Current State of Knowledge and Research Needs of Intralogistics

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Abstract:

Purpose: *The purpose of this article is to systematize the results of research in the field of intralogistics as a result of a systematic review of the literature based on data from Web of Science and Scopus databases from 2007-2023. The article answers the research questions posed: what is the current state of knowledge about intralogistics, how is the issue of intralogistics developing, what are the main areas and research topics in this subject area, and what are the research needs in the field of intralogistics?*

Design/Methodology/Approach: *The undertaken research issues and the set goal determined the choice of research methods, such as critical literature review, analysis and synthesis methods. VOSwiever and Bibliometrix software were used to visualize the research results.*

Findings: *The widespread digitization and automation of businesses is a topic often discussed in the literature. A key aspect is intralogistics - responsible for the implementation of internal processes based on the efficient flow of information. As a result of the analysis, nine areas of research on intralogistics were identified, which indicate a great diversity of topics. Taking into account the degree of development and importance of intralogistics, four thematic areas were identified.*

Practical Implications: *Current issues being addressed in the field of intralogistics were identified, and topics requiring future research were identified. As a result, the article identifying the state of the art of intralogistics provides theoretical foundations and important information on intralogistics.*

Originality/Value: *This paper addresses a gap in the literature o systematize the existing body of scientific work, indicating the rationale, scope and importance of intralogistics in the enterprise. Systematization of knowledge in the field of intralogistics can be helpful in the exchange of experiences of applied solutions, especially for the small and medium-sized enterprise sector. The article can serve as a basis for further scientific research.*

Keywords: *Organization, logistics 4.0, intralogistics development trends, Industry 4.0, Industry 5.0, automation.*

JEL classification: *D2, O3, P4.*

Paper type: *Research article.*

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1. Introduction

The global marketplace is contributing to increasing stakeholder demands for high-quality products, delivered at the right place and time and at the lowest possible price. Ever-changing consumer buying behaviour demands individualization of production, flexibility and shorter delivery times (Mariotti, 2014; Facchini *et al.,* 2020). The aforementioned factors are driving companies to look for proven solutions to meet market expectations.

Enterprises on the cusp of the Fourth Industrial Revolution are focusing on using new technologies in ways that will increase the efficiency of an organization's operations (Abele *et al.,* 2015; Zoubek and Simon, 2021). Typically, the implementation of such solutions comes down to the application of changes within the organization. The focal point is the areas related to production and logistics, on which most depends in terms of adjusting to changes in the environment.

The challenge is to apply available technologies and equipment in terms of Industry 4.0 (Saniuk *et al.,* 2018; Sytnik *et al.,* 2023), or Industry 5.0 taking into account environmental and social aspects in addition (Broo *et al.,* 2021; Saniuk *et al.,* 2022).

Another of the revolutions involves human-machine cooperation, human-artificial intelligence interaction (Demir *et al.,* 2019; Nahavandi, 2019), taking into account environmental aspects by eliminating harmful impacts on it, and resilience to crises (European Commission, 2021). The solutions available on the market and currently used in companies are linked to automation, digitization, allowing for rapid decision-making, increased flexibility, which consequently affects adaptation to changing consumer requirements (Sartal *et al.,* 2020).

Key technologies include intra-organizational logistics - called intralogistics (VDMA, 2018). The use of intralogistics solutions can assist companies in streamlining material and information flows within the organization, thereby allowing faster response to customer needs (Winkler and Zinsmesiter, 2019; Wagner and Wlochowicz, 2021). However, not all organizations are fully ready for their use, and there is a need to disseminate knowledge about the applicability of available solutions, including employee training (Kadir *et al.,* 2019; Winkelhaus and Grosse, 2020; Neumann *et al.,* 2021; Winkelhaus *et al.,* 2021).

Nowadays, companies are looking for innovative solutions, investing in improvements that will allow for efficient information flow and quick response (Dobini, 2010; Cho and Pucik, 2015). The selection of the right equipment or software determines the speed of goods and information flows, maintaining the quality and efficiency of the logistics processes implemented. Intralogistics is crucial in influencing the optimization of internal processes, increasing flexibility, improving customer service and reducing the risk of product damage or delivery delays (Ashraf *et al.,* 2022).

Given the development of technology, the development of a knowledge area related to intralogistics is essential. To date, no such study has been produced. Based on the available articles, there is no collective study of a topic related to intralogistics.

The available works usually address a selected area of intralogistics (Rochacz and Strassburger, 2021; Fragapane *et al.,* 2021), discussing selected solutions (Dabić - Miletić and Raković, 2023; Unger *et al.,* 2018; Min and Huang, 2022), or examining the human factor (Wagner and Wlochowicz, 2021; Winkelhause *et al.,* 2021).

Therefore, the purpose of this article is to systematize and explore the knowledge of intralogistics by seeking answers to the following research questions:

> *RQ 1: What is the current state of knowledge about intralogistics?*
> *RQ 2: How is the issue of intralogistics developing?*
> *RQ 3: What are the main areas and research topics in this subject area?*
> *RQ 4: What are the research needs on intralogistics?*

Based on a systematic review of the literature, the article attempts to systematize the existing body of scientific work, indicating the rationale, scope and importance of intralogistics in the enterprise. Analysing the progression of this issue, examining the main areas and topics of research at the same time indicates the key research needs. The realization of such a research objective adds value by providing and expanding theoretical and practical knowledge.

VOSwiever and Bibliometrix software were used to visualize the research results. The former was used for cluster analysis, while the latter was used to present a thematic matrix describing research needs.

2. Literature Review

Intralogistics is a relatively new concept in the literature. Its definition was first presented in 2005 at CeMAT in Germany by the International Network of Machinery Manufacturers (VDMA, 2018).

According to VDMA, intralogistics *"encompasses the organization, management, control and optimization of the internal flow of products from inbound to outbound goods, linking the flow of information and services in order to increase the value of the basic offering in industry, commerce and public facilities"* (Hompel and Heidenblut, 2008).

From the definition cited, intralogistics refers to organizations whose activities involve the internal movement of materials. It is applicable to manufacturing companies or those engaged in receiving goods and/or moving them between specific points. It includes subsystems such as warehousing, storage, picking and conveyor and transport systems (Pfohl, 2018; Gudehus, 2010).

In addition, three points are worth noting first, the flow of materials is linked to the flow of information; second, the flows can be applied to various establishments, such as manufacturing companies, distribution centers, rail terminals, ports, airports, and supermarkets, hospitals and similar institutions; and third, good ideas in the area of intralogistics should be disseminated in a useful way, both by system suppliers and users, researchers and industry associations (Dieter, 2006).

Using a program that has a "word cloud" tool, intralogistics was identified. Related concepts to intralogistics are represented by the word cloud shown in Figure 1. It was developed based on definitions and concepts appearing in articles (VDMA, 2018; Hompel and Heiedenblut, 2008; Gudehus, 2010; Dieter, 2006; Wang and Anderl, 2016, Pfohl, 2018; Winkelhause *et al.,* 2021; Zampeta and Chondrokoukis, 2023).

Figure 1. *Word cloud associated with the term Intralogistics*
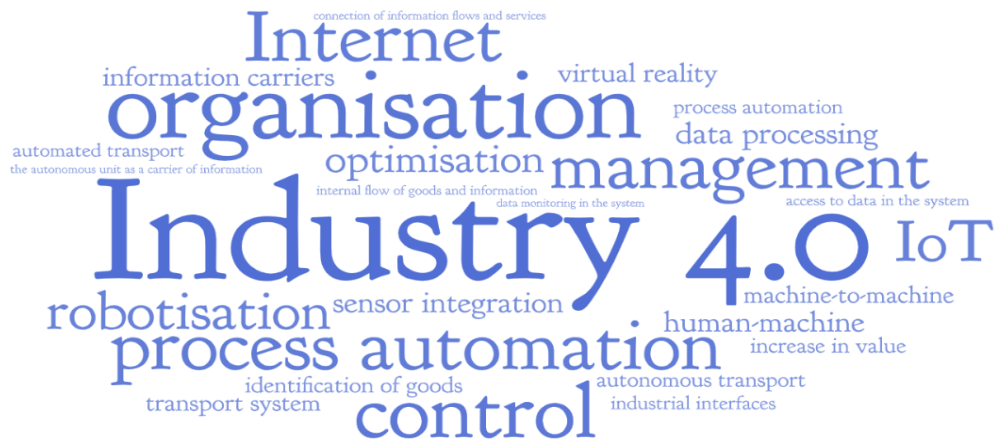
Source: *Own development using wordart.com*

The word cloud presented (Figure 1) shows that:

1. For most definers, intralogistics is generally identified with Industry 4.0 and robotics and process automation. The implementation of available solutions includes, but is not limited to: sensor integrations, data processing on both the machine-to-machine and machine-to-human lines, the use of an appropriate transportation system, the labelling of transported materials as information carriers and the storage of goods along with the monitoring of data in the system (Wang *et. al.,* 2016).

2. The role of intralogistics in the industrial world is playing an increasingly important role, due to the optimization and automation of processes and facilitating the flow of information and materials in the enterprise (Fernandes *et al.,* 2016). It is difficult to disagree with this statement, especially since technological advances,

emerging systems, robots are designed to facilitate human work, automating it, eliminating the possibility of error and streamlining processes in the organization.
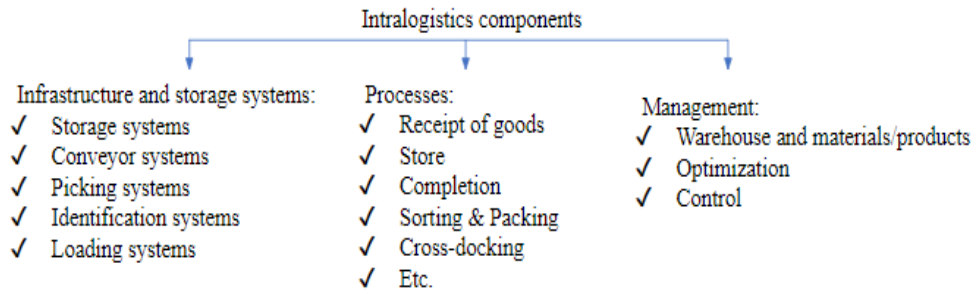
3. Intralogistics can be described as a process aimed at designing appropriate technological solutions to integrate and manage the flow of information and goods between warehouses, production units or distribution centres. Enterprise Resource Planning (ERP) and Warehouse Management Systems (WMS) are used to gather information and manage intralogistics processes. Intralogistics can make it possible to increase the productivity of resources and reduce the operating costs incurred. This is possible with the implementation of IT software, hardware and technology appropriate to the needs of the enterprise, their combination and the ability to use them controlling and processing information flows.

4. Key areas of intralogistics are the use of appropriate infrastructure and storage systems for the implementation of internal logistics processes, management and the use of information technology. Appropriate combination and matching of solutions, promotes transparency of processes, exchange of information and efficient implementation of intended tasks. It can be assumed that intralogistics (Figure 2) consists of three main functional modules:

- Storage infrastructure and systems, i.e., technical equipment selected based on the goods to be handled,
- internal processes,
- management, planning, organizing, controlling and optimizing transport and storage processes of goods and related information flows.

The infrastructure and warehousing systems include tailored storage, conveyors, picking, identification and loading systems. Defined processes include warehouse and transport processes within the organization, i.e. receipt of goods, storage, picking, sorting, packing, internal transport. Management includes: data collection, data analysis for inventory and warehouse management, optimization - including internal transportation management, work organization, unit/product monitoring and control. Information and communication technologies are designed to support the implementation of these activities.

Figure 2. *Components of intralogistics*

Intralogistics components

Infrastructure and storage systems:
✓ Storage systems
✓ Conveyor systems
✓ Picking systems
✓ Identification systems
✓ Loading systems

Processes:
✓ Receipt of goods
✓ Store
✓ Completion
✓ Sorting & Packing
✓ Cross-docking
✓ Etc.

Management:
✓ Warehouse and materials/products
✓ Optimization
✓ Control

Information and communication technologies

Source: Own compilation based on (Rohrhofer and Graf, 2018).

In summary, it can be assumed that intralogistics defines a future-oriented industry, representing all suppliers of conveyor technology, warehouses, systems, services and logistics software, enabling the organization, optimization and control of the flow of materials and information in industry, commerce and public institutions. It emphasizes the use of the right equipment, and thus the right selection of suppliers of equipment, systems, software, along with accompanying services.

3. Methodology

In the literature, articles describing a specific solution belonging to the field of intralogistics are most common (Günther, 2016; Kaspar and Schneider, 2016; Wagner and Wlochowicz, 2021; Rohacz and Strassburger, 2021; Min and Huang, 2022) and their descriptions can be found in trade journals or in summaries of the annual LogiMAT trade fair in Germany (Janiak, 2016) as marketing and advertising material for companies offering such solutions to the market.

Therefore, a systematic literature review method was used to achieve the stated objectives of the article. It allows to understand the complexity of intralogistics, using a variety of perspectives and insights provided by the literature. It enables the collection of data and information scattered in many publications. The research procedure was conducted in December 2023, using the Scopus database, searching for terms used in English "intralogistics" or German "intralogistik." The search was conducted in titles, keywords and abstracts with no time restrictions.

Scopus and Web of Science were selected as bibliographic databases to conduct bibliometric studies. They are considered to be the most important resources due to the wide range of scientific literature from different disciplines (Saher *et al.,* 2024). The huge repositories of these two databases make them invaluable tools for tracking and analysing trends in academic research.

The search identified 502 publications. The second stage excluded publications that:

- addressed topics outside the field of management - 368 publications were identified;
- were not traditional articles, papers, chapters - 5 records were identified;
- were written in a language other than English or German - 1 in Spanish was identified;
- were authorless (no attribution of author(s)) - 4 such publications were identified.

This resulted in 124 publications, which were finally accepted for analysis. VOSwiever and Bibliometrix were used to analyse the results obtained. Each tool offers unique capabilities for depicting and analysing bibliometric networks, enabling multi-faceted exploration of the scientific literature in the field.

4. Empirical Results and Discussion

As written earlier, intralogistics in the literature is an issue with a relatively short history. Initially, there were single publications. From 2010-2015, 3-6 articles were published, in which a specific solution belonging to the field of intralogistics was presented. The greatest increase in interest in intralogistics can be observed since 2016, when publications addressed solutions based on automation and Industrial Revolution 4.0. The growing interest in the subject of intralogistics is shown in Figure 3.

Figure 3. *Number of publications in years*
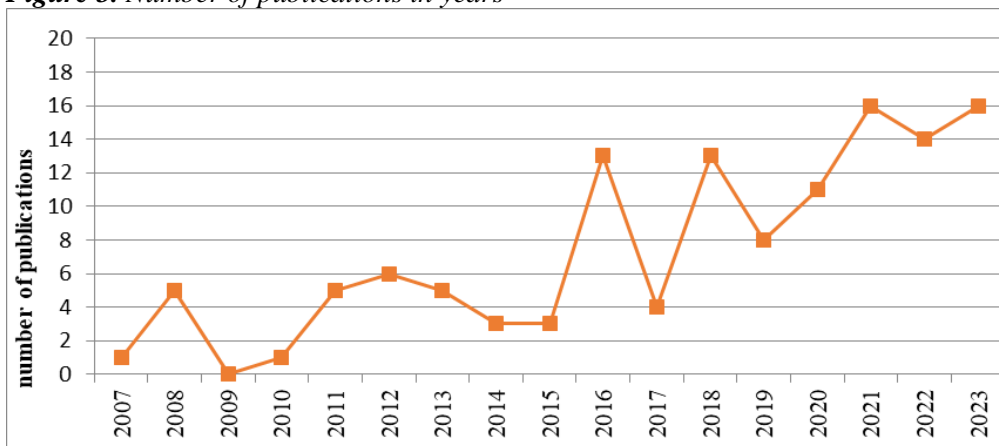
Source: Developed by the authors.

Research on intralogistics is mostly published in Logistics Journal, Productivity Management, ZWF Zeitschrift fuer Wirtschaftlichen. Chapters in books are recent publications (2021-2023) in "Management for Professionals," "Springer Series in Supply Chain Management" or "Work and AI 2030: Challenges and Strategies for Tomorrow`s Work".

4.1. Main Areas and Research Topics in Intralogistics

VOSwiever was used to identify areas of research on intralogistics, enabling visualization of links between key issues analysed in the subject area undertaken. Analyses were carried out on the basis of bibliographic data, taking the author's keywords and from indexes that appeared a minimum of 2 times. The results obtained are presented in Figure 4.

The results obtained indicate that several subject areas can be identified in the research problem of intralogistics, namely:

1. Intralogistics - an area presenting research in the field of intralogistics in the broadest sense and focusing on material flow simulation, market survey. It has 21 links to other keywords. According to the definition of intralogistics, it deals most generally with "material flow." It is important to properly design the flow of material, using the appropriate equipment/tools.

Figure 4. *Main areas of research in intralogistics*
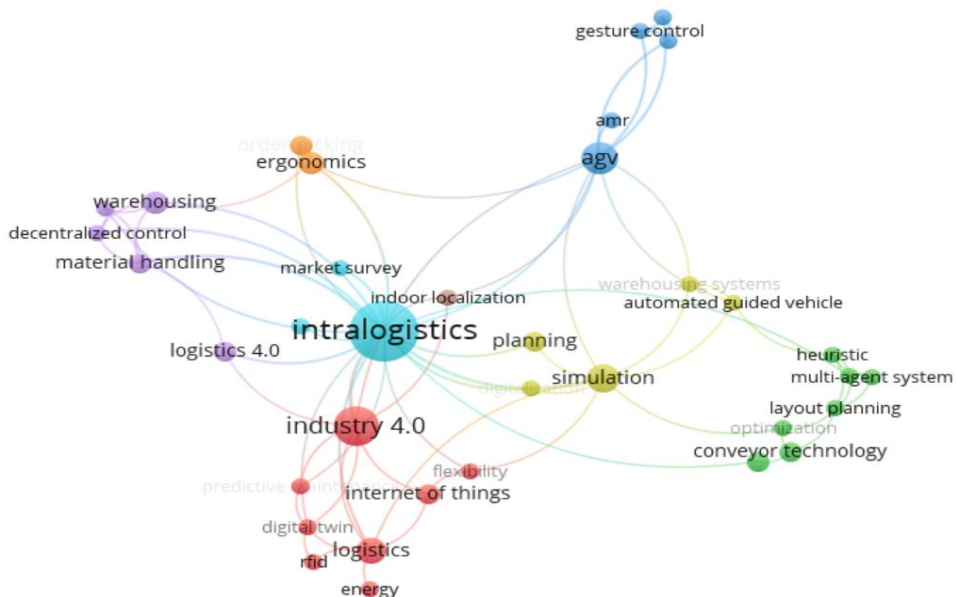
Source: Own elaboration based on VOSwiever version 1.6.20.

2. Industry 4.0 - an area in which research is undertaken that takes into account the desire of companies to make greater use of Industry 4.0 tools. e.g. IoT (internet of things), digital twin, RFID (Radio-Frequency Identification). It has 8 connections to other keywords. It is noteworthy that the tools mentioned as key to Industry 4.0 are often combined with intralogistics. As you can see, it is the epicentre of the implemented processes inside the company, significantly influencing the time of receipt, processing of information (e.g. about an order), execution of the assigned

task, the ability to track processes in real time and what happens to a given customer order.

3. Indoor localization - an area addressing the topic of indoor localization. As the name suggests, the planning and designation of internal logistics.

4. Warehousing - area undertaking research on warehousing, material handling, logistics 4.0, distributed and decentralized control, material handling, distribution control and decentralized control. Has 5 links to other keywords. Related to material flow along with material management processes. Key issues to maintain the effectiveness, efficiency of the implemented processes.

5. Automated Guided Vehicles (AGV) - area related to AGVs, Autonomous Mobile Robot (AMR), person following - robot automatically controlled vehicles. Has 11 links to other keywords. Topics similarly often related to process automation - in this case, material handling. Articles mainly cover topics related to vehicle routing.

6. Conveyor technology - referring to conveyor technology, layout planning, multi-agent system, energy efficiency, system planning, optimization. It has 3 links to other keywords.

7. Simulation- research is being undertaken on digitalization, simulation, automated guided vehicle, storage systems. It has 9 links to other keywords. It is worth using the available solutions in the form of process simulation, which will allow the selection of the optimal scenario in terms of selecting the layout of the hall, determining the routes of travel for internal transport, verifying the effectiveness and efficiency and the number of transport means needed.

8. Ergonomics - an area focusing on ergonomics and order picking . It has 4 links to other keywords. Key issue, primarily touching on aspects of ergonomics - tools/equipment should facilitate human work, which is also related to designing them ergonomically. An important element - how to make the work of order picking easier to avoid mistakes, speed up the completion time of picking.

The number of links between keywords indicates a broad spectrum of issues. The identified research areas indicate, on the one hand, the interconnectedness of the topics addressed, and on the other hand, their complementarity.

A thematic map of issues in the area of intralogistics, prepared in Bibliometrix software on the basis of keywords, can supplement the earlier analysis illustrated in Figure 5.

Figure 5. *Thematic map of intralogistics issues*
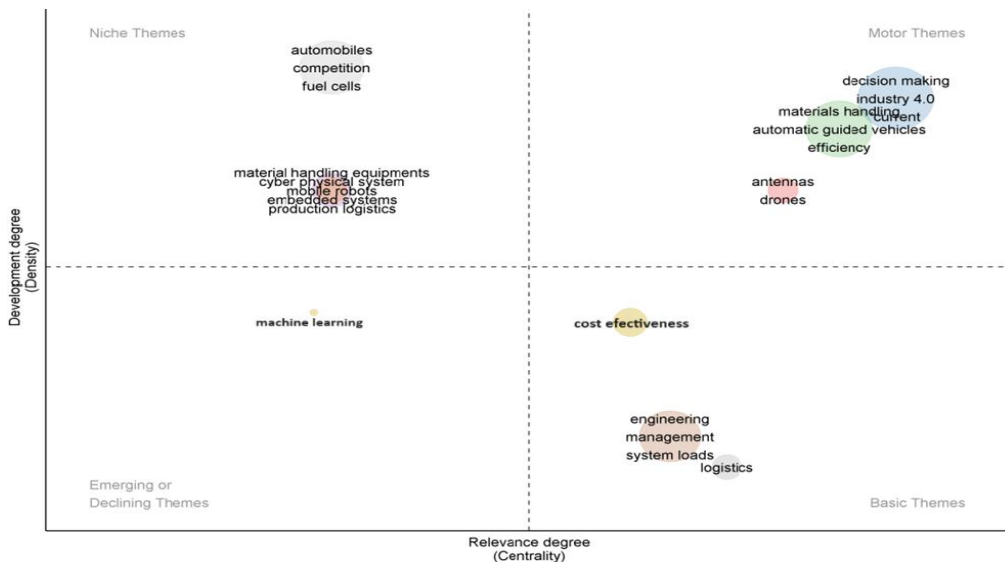
Source: Own compilation using Bibliometrix.

Building the thematic map was limited to two elements affecting the identification (evolution) of the state of knowledge in the subject of intralogistics - the degree of development and the degree of relevance. Thus, four thematic areas were identified:

- basic- in which intralogistics issues are described in general from the point of view of engineering, management or loading system and logistics. In the context of the core, the topics of cost-effectiveness of intralogistics solutions are presented.
- driving - in which intralogistics addresses issues related to technological development, e.g. Industry 4.0, Internet of Things IoT, automated vehicles, drones, autonomous vehicles.
- emerging - concerning the topics of machine tools, where artificial intelligence (AI) and machine learning (machine learning) will play a key role in intralogistics in the future
- niche - covering issues related to mobile robots, material handling equipment, production logistics or fuel cells, competition.

A detailed analysis of Figure 4 reveals that the first two subject areas cover the largest number of issues and indicate the most popular research topics. It can be assumed that they will determine the further development of intralogistics.

4.2 Development of Issues and Key Research Needs in the Field of Intralogistics

Identification of research needs in the field of intralogistics began with an attempt to answer the question " how the issue has developed over the years". The results of the analysis are shown in Figure 6.

Figure 6. *Development of intralogistics problems*
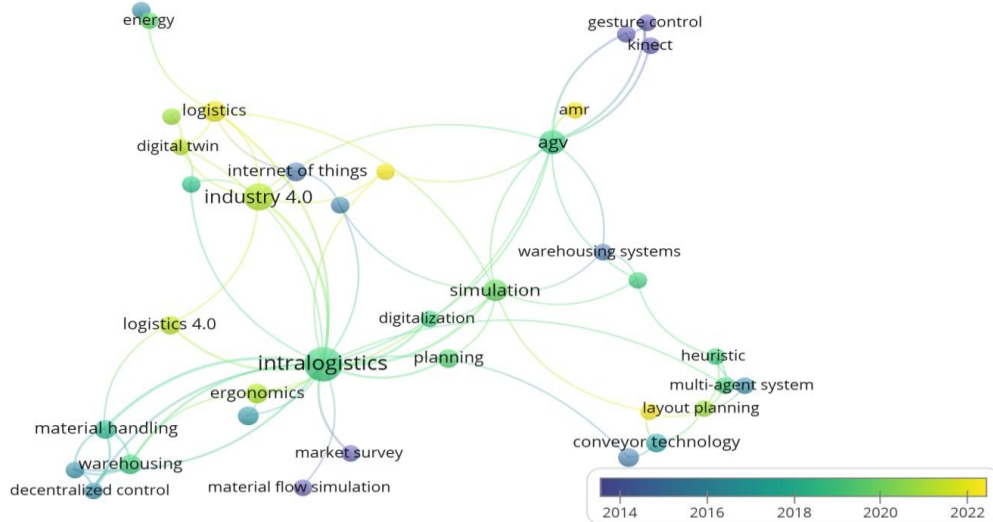
Source: *Own development using VOSwiever version 1.6.20.*

Based on Figure 6, three periods of development of intralogistics research can be distinguished:

• The first - up to 2015 (blue), when the original intralogistics research problems included issues describing material flow simulation (2011), gesture control, market survey, human following - robot (2013), energy efficiency, internet of thoughts (IoT), warehousing systems (2015) or order picking (2016).

• The second - 2016 - 2020 (green) in which research issues included Industry 4.0 (Internet of things, digitalization). Industry 4.0 is a concept for the transformation of enterprises related to the improvement of processes carried out internally using available technologies. Attention was paid to the aspirations of companies to digitize and automate processes.

• The third - currently underway from 2021. There is a noticeable research trend towards Logistics 4.0. Logistics for the Fourth Industrial Revolution focuses on how to use new technologies in a way that will increase the flexibility, efficiency and productivity of an organization's operations.

The review of publications conducted allowed us to identify the following research needs:

1. To systematize the knowledge of intralogistics solutions implemented in various business entities (SMEs);
2. The impact of intralogistics tools on the efficiency of logistics processes;
3. Increase empirical research on intralogistics;
4. Factors limiting and driving the implementation of intralogistics tools;
5. Impact of environmental conditions (sustainability) on intralogistics;

6. Applications of various intralogistics solutions dedicated to production and supply chain management;
7. Identification of key tools in intralogistics;
8. Future trends of intralogistics solutions and their limitations/problems;
9. Increasing research on intralogistics solutions in logistics processes and supply chains.
10. Risk management in intralogistics .

To describe and systematize knowledge of intralogistics solutions related to the use of Industry 4.0 tools and equipment, material and information flow, to examine the impact of these solutions on organizations, human labor and environmental impact.

The impact of intralogistics solutions on an organization covers a number of aspects, including how the use of specific solutions affects the optimization of work, reduction of operating costs, connection to systems and programs used in the company, flexibility, sustainability measures (e.g., impact on energy costs, waste), reduction of the risk of errors, damage, accidents at work.

It is also worth evaluating and examining whether solutions, according to the concept of Industry 5.0, are crisis-proof and make it easier for people to work, and whether they reduce environmental nuisance.

Previous articles describe separate topics, due to the specificity of each of the available solutions and the difficulty of investigating, describing solutions used in companies that are not always open to sharing knowledge and their own experience. Based on the results, there is a need to collect basic descriptions of intralogistics solutions, along with a general description of the tools and solutions used in their field.

5. Conclusion

The results described above indicate the topics described under intralogistics. The answers to the research questions posed are presented below.

RQ 1: Intralogistics is a relatively new concept, at the same time it is rapidly developing. From 2010-2015, 3-6 articles were published that presented a specific solution belonging to the field of intralogistics. The greatest increase in interest in intralogistics can be observed since 2016, when publications covered solutions based on automation and Industrial Revolution 4.0.

The increase in popularity and interest in the Fourth Industrial Revolution, the adaptation of companies to the growing expectations of consumers in terms of flexibility, responsiveness, and thus digitization and automation will affect the popularization of the term "intralogistics."

RQ 2: Emerging publications in this area show a growing trend, indicating a great interest in this issue. This is due, among other things, to the interest in tools and solutions on the scale of Logistics 4.0. Often publications in this area are combined with solutions directly related to Industry 4.0, with automation, digitization, or Logistics 4.0.

This indicates the important aspect that intralogistics represents to come to the conclusion that on it, on the use of appropriate tools, equipment and their connection with systems, software, depends on what level of maturity the enterprise will be.

RQ 3: 9 research areas of intralogistics have been identified, which indicate the basic research streams undertaken in this field. The co-occurrence of research problems, which are often complementary to each other, is evident. Four thematic areas were identified: core, driving, emerging and niche.

The first two topic areas cover the largest number of issues and indicate the most popular research topics. The core topics are related to logistics, loading systems, engineering, management and cost efficiency. The driving ones are related to decision-making, Industry 4.0, automated AGVs, efficiency, productivity, material handling, drones, antennas, among others. It can be presumed that they will determine the further development of intralogistics.

An emerging topic area is machine learning, while a niche area is mobile robots, material handling equipment, vehicles, competition, fuel cells, production logistics, embedded systems. Two more are the future and the need for further in-depth analysis. Distinguished research areas indicating the need to describe the tools, devices, how to manage them, to study their impact on logistics, efficiency and productivity of the implemented processes in the company.

The topic is so complicated that the study of the impact on the enterprise of, for example, automated vehicles depends on many variable factors, which, depending on the size of the enterprise, its industry, the way it is used and what other devices and systems are used in the organization, may be different each time. However, there are some universal conclusions that can be described. In addition, the use of available solutions for Industry 4.0 involves their impact not only on the organization, but also on the environment.

RQ 4: It has been established that current research on intralogistics is concerned with specific solutions used in intralogistics in the form of equipment, tools: related to material flow, internal transportation, robotization, digitization and automation, among others. There is a lack of collective studies describing intralogistics solutions with brief characteristics and their impact on organizations.

With the creation of such a study, it can be assumed that further areas to explore and describe will arise. First of all, related to the study of their impact on people, on the

environment, on the effectiveness and efficiency of the processes implemented, and how to appropriately adapt the solutions to the needs and size of the organization, so that the set goals of automation and digitization of processes can be achieved, while allowing companies to maintain optimal costs.

Intralogistics occupies a key place in works describing companies that fall into the level of the fourth industrial revolution. Modern solutions are aimed at raising the level of service, so that companies can be characterized by faster response to customer needs, increased flexibility and better use of resources. The implementation of available solutions is related to process automation.

The above findings make it possible to systematize knowledge about intralogistics, indicating the need for further intensification of research through case studies and comparative research. It is also worth considering, to study the impact of applied intralogistics solutions on the environment, resilience of supply chains. Describing their impact and drawing conclusions can be crucial in designing, modifying solutions used inside the organization, favouring the underlying goals of Industry 5.0.

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