L., Fragapane, G., Strandhagen, J., Stangeland, A., & Sharma, N. (2017). Logistics 4.0 and emerging sustainable business models. *Advances in Manufacturing, 5*, 359-369. https://doi.org/10.1007/s40436-017-0198-1
[17] Zoubek, M. & Michal, S. (2021). A framework for a logistics 4.0 maturity model with a specification for internal logistics. *MM Science Journal*, 4264-4274. https://doi.org/10.17973/MMSJ.2021_03_2020073
[18] Dallasega, P., Woschank, M., Sarkis, J., & Tippayawong, K. Y. (2022). Logistics 4.0 measurement model: empirical validation based on an international survey. *Industrial Management & Data Systems, 122*(5), 1384-1409. https://doi.org/10.1108/IMDS-11-2021-0694
[19] Amr, M., Ezzat, M., & Kassem, S. (2019). Logistics 4.0: Definition and historical background. *Novel Intelligent and Leading Emerging Sciences Conference (NILES) - IEEE*, 1, 46-49. https://doi.org/10.1109/NILES.2019.8909314
[20] Strandhagen, J. O., Vallandingham, L. R., Fragapane, G. et al. (2017). Logistics 4.0 and emerging sustainable business models. *Advances in Manufacturing, 5*, 366-367. https://doi.org/10.1007/s40436-017-0198-1
[21] Winkelhaus, S. & Grosse, E. (2020). Logistics 4.0: a systematic review towards a new logistics system. *International Journal of Production Research, 58*(1), p. 21. https://doi.org/10.1080/00207543.2019.1612964
[22] Winkelhaus, S. & Grosse, E. (2020). Logistics 4.0: a systematic review towards a new logistics system. *International Journal of Production Research, 58*(1), p. 34. https://doi.org/10.1080/00207543.2019.1612964
[23] Bag, S., Gupta, S., & Luo, Z. (2020). Examining the role of logistics 4.0 enabled dynamic capabilities on firm performance. *The International Journal of Logistics Management, 31*(3), 607-628. https://doi.org/10.1108/IJLM-11-2019-0311
[24] Bag, S., Gupta, S., & Luo, Z. (2020). Examining the role of logistics 4.0 enabled dynamic capabilities on firm performance. *The International Journal of Logistics Management, 31*(3), p. 620. https://doi.org/10.1108/IJLM-11-2019-0311
[25] Frederico, G. F., Garza-Reyes, J. A., Anosike, A., & Kumar, V. (2019). Supply Chain 4.0: Concepts, Maturity and Research Agenda. *Supply Chain Management*, p. 18. https://doi.org/10.1108/SCM-09-2018-0339
[26] Twenge, J. (2018). *iGen: Why Today's Super-Connected Kids Are Growing Up Less Rebellious, More Tolerant, Less Happy--and Completely Unprepared for Adulthood--and What That Means for the Rest of Us*. Atria Books, Simon & Schuster, Reprint edition, New York.
[27] Skobelev, P. & Borovik, S. (2017). On the Way from Industry 4.0 to Industry 5.0: From Digital Manufacturing to Digital Society. *International Scientific Journal Industry 4.0, 2*(6), 308-309.
[28] Ishiguro, K. (2022). *Klara and the Sun*. Faber & Faber, London.

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