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DETERMINANTS AND TRENDS OF LOGISTICS PARADIGMS IN INDUSTRIAL REVOLUTIONS

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ABSTRACT: Undoubtedly, fundamental technological, economic, social and cultural changes, i.e., industrial revolutions (IR), have an impact on the determinants of industrial operations, including logistics. The purpose of this article is to identify logistics paradigms (LP) in the context of IR and current trends in the literature. The method used to achieve this goal is a systematic literature review (SLR). The research problem was encapsulated in the finding that there are no clearly defined LPs in the literature. To solve the research problem, the authors conducted SLR by searching the bibliometric-abstract databases for articles with the LP phrase in the title, abstracts, and keywords. An attempt was then made to systematise the content of the articles. A major limitation of the research conducted was the lack of previous research work on LPs. The article discusses the concept of systematising LP according to IR and current trends in logistics.

KEYWORDS: logistics paradigm, industrial revolutions, physical internet

Introduction

Revolutionary changes can be transformative phenomena, changing and interacting with many systems. They generally depend on changes in scientific paradigms, and technological ones require human participation (Pinheiro et al., 2019). The fundamental social, economic, technological and other changes underpinning IR undoubtedly have an impact on the evolution of logistics. It can take the form of the simple coordination of logistical processes of transportation, warehousing, order handling, packaging, or inventory management to the management of complex and integrated supply chains. The adaptation of physical flows to the changes brought about by IR requirements could change or create new paradigms according to which logistics operates, that is, the accepted ways of seeing reality in the field of logistics. However, it is the changing industry that transforms logistics and adapts to its challenges.

The authors took as the main goal of the presented article to identify LPs and their connections with IRs or other new trends in literature. This is because it was recognised that such fundamental changes that IR brings should also have an impact on logistics. For this purpose, SLR was used.

Based on the main goal, a research problem was defined, claiming that there are no clearly defined LPs in the studied literature. The research problem posed implies the following four research questions:

1) Does the reviewed literature review include articles that relate to LPs?
2) Does the reviewed literature review include articles that define directly to LPs?
3) Can the analysed literature review identify references of LPs to IRs?
4) Can the analysed literature review identify references to LPs other than to IRs?

The authors analyzed 61 articles from bibliometric and abstract databases of Scopus and Web of Science that contained the phrase "logistics paradigms" in the title, keywords or abstracts. This made it possible to identify LPs described in the literature, analyse LPs' references to IRs, and identify trends of change in logistics.

The SLR carried out by the authors showed quite a lot of diversity, both conceptually and structurally, on the question of available LPs. The literature lacks a coherent approach to the issue of LPs. They refer to many issues and thus do not form a coherent approach, building a homogeneous framework of a set of concepts and theories that form the basis of modern logistics. This is an apparent research gap, which was identified by the authors of this article and contributed to them proposing their own approach to the issue of logistics paradigms.

Important research limitations of the conducted research were:

- narrowing the search for publications to only two bibliometric and abstract databases – Scopus and Web of Science,
- the thematic discrepancy of the publications,
- lack of previously conducted research on the topic discussed.

The added value is what is proposed by the authors the conceptual logistics paradigms framework (CLPF), which is a novel attempt to organize LPs according to the proposed groups of criteria. This concept can also become a good starting point for discussion of the topic of LPs at hand.

Literature review

The very concept of a paradigm was created by American scientist Thomas Kuhn in 1962. According to Kuhn, paradigms should be defined as recognised scientific achievements that are model sets of theories and concepts that make it possible to provide solutions to problems for practitioners (Kuhn, 1970). Paradigms describe reality by becoming the foundation of the world of science and practice for a period of time. Paradigms also change according to how the environment changes and based on the latest scientific discoveries (Janda et al., 2010).

Paradigms are applicable to many spheres of management. For example, Tang and co-authors have attempted to systematise paradigms related to production (Tang et al., 2005). Logistics, which is one of the key processes supporting production, should also have its own paradigms (Johansson, 2007). For years, it was viewed in a military spirit, and its transfer from the military to the economic

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sphere did not occur until the late 18th and early 19th centuries, during the First Industrial Revolution (1IR).

Modern business logistics is, therefore, more than a hundred years old and allows the movement of goods, information, and money to support the industry. Most organisations use logistics operating according to certain principles or rules, which could be defined as LPs (Gołembska, 2019). In attempting to identify LPs, it would first be necessary to define a certain benchmark against which specific changes in logistics and supply chains could take place (Ishimatsu et al., 2011, 2012, 2016).

The beginning of industry is the beginning of logistics. IRs changing economic reality forced logistics to adapt to various challenges. As the type (size) of production increased, logistics began to play an increasingly important role. The beginning of industry is identified with the 1IR, so the beginning of the search for LPs would have to start with 1IR, assuming that each of the subsequent revolutions changed logistics and its paradigms.

1IR (late 18th century), a process of technological, economic, social, and cultural change, was associated with the transition from an economy based on agriculture and manufacturing or craft production to one based mainly on mechanical factory production. It began with the development of the steam engine and the introduction of heavy mechanical manufacturing equipment (Barreto et al., 2017; Richnák, 2022).

Logistics was perceived through the prism of transport mechanization (Frazzon et al., 2019). During the 1IR, the dominant approach at this stage of logistics development, was functionally oriented, which means that the optimization of logistics operations was perceived as a part of separate functions, and not as a part of the entire supply process (Bukowski, 2019).

The Second Industrial Revolution (2IR) (turn of the 20th century), one of the key moments of which was the creation of the Ford assembly line, ushered in a significant increase in the manufacturing capacity of companies. Serialisation of production, transforming into mass production in the following years, began to pose ever newer challenges to the physical flow of goods and information. Almost from the 1950s, logistics began its evolution, initially coming out of dormancy to then undergoing a time of development and integration (Kadłubek, 2010). Changes in business operations have led to a redefinition of logistics. For example, Christopher described logistics as the process of strategically managing the purchasing, movement and storage of materials, parts, finished goods and their information along the organisation and environment in such a way as to maximise profits through efficient order handling (Christopher, 2005). This ultimately allowed logistics to be shaped in terms of its phased approach, distinguishing three basic phases: procurement, production, and distribution, which were joined in the 1990s by reverse logistics. Within each phase, five key processes were identified, i.e., transport, warehousing, packaging, order handling and inventory management, which have different characteristics and challenges. During this period, logistics therefore, began to be viewed through the prism of the phases and processes, forming the nucleus of a Phase and Functional Paradigm (PFP). For organisations, the most important criteria for process optimisation in the 2IR were cost, time, and quality (C/T/Q).

The symbols of the Third Industrial Revolution – 3IR are computerisation and automation, which have brought tangible benefits to logistics processes and phases. Examples include microprocessors, which increase computing power, and microchips, which facilitate, among other things, the identification of goods. Or portable computers (Jedlinski, 2022), which allow logistics data to be analysed more quickly and thus enable the development of information technologies (IT) at the service of logistics (Efthymiou & Ponis, 2021). In turn, the automation of physical operations and business processes has eliminated errors and mistakes, which are the frequent domain of employees, speeding up the logistical processing of orders, e.g. automatedguided vehicles (AGV) have been supporting logistics processes for more than 60 years (Modica et al., 2021). The use of automation or computerisation has enabled the comprehensive management of the flow of goods in supply chains, which has become a reflection of the logistics of this period (Bukowski, 2019). 3IR has shaped a paradigm whereby supply chain management is becoming global, automated and supported by advanced ERP (Enterprise Resource Planning) systems. This change in perspective on logistics issues has enabled a comprehensive approach to optimisation, from flexibility in supply management to a higher level – agility (Bukowski, 2019), e.g. for frequent changes in product types and characteristics (Borangiu & Raileanu, 2023). It can be said that during this time, the concept of agile and globally resilient logistics supported by automation and information took shape. However, this does not change the fact that at

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the foundation of this concept is the phased and functional division of logistics; thus, PFP has its roots in 2IR.

Finally, the evolution of cyber-technologies and their integration into the digital ecosystems of the entire industrial value chain have contributed to the Fourth Industrial Revolution (4IR) (21st century), called Industry 4.0 (I4.0). The concept, initially announced in 2011 in Germany, was only meant to be a strategy for the development of the German manufacturing industry (Kagermann et al., 2013). It has introduced quite a few challenges to logistics, such as changing the sphere of flows hitherto seen through the prism of an automated and computerised view of phases and functions. Its symbol, in which logistics is embedded, are smart factories with cyber-physical production systems, surrounded by the Internet of Things (IoT), People (IoP), Services (IoS) and Data (IoD). These systems go beyond traditional automation (Çınar et al., 2021). 4IR is once again transforming logistics and supply chains, challenging previous paradigms. Logistics 4.0 paradigm (L4.0P) can connect actors, machines, physical objects, products, and enterprise resources through sensors, devices, and the internet within supply chains. This paradigm enables more efficient production and distribution systems that attract stakeholder attention due to their potential to lead to high-performance supply chains. Additive manufacturing technologies (3D printing (3Dp)) and product digitisation offer the opportunity to move away from classic global physical flows to digital product flow and manufacturing in the area of last-mile logistics.

In addition, the infrastructure and logistics systems already established provide the opportunity to create an online network of physical flows called the Physical Internet (PI) (Montreuil, 2011). The shortcomings of logistics sustainability in the social, economic, and environmental contexts identified by Montreuil in the aforementioned article, as a consequence of the use of PFP, pave the way for a new view of logistics. Thus, we should expect the possibility of the emergence of a completely new paradigm of logistics functioning, which authors called the PI paradigm (πP).

It can, therefore, be concluded that with the successive IRs, LPs, i.e. the sets of concepts and theories forming its foundations in each period, also changed. As Sadowski (2019) mentions, logistics moved "from cognitive eclecticism to subjective originality". The empirical orientation of logistics theory was the reason for the improvement of both logistics processes and formed the foundations for the contemporary philosophy and principles on which modern logistics theory is based. The wide scope of capturing the actors of logistics, resulting from the empirical orientation towards solving logistics problems in practice, allows for the continuous delimitation of new stakeholders in logistics processes. This is directly based on the applicability of logistics theory and its principles (Sadowski, 2019).

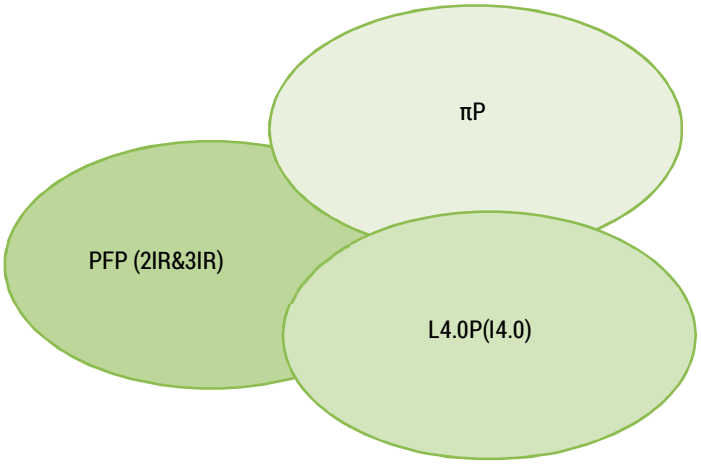

Figure 1. Conceptual logistics paradigms framework based on the Industrial Revolution

Based on the literature review presented, the authors will try to identify LPs and other trends. This asset may be shaped by new LPs or complement existing ones with key issues. Therefore, the following conceptual logistics paradigm framework (CLPF) has been proposed, consisting of three basic elements:

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- PFP (2IR&3IR),
- L4.0P (I4.0),
- πP (Physical Internet) – Figure 1.

The basic paradigm is certainly PFP, which has parts in common with the L4.0P and πP paradigms. It can be refined by the aforementioned paradigms, or discarded in favor of a completely new approach (Yang & Liao, 2010).

In the presented CLPF, the 1IR paradigm current was not included due to the conditions of this stage of industry development and, therefore, logistics. The authors considered that it presents rather archaic solutions that are not applicable in the modern world. Since the paradigm of 2IR was covered the least in publications, it was decided to combine it with the paradigm of 3IR in the following section, as it was acknowledged that the 3IR paradigm is a paradigm of 2IR extended by IT technologies and automation. Based on the presented literature review and the assumptions adopted by the authors, the next part of the work will present the results of literature research on the discussed issue in the context of the proposed CLPF.

Research methodology and results

A few literature review models are currently available. One of the more popular models is the SALSA model (Search, Appraisal, Synthesis, Analysis), which can take different forms depending on the purpose of the review being implemented (Booth et al., 2016). The literature review process itself can also have different stages (Levy & Ellis, 2006), and it can distinguish specific aspects of the process involved in creating a literature review (Rowley & Slack, 2004). To identify LPs, the authors proposed the following steps of the SLR process – Figure 2.

Below, referring to Figure 2, the individual steps of the SLR carried out are described in detail.

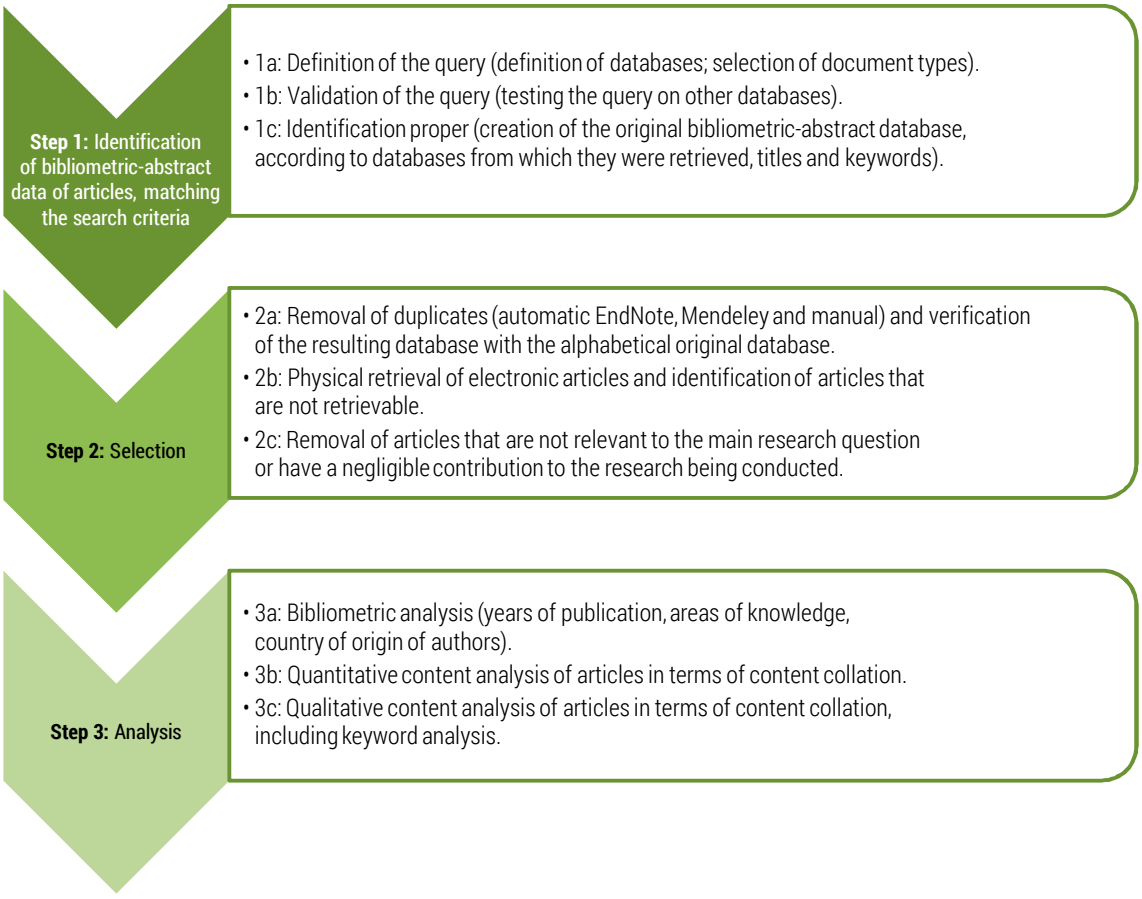

Figure 2. Steps of the SLR process

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Step 1: Identification of bibliometric-abstract data of articles, matching the search criteria

1) Step 1a: The two most popular bibliometric-abstract databases, i.e. Web of Science (WoS) and Scopus (Scp), were used for the literature survey.
2) Step 1b: A test query was formulated in the databases to identify all articles of a given database having the phrase "logistics paradigms" in the title or in the keyword. As this phrase showed a poor ability to identify articles (only 9 were identified), the search algorithm was decided to extend to identify articles having the phrase "logistics paradigms" in the abstract or the words "logistics" and "paradigms" in the title or keywords – the search scope identified more than 50 articles. At this stage, the phrases included in the analysis were standardised.
3) Step 1c: The creation of the original article database was based on searches of the Scp and WoS databases according to the following keys and stages:
   a) 9 Literature item (LIt) identified in the Scp database that had the phrase "logistics paradigms" in the title or keywords,
   b) 2 LIt in the WoS database that had the phrase "logistics paradigms" in the title or keywords,
   c) 54 LIt in the Scp database that had the phrase "logistics paradigms" in the abstract or had the words "paradigms" and "logistics" in the title or keywords at the same time,
   d) 9 LIt in the WoS database that had the phrase "logistics paradigms" in the abstract or had the words "paradigms" and "logistics" in the title or keywords at the same time.

   In the end, the primary base was 74 Lit, the search period for the articles is 5-7.11.2023.

Step 2: Selection

1) Step 2a: The removal of duplicates took place in four stages:
   a) Stage 0 – 9 Lit,
   b) Stage 1 – 2 LIt, both were duplicate LIt from stage 1 – 9 LIt remaining,
   c) Stage 2 – 54 LIt, 5 LIt were duplicates of LIt from Stage 1 – 49 LIt from Stage 2 and 9 LIt from Stage 1 remained – 58 in total,
   d) Stage 3 – 9 LIt, 6 LIt were duplicates of LIt from Stage 3 – 3 LIt remained, making a total of 61 Lit.

   This resulted in a bibliometric-abstract database of 61 articles, of which 57 were from the Scp database and 4 from the WoS database. The study included all publications that were not duplicated.

2) Step 2b: Having bibliometric-abstract data of 61 articles, the authors proceeded to collect articles. Using the e-library resources of both the University of Lodz and the Lodz University of Technology, the authors managed to identify 52 publications on their own. The issue of finding a further 9 publications was passed on to the libraries. In this way, all 61 articles were retrieved.
3) Step 2c: The authors of the study identified 3 LIt from the Scp database and 1 LIt from the WoS database in the database created, which are not relevant to the main research question or have a negligible contribution to the research conducted (article about the machinery and equipment industry in Slovakia (Richnák, 2022), article on combining Bayesian network and fuzzy logic for QoS quantification in VANET (Khalfaoui et al., 2023), article in the form of a case study about the steel processing industry (Köhler et al., 2019), report on the Chair at the Johannes Kepler University in Linz (Lv, 2021).

Step 3: Analysis

1) Step 3a: The first publications on logistics paradigms appeared in 2003, with the highest number of publications in 2022. The largest number of these articles was assigned to the knowledge areas "Engineering", "Computer Science" and "Business & Management". This was followed by "Social Sciences" and "Decision Sciences". In the other three LIt, the structure is similar, as in addition to the knowledge areas "Engineering" and "Management", there is also the area "Environment", which ranks 10th with 3.6% in the Scp distribution. The largest number of articles on logistics paradigms come from China, the USA, Germany, Japan, and Poland. India, Italy, and the United Kingdom are also among the leaders. The WoS database has classified its articles into three territorial areas, i.e. the USA, Brazil, and Thailand. This arrangement means that the group of States with 3 publications in this area would also include Brazil.

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2) Step 3b: More than 54.7% of the publications are articles, and 35.8% are conference proceedings. In the WoS database, all three LIt are articles. Book chapters and reviews account for less than 10%. As part of the bibliographic analysis, it was also decided to check how researchers collaborate on the topic under discussion. The tool used for this was VosViewer, for which a Mendeley file generated from the database was used. The study showed that, in general, the network of links between authors (co-authorship) for the 61 publications studied was small. Only 4 authors created a network of co-authorship links. The authors of these publications have little collaboration with each other on the topic under discussion. The study showed that, in general, the network of links between authors (co-authorship) for the 61 publications surveyed was small. Only 4 authors created a network of co-authorship links.

   Among the interconnected co-occurring keywords and calculated using the full count method, 15 words can be found that are not connected by any network to the others. The largest network of connected words forms a group of 10 words related to various concepts of waste, paradigm composition, reverse logistics, goal diversification or sourcing separation – Figure 3.

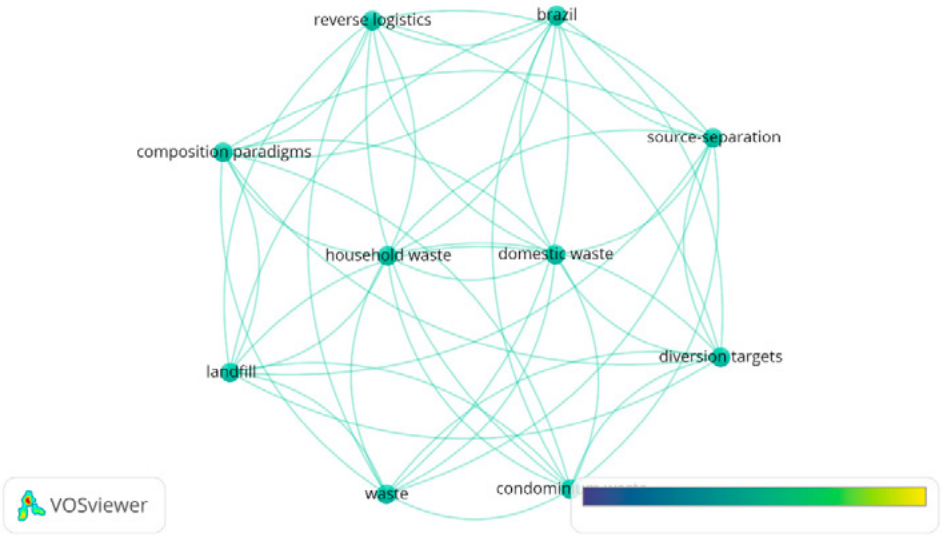

Figure 3. Visualisation of keywords relating to the created LIt database

Source: authors' work using the VosViewer application.

As the authors note, the prepared semantic map (Figure 3) refers to various, often semantically distant from LPs concepts: waste, paradigm composition, reverse logistics, diversification of goals or separation of sources of supply. The key connection between the words paradigm and logistics is missing here. Therefore, the literature on the subject lacks a coherent approach to LPs, and there are no proposals to organise them according to specific categories, which only confirms the existing research gap.

3) Step 3c: A qualitative analysis of LIt was carried out, indicating specific publications that became the basis for the conceptual framework of the LPs. As it turned out, the connection 2IR and 3IR in one PFP paradigm has also been confirmed in the number of publications. LPs relating to 2IR were least frequently discussed in publications. Therefore, combining the achievements of 2IR and 3IR into one PFP paradigm was the right assumption. SLR identified two further dominant trends in the literature relating to LPs. They are concerned with aspects of logistics management and environmental issues in logistics – Table 1.

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Table 1. Categories in which logistics paradigms derived from SLR were considered with selected publication titles

Paradigms	Publication titles
PFP	1) ICT in resilient global Logistics (Grøtan & Asbjørnslett, 2007), 2) Information logistics as a paradigm (Bobkowska, 2015), 3) An agent-based freight activities and logistic chains optimized network simulator (Abed et al., 2014), 4) Application of discrete rate based mesoscopic simulation models for production and logistics planning (Reggelin et al., 2017), 5) Privacy-Preserving Vertical Collaborative Logistic Regression without Trusted Third-Party Coordinator (Yu et al., 2022), 6) Analysis of AGV indoor tracking supported by IMU sensors in intra-logistics process in automotive industry (Grilo et al., 2021), 7) Lean and Agile Paradigms in Humanitarian Organizations Logistics and Supply Chain Management (Shafiq & Soratana, 2019), 8) Electronic operations – Factor of change of marketing-logistics paradigm (Zelenika et al., 2002).
L4.0P	9) Cargolifter AG: Logistics solutions using lighter-than-air (Gottlieb, 2001), 10) Scalability investigations on communication traffic in distributed routing of autonomous logistic objects (Wenning et al., 2009), 11) Towards fourth-party logistics providers: A business model for cloud-based autonomous logistics (Schuldt et al., 2011), 12) An autonomous control concept for production logistics (Rekersbrink et al., 2010), 13) The intelligent container: A cognitive sensor net for fruit logistics (Lang et al., 2014), 14) Blockchain and IoT Based Disruption in Logistics (Pervez & Haq, 2019), 15) Go with the flow – Design of cloud logistics service (Glöckner et al., 2017), 16) A Reference Architecture for IoT-Enabled Dynamic Planning in Smart Logistics (Koot et al., 2021), 17) Smart product-service systems in interoperable logistics: Design and implementation prospects (Pan et al., 2019), 18) Smart city logistics (Savin, 2020), 19) Review of space logistics (Guo et al., 2009), 20) Blockchain in transport and logistics-paradigms and transitions (Koh et al., 2020).
πP	21) Logistics Response to the Industry 4.0: The Physical Internet (Maslarić et al., 2016), 22) Digital interoperability in logistics and supply chain management: state-of-the-art and research avenues towards Physical Internet (Pan et al., 2021).
In addition, the identified paradigm categories	
Logistics management paradigm (LMP)	23) A simulation modelling paradigm for the optimal management of logistics in container terminals (Legato & Trunfio, 2007), 24) Modelling, simulation, and optimization in logistics (Trunfio, 2011), 25) Moving beyond the systems approach in SCM and logistics research (Nilsson & Gammelgaard, 2012), 26) Modern intelligent logistics management paradigm based on management information system model (Wan, 2022), 27) Supply chain management: notes on the capability and the limitations of a modern logistic paradigm (Bretzke, 2009).
Environmental issue in logistics paradigm (ELP)	28) The impact of reverse logistics in green supply chain management: A system dynamics analysis (Mutingi, 2014), 29) Lean and green paradigms in logistics: Review of published research (Pejić et al., 2016).

From the literature research conducted, it was not possible to directly identify defined LPs. As a result, there was no division according to any criteria. Therefore, the division of LPs based on IRs proposed by the authors in the literature review, supplemented with the results of literature research categories, is a good starting point for discussion (Malyshenko et al., 2018). Considering the content of the articles, they can be assigned to groups representing IRs and PI. Furthermore, it should be noted that there were articles that referred to logistics management and environmental aspects. On this basis, the authors proposed the CLPF. This concept is a novel attempt to define and organise scope LPs according to the proposed groups of criteria. Based on SLR, the authors presented a proposal for organizing LPs within CLPF which was supplemented with two additional elements, i.e. LMP and ELP– Figure 4.

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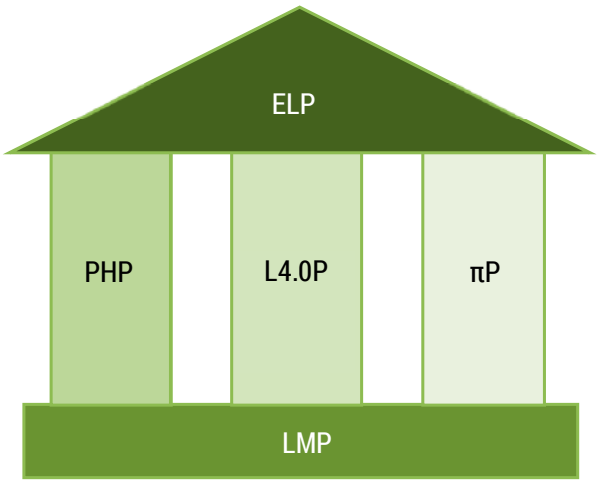

Figure 4. Conceptual logistics paradigms framework supplemented with research results

The SLR carried out by the authors showed quite a lot of diversity, both conceptually and structurally, on the question of available LPs. The literature lacks a coherent approach to the issue of LPs. They refer to many issues and thus do not form a coherent approach, building a homogeneous framework of a set of concepts and theories that form the basis of modern logistics. This is an apparent research gap, which was identified by the authors of this article and contributed to them proposing their own approach to the issue of logistics paradigms. Discussion on this topic is described in the next section of the article.

Discussion

The presented CLPF may constitute an interesting basis for further research on LPs. The first three industrial revolutions established PHP, while 4IR indicated possible directions of development towards logistics 4.0 and the Physical Internet. In the case of all three IR-based paradigms, it should be noted that environmental issues are extremely important as well as issues of logistics management and supply chain management are becoming a key element ensuring the efficiency and effectiveness of logistics activities.

The ELP paradigm results from the negative impact of logistics and supply chains on the environment. While in the early phases of PHP's operation, industry and logistics developed without respect for environmental issues, automated and computerised PHP must take these issues into account. The foundations of modern logistics paradigms, namely L4.0P (Bielecki, 2022) and πP (Montreuil, 2011), already have environmental issues written into their foundation. LPs based on environmentally sensitive IRs must focus on sustainability and the circular economy, creating closed-loop or circular supply chains for each paradigm.

LMPs are the basis of the entire CLPF (Gunasekara et al., 2023). LMPs should guide the management contexts of all three basic paradigms (PHP, L4.0P, πP). In doing so, attention should be paid to the issue of using reverse logistics in this area, complementing the phased division of logistics, which has so far been unidirectional – forward logistics as pointed out by Tao and Yin (Tao & Yin, 2014).

The PHP paradigm has shaped and continues to shape logistics and supply chains. Identification of subsequent logistic phases (supply, production and distribution) in which the logistic processes of transport, packaging, warehousing, order processing and inventory management (Pfohl, 2022) occur with different intensity and characteristics describe forward logistics. In this paradigm, the key criteria are C/T/Qoptimisation (in the given order) (Fehr et al., 2010), which allows the implementation of the 7R logistics principle (Shapiro & Haskett, 1985). The PHP paradigm is a typical example of a paradigm based on a linear economy and forward logistics. Only by taking into account the assumptions of the circular economy can we close the loop by creating closed or circular logistics and supply chains.

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Both 1IR, 2IR and 3IR generated adaptive changes in logistics – technologies in the industry were implemented in the sphere of logistics phases and processes (PHP). In the case of the 4IR, the technologies presented offer opportunities for their gradual implementation, but their combination, in many cases, breaks with the previous perception of logistics, e.g. the use of cloud computing in logistics, characterised by a high degree of computational complexity and high dynamics of change, is significant (Schuldt et al., 2011). The cloud logistics paradigm (CLP), being part of L4.0P enables logistics to evolve towards being even more flexible and collaborative (Glöckner et al., 2017). I4.0 technologies connect the virtual and real worlds through different types of technology (Radivojević & Milosavljević, 2019). This is creating a new dimension of logistics tatis based on real-time information (Frazzon et al., 2019). I4.0 technologies can, therefore improve logistics operating according to the PHP and ELP paradigms. On the other hand, I4.0 technologies such as additive manufacturing – 3Dp, IoT, virtual and augmented reality (VR/AR), and artificial intelligence (AI) can change physical flows to digital ones, focusing only on last-mile logistics. Then, the PHP paradigm may no longer be relevant. Adaptive implementation of selected I4.0 solutions can improve the still archaic I2.0 and I3.0 indicators, but without a revolutionary departure from the old paradigms (I2.0 and I3.0), logistics will be stagnant. Only the synergetic use of I4.0 tools and the construction of new business models guarantee the emergence of a new quality of logistics.

In the spirit of adaptive change, PHP was created as a πP paradigm. It is intended to be a response to the lack of sustainability in logistics, as Montreuil described it (Montreuil, 2011). The implementation of the PI concept, which breaks with the existing logistics order based on PHP. The idea of PI is based on the application of the principles of the digital Internet (connecting computers in a network according to specific rules – TCP/IP protocols) to the physical flow of goods and information about them (Ballot, 2019). This means that the currently created logistics networks create an infrastructure resembling a web, and the recipients of logistics services can gain access to the network wherever it exists without having to worry about who the operator or service provider is (Ballot et al., 2021). With such assumptions, the πP paradigm destroys existing business models operating in logistics and supply chains. It is based on certain solutions developed by the PHP paradigm, but it radically changes the way it is operated.

The most flexible in the overall paradigms remains the sphere of logistics management, which will be forced to create hybrid solutions from the rich heritage of management and quality sciences to support adaptability or comprehensive change. It will be very difficult here to present collective models of theories and application concepts that will constitute one detailed description, i.e. paradigm. This will result from the specificity of business activity, the conditions of which will affect logistics. Studies on logistics and supply chain management (Christopher, 2005) will be helpful in defining LMPs, but this has already been described in many cases (Pfohl, 2022). There is no doubt that LMP issues constitute the basis for the functioning of logistics and supply chains in the context of their effectiveness and efficiency.

Conclusions

The analysis shows that it is difficult to find articles defining LPs in the literature. Even more lacking is the reference to articles on the relationship between the concepts of LPs and IRs.

Regarding the research questions posed in the introduction of this article, the authors showed that there are no clearly defined and structured issues related to LPs in the literature. The only logistics paradigm described by the authors but not included in the literature as a paradigm is the PHP, in which the logistical phases of supply, production and distribution include the logistical processes of transportation, warehousing, handling, packaging and inventory management.

It must be objectively stated that IRs have had a significant impact on the perception and scope of LPs. Although the reference of the LPs to the IRs and the phenomena, philosophies, processes, or technologies occurring in them is apparent, the authors have not succeeded in finding in literature a pattern to organise them. The CLPF, which aims to unify LPs perception and understanding proposed by the authors, makes it possible to assign articles with respect to the IR criterion, i.e. technological, organisational and infrastructural achievements. It was also able to identify additional areas that may affect LPs, i.e., Physical Internet, environmental aspects and those related to management. Asa conse-

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quence, PFP was changing through the adaptation of computer-aided business models and automated logistics processes, ending with the synergetic use of I4.0 tools and the construction of new business models or concepts, such as the PI.

The authors emphasised that contemporary changes in LPs are possible not only because of technological developments but also because of the need to adapt logistics to environmental requirements relating to sustainable development and circular economy assumptions. Furthermore, they pointed out that the creation of contemporary paradigms must be based on a strong foundation of logistics management.

The research was limited to keyword searches and literature collected in e-resources. Older books or articles physically located in libraries, are missing here. Many publications certainly address model theories and concepts without having the term paradigm in the title or key words. This is also a limitation of the research presented.

In the authors' opinion, further research should be carried out in one main direction: characterise in detail the paradigms correlated with the approach taken, based on the following:

- I4.0 and its technologies (L4.0P),
- PI (πP),
- CSC and CLSC (ELP).

The arrangement of logistics paradigms should become an important part of research work. The presented article can be the beginning of a discussion on this topic. The result of such research can become an important knowledge resource for practical logistics and chain management and development management.

The contribution of the authors

Establishing the concept, M.B.; establishing research methods, M.B., B.G. and D.T.; text creation, M.B., B.G. and D.T.; analytical description of the phenomenon, M.B., B.G. and D.T.; implementation of the research idea, M.B., B.G. and D.T.; critical evaluation, M.B., B.G. and D.T.; data collection, M.B., B.G. and D.T.; data analysis and interpretation, M.B., B.G. and D.T.; development of research results, M.B., B.G. and D.T.; literature review, M.B., B.G. and D.T.

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Maciej BIELECKI • Barbara GALIŃSKA • Daniel TOKARSKI

UWARUNKOWANIA I TRENDY PARADYGMATÓW LOGISTYKI W REWOLUCJACH PRZEMYSŁOWYCH

STRESZCZENIE: Niewątpliwy wpływ na uwarunkowania funkcjonowania przemysłu, w tym logistyki, mają fundamentalne zmiany technologiczne, ekonomiczne, społeczne i kulturowe, czyli rewolucje przemysłowe (IR). Celem artykułu jest identyfikacja paradygmatów logistycznych (LP) w kontekście takich zmian oraz obecnych trendów w literaturze. Wykorzystaną do realizacji tego celu metodą jest systematyczny przegląd literatury (SLR). Problem badawczy postawiony przed prezentowanym artykułem zawiera się w stwierdzeniu, że w literaturze nie ma jednoznacznie zdefiniowanych LP. W celu rozwiązania problemu badawczego autorzy przeprowadzili SLR przeszukując bazy bibliometryczno-abstraktowe pod kątem artykułów posiadających frazę LP w tytule, abstrakcie i słowach kluczowych. Następnie podjęto próbę usystematyzowania treści artykułów. Poważnym ograniczeniem prowadzonych badań był brak wcześniejszych prac badawczych nad LP. Efektem artykułu jest koncepcja usystematyzowania LP według IR oraz obecnych trendów panujących w logistyce.

SŁOWA KLUCZOWE: paradygmat logistyki, rewolucje przemysłowe, Internet fizyczny

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