

Article

The Role of the Logistics Operator in the Network Coordination of Omni-Channels

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Abstract: This research aims to bridge a critical gap within the realm of logistics coordination, specifically targeted at bolstering the coordination of flows in omni-channels. The outcome of this study culminates in the creation of a comprehensive tool for evaluating logistics operators, discerning those who exhibit supreme proficiency in orchestrating network dynamics within omni-channel contexts. To fulfil the objectives of this paper and elucidate pertinent research inquiries, an exhaustive literature review is coupled with meticulous scrutiny of the SCOPUS database via the advanced VOSviewer 1.6.20 software. The research delineates an array of coordination mechanisms accessible to logistics operators, which can be judiciously tailored as a bespoke fusion of market-driven, social, hierarchical, and logistical coordination tactics. These mechanisms expand upon antecedent investigations, encompassing both network coordination paradigms and the pivotal role of logistics operators within omni-channel frameworks. Experts assessed that forecasting network flows is the most significant element in logistical coordination, receiving a weight of 0.1312, while managing network participants' resources from the logistics operator level received a weight of 0.1148. A tangible contribution to the academic discourse transpires as we introduce a pioneering tool meticulously designed for stakeholders entrenched in omni-channel distribution networks. Termed the 'Multicriteria Assessment Sheet for Evaluating the Coordination Competence of Logistics Operators within Omni-channel Systems,' this instrument augments the scholarly landscape.

Keywords: network coordination; logistics coordination; omni-channel; 3PL; logistics operator; AHP; coordination mechanism



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1. Introduction

The upward trend associated with the emergence of new distribution channels and the expansion of logistics operators has been ongoing since 1980 [1]. Among the main challenges posed to the logistics service of new distribution channels, the need to take into account different stakeholders in building a high-quality service is indicated [2,3]. The development trend of the e-commerce market is undeniable [4], but interestingly not from the beginning has this form of product delivery to the market been recognised as something that can match or surpass traditional distribution channels. Authors [5] summarised research conducted between 2000 and 2005, which concluded that the online form of selling was no more satisfying to customers than the traditional form of selling. However, a number of factors, including, inter alia, digitalisation, which has increased the transparency of markets at a very fast pace [6], have made e-commerce a significant form of distribution. Along with this, the issue of handling the logistics of multi-channel distribution systems has become more prominent. Based on a study conducted in 2006, of the 200 e-commerce-related companies surveyed, approximately 30% [7] worked with an LSP (logistics service provider; in this paper, LSP will be used interchangeably with 3PL—third-party logistics and with the phrase logistics operator). In 2023, this trend was reinforced by the increasing needs arising from the integration of online sales channels and the growing demands

of end customers. The new distribution channels and, in particular, their integration, present challenges in the logistics service provided by specialised operators. Coordinating such complex systems requires a high level of competence [8] and the ability to influence cooperating organisations [9].

Taking into account the work accomplished to date in the field of multi-channel distribution channels, especially omni-channels, as well as the logistical handling of these channels, this paper identifies assumptions for network coordination carried out at the logistics operator level. The aim of this research was to fill the gap in the area of logistics coordination aimed at supporting logistics operators in the coordination of flows in omni-channels. The result of the research was to develop a tool to assess logistics operators and identify those with the highest competence in the network coordination of omni-channels. In order to realise such a goal, it was necessary to conceptualise logistics coordination as an additional form of network coordination, which makes use of the flow mechanisms developed so far by other authors. Flow mechanisms are identified by various authors [10] as mechanisms of network coordination alongside the price and non-price mechanisms characteristic of the hierarchical, social, and market forms of network coordination. Indeed, each of these forms of coordination uses specific mechanisms. In terms of flow mechanisms, research to date has significantly limited the range of logistical instruments that can be used by the coordinator. Attempts related to the alignment of logistic operators with the principles of network functioning and network mechanisms have been undertaken by researchers [11–13]. However, none of these works present a set of characteristics that predispose logistic operators to network coordination. We believe that seeking opportunities for logistic operators to assume functions related to network coordination makes sense. This aspect has been emphasized multiple times in articles, indicating that third-party logistics companies (3PL) are capable of undertaking coordination actions, whether in terms of disturbance reduction [14,15], implementation of modern solutions aimed at improving network performance [16], or other elements crucial for material and information flows [17] from the perspective of flows of materials and information. This is currently an important area because of the development of network distribution systems and the need to support them with logistics services. Therefore, we have extended the range of flow mechanisms analysed, while recognising that for omni-channel distribution, it is necessary to take into account, in addition to market, hierarchical, and social forms, a form of logistical network coordination. Considering the adopted assumptions and gaps related to the previous research presented in the literature, we sought answers to three posed questions:

RQ.1: What role can a logistics operator play in the network coordination of omni-channels?

RQ.2: What forms of network coordination can a logistics operator use to ensure reliable omni-channel flows?

RQ.3: Which network coordination mechanisms are most powerful in building customer satisfaction in omni-channel systems?

Using the AHP method, we investigated how individual network coordination mechanisms, specific to a particular form of coordination, contribute to the reliable realisation of omni-channel flows. At this stage, we drew on the knowledge and experience of experts. The key criteria for selecting experts for the study were knowledge and experience of omni-channel distribution network coordination. Since in the research we were considering the role of logistics operators in the coordination of omni-channel distribution, the experts were the senior managers of such organisations.

The layout of the paper follows these objectives: The research started from the theoretical background, in which we identified the concept of network coordination and, against the background of previous research on it and the challenges posed by complex distribution systems such as omni-channels, we presented the construct of logistical coordination. We discussed the issue of omni-channels from the perspective of the logistical service provided by logistics operators. In the Methods section, we presented the research procedure and also justified the selection of experts for the study and the use of the AHP method. In the Results section, the discussion concerning the results of the conducted research is pro-

vided, which fills a gap in the existing research on both network coordination and logistics service of omni-channels. Central to this stage of the research was the identification of the overarching importance of logistics coordination, which enhances the effectiveness of the logistics operator in ensuring reliable flows in omni-channels, while, among its mechanisms, the emergence of resources management and demand forecasting methods are the main mechanisms that allow the logistics operator to coordinate flows. In the Discussion section, the discussion concerned the results obtained against the background of the existing body of the literature and it also pointed out the limitations of the study and prospects for further research.

2. Theoretical Background

2.1. Literature Gap

As part of the preliminary literature research into the issues of logistics operators' activities in omni-channels and network coordination, the authors conducted a review of the SCOPUS article database. The analysis focused on extracting articles thematically related to business, management, and accounting sciences. The time frame for the searched articles extended to August 2023 in the SCOPUS database. The authors, in the first step, created an overview of the papers connected with keywords (of papers, authors, and journals) in the range of the following: "network coordination", "network governance", "omni-channel", "3PL", "logistic operator", or "logistic service provider". Based on the SCOPUS database, 1796 articles were extracted, for which analyses were conducted using the VOSviewer tool. This is a tool used for creating clusters, networks of connections, and relationships between topics appearing in various scientific works. VOSviewer is employed as a tool to support the literature analysis in various scientific disciplines [18–20]. Figure 1 depicts the connections of keywords and the formed clusters for the mentioned guidelines.

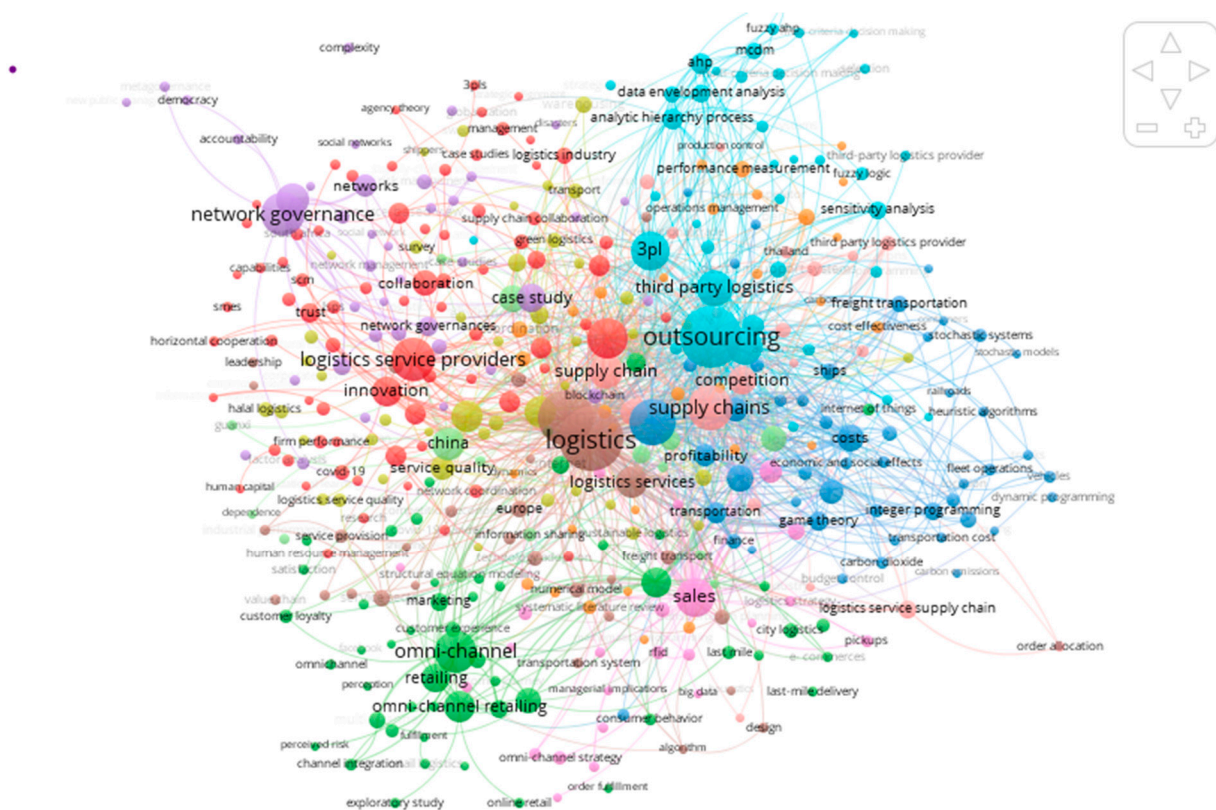


Figure 1. Clusters and connections between the main keywords based on SCOPUS elaborated on VOSviewer.

Based on the main keywords connection map it could be concluded there is no connection for every examined keyword. However, the connection with the main clusters is also shown in Figures 2–4. The cluster of network governance is linked with the supply chain, implying that this theme is frequently addressed in publications related to supply chain sciences, potentially involving the description of mechanisms governing flows. However, this cluster is not associated with either omni-channel or logistics operators, suggesting that these themes are not considered together. Network coordination and logistics coordination do not form a visible cluster on the map, which is attributed to the relatively low percentage of works addressing such topics. The 3PL cluster is connected, among others, with the AHP methodology, indicating that authors frequently examine the issues of third-party logistics providers using this method. Additionally, 3PL is also strongly linked to the supply chain, but not in the context of considering 3PL actions within the scope of network governance or network coordination. The omni-channel cluster is strongly connected with the supply chain, but similar to the previous case with 3PL, it does not associate with the topics related to network governance or network coordination. Omni-channel exhibits connections with 3PL as well, but these associations are not as frequent and well established in the literature as in the case of other, stronger connections depicted in the provided figure. Also, based on the analysis of search phrases in titles, keywords, and abstracts, it can be indicated that the topic related to network coordination is relatively prevalent. A total of 396 articles were found in the database that were related to this subject, although the majority of them were associated with computer science (63.89%) and engineering (67.17%). Articles strictly linked to business, management, and accounting that could address the issue of network coordination concerning collaborating networks of enterprises were encompassed in 57 articles. Similarly, the situation is similar in the case of “network governance”, which often addresses a similar topic. The number of articles here is greater than in the previous case (279 articles), and the upward trend for new articles on this subject is more noticeable (Figure 5).

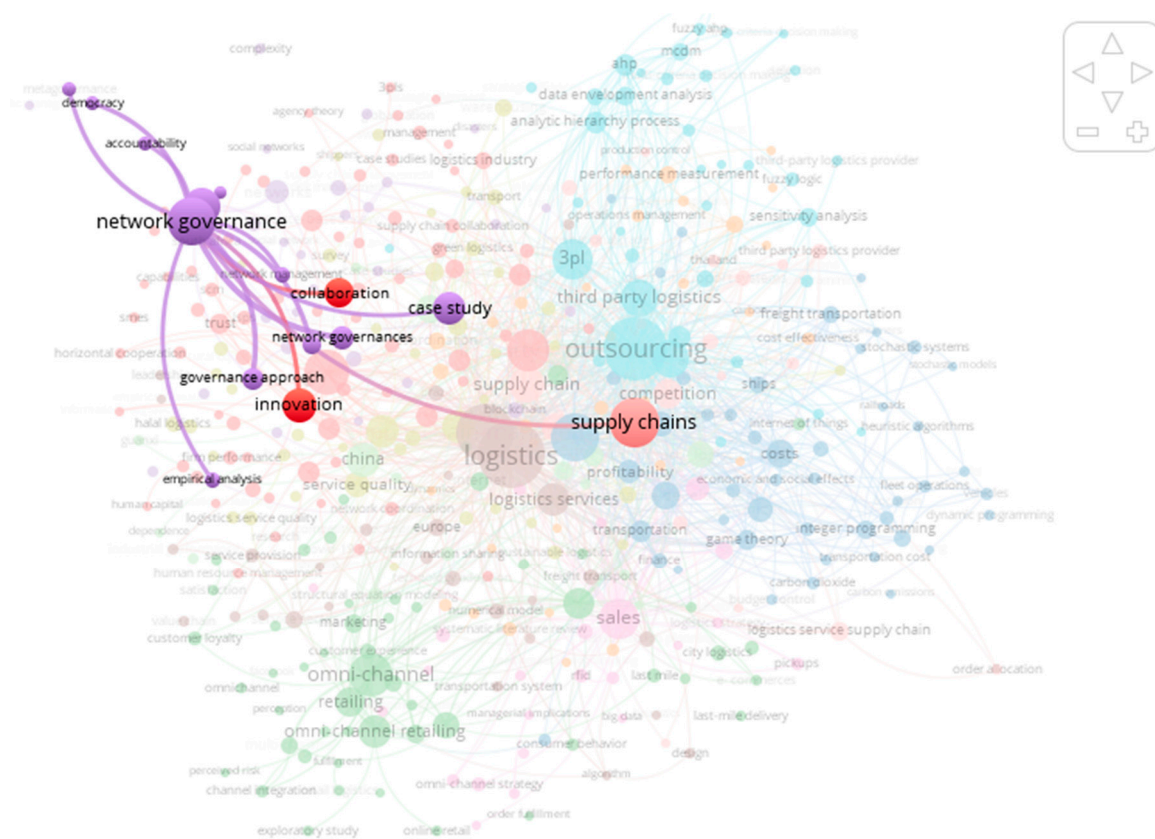


Figure 2. Connection with main cluster “network governance” elaborated on VOSviewer.

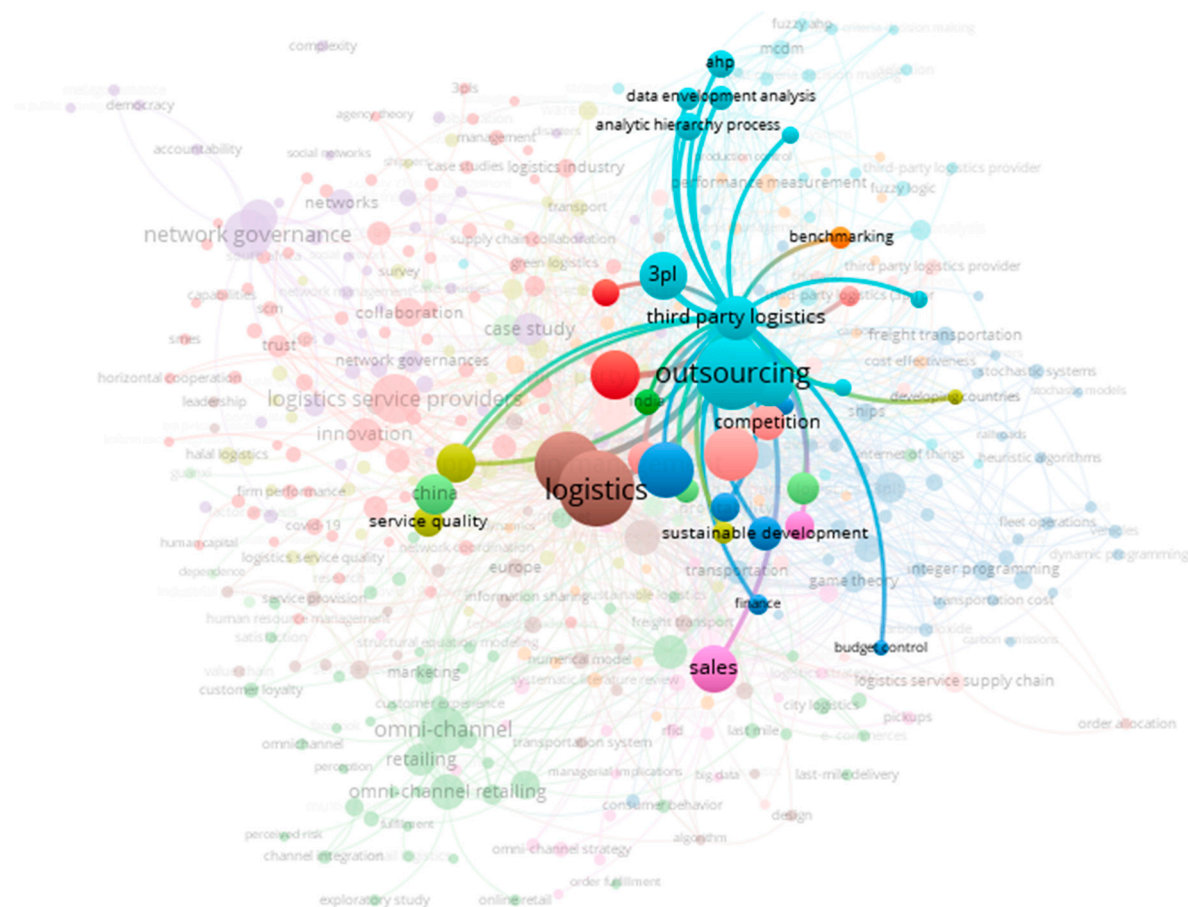


Figure 3. Connection with main cluster “3PL” elaborated on VOSviewer.

According to the SCOPUS database, the number of articles related to network coordination was highest in the year 2022, with a total of 10 articles (17.54%) indexed in the SCOPUS database in this subject area. Thus, it can be considered that the topic of network coordination has become relatively popular in recent times. Narrowing down the focus of network coordination to issues related to logistics, where “logistics” appears in the searched areas, allows for the identification of five articles centred around this theme. Further analysis, which combines network coordination with logistic service providers (3PL or LSP), revealed one article in this context. However, an analysis of network coordination in the context of articles addressing omni-channel issues showed a lack of articles in this area. The SCOPUS database also contains topics related to typical logistics coordination, which to some extent overlap with the concept presented in the article (17 articles). The collective results of the SCOPUS database review are presented in Table 1.

As evident from the review of the SCOPUS database, the subject matter related to network coordination or network governance in omni-channels and the role of logistic coordination involving service providers requires further expansion. The existing literature also does not present criteria for evaluating a service provider who could be predisposed to assuming the role of network or logistical coordination in omni-channel distribution. The authors discuss selected aspects, focusing either on the forms and mechanisms of network coordination in distribution networks or on the role of logistics operators in omni-channels. However, there is a lack of research on the mechanisms of network coordination, especially logistics, which predisposes logistics operators to coordinate omni-channels. Meeting this challenge requires consideration of two aspects: the features that distinguish omni-channels from other distribution networks, which affect network coordination, and the capabilities of logistics operators in terms of logistics coordination of omni-channels.

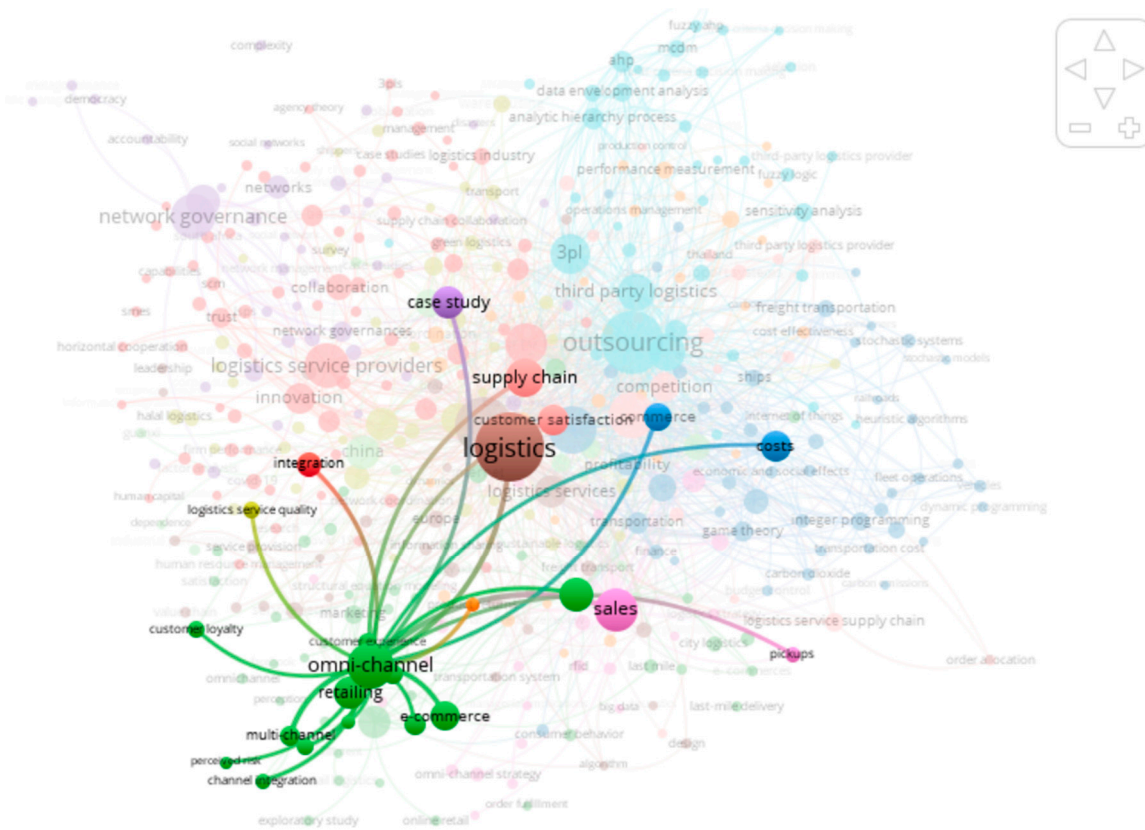


Figure 4. Connection with main cluster “omni-channel” elaborated on VOSviewer.

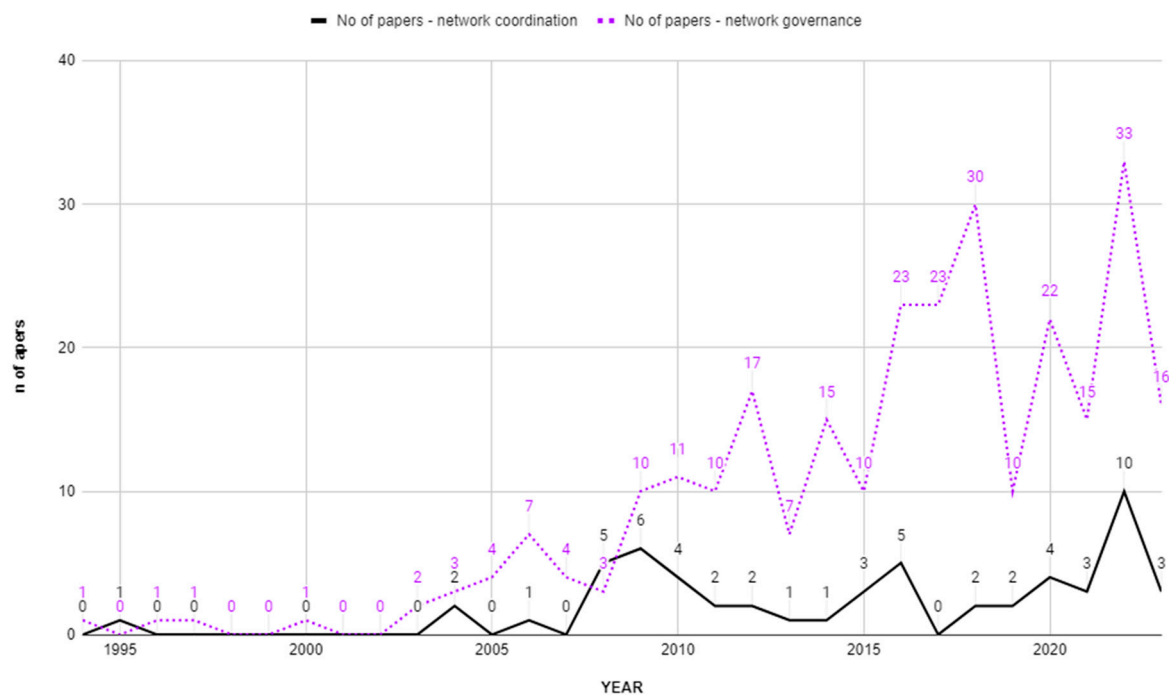


Figure 5. Number of papers about “network coordination” or “network governance” according to SCOPUS database.

Table 1. Network coordination or network governance aspects connected with logistics based on research papers indexed in SCOPUS.

Research Papers	Network Coordination or Network Governance Aspects			
	Important Role of Logistics in the Network Coordination	Logistics Coordination Concept	Important Role of Logistics Outsourcing (Like 3PL or LSP)	Network Coordination in the Context of Omni-Channels
[11–13]	yes	yes	yes	no
[21–26]	yes	no	no	no
[27–35]	no	yes	no	no
[36]	no	yes	no	yes
[37–41]	yes	yes	no	no
[42–45]	no	yes	yes	no

2.2. Network Coordination in Omni-Channels

Distribution systems are undergoing a transformation. Classic solutions in which channels are dedicated to specific customer segments are being displaced by multi-channel and omni-channel systems. This is influenced by a number of factors; supply-side factors include the digitalisation of supply chains, technological developments, and a change in the way companies think about return logistics, while demand-side factors [46] include an increased interest in e-commerce systems, widespread access to and ability to use various technologies, and changing customer behaviour patterns as a consequence of the COVID-19 pandemic (e.g., fear of crowds) as well as new shopping habits developed by the public during the pandemic (e.g., online shopping, use of parcel machines, and others) [47]. The development of e-commerce systems has been noticeable for many years; however, the pandemic period has made this form of sales even more dynamic. It can therefore be concluded that it is not the shopping trends themselves and the way in which e-commerce systems are organised, which are not new, but their dynamic development over the last five years that is transforming distribution systems and the market for logistics services. The complexity of modern distribution systems results from combining different distribution channels to serve the same customer. The network thus created, made up of many different channels between which product, information, risk, and finance are moved, is referred to as a multi-channel system [48]. In such systems, it is the customer who decides how he or she wants to purchase the product given the various purchase options available [49]. The multi-channel strategy has been discussed by both theorists and practitioners for many years. Some authors [50] also studied sales effectiveness in companies, with a focus on the use of different communication channels such as customer visits, telephone calls, and letters, as well as the then developing sales channels such as customer service centres and e-commerce. The paper indicated that the use of an omni-channel strategy could bring benefits in the form of greater sales efficiency, improved customer satisfaction, and increased market share. Since then, a multi-channel strategy has become a popular approach in the field of marketing, which is also reflected in numerous academic studies. Omni-channel distribution involves purchasing through indirect and direct marketing channels including websites, apps, retail shops, mail order catalogues, direct mail, email, etc. [51]. A characteristic feature of these types of channels is their independence. Each channel has its own prices, resources, and possibility to contact and interact with the customer [52]. The aim of the multi-channel idea is to reach the widest possible audience with the help of the media in which each group happens to be. As a result, an online shop can use Facebook, Instagram, a website, sponsored blog posts, and many others, for which a strategy can be developed separately. Consequently, the messaging and standard of service in the different venues may differ. Although the company appears in many places, it does not exploit the potential of building a relationship with its audience and getting them used to its presence.

This weakness was the reason for further exploration and improvement of the service by integrating channels and increasing interaction with the customer, and omni-channels were created through evolution. Omni-channel is an extension of the multi-channel strategy, as it uses a variety of sources to reach the customer, linking them together. It represents another level of care for the customer and their needs, due to the clarity of the message of each company that uses it. It mandates that marketing and sales activities be seen as a coherent whole. Omni-channels therefore provide the same level of customer service regardless of the channel chosen [53]. Omni-channel structures include a website and online shop, mobile apps, desktop shop, social media, email marketing, acquisition, call centre, smart TVs, and games consoles. In each of the marketing channels, the customer can place an order, check the status of the order, choose the method of physical distribution, or make a complaint regardless of the channel choice at earlier stages [54]. This implies the need to integrate the information that is made available in each channel, such as the price of the product, its description, pictures, and also shipping and traceability information during the physical flow of the product from the seller to the customer [52]. These channels have common stock levels; therefore, the role of logistics operators undertaking the handling of such complex systems is increasing.

Omni-channel, as a sales strategy, shows that brands not only ensure that more channels are available for customers to purchase goods but also ensure that the experience they have at each channel is consistent and ‘works’ together [55]. This is why advanced IT solutions are important in such distributions, the use of which facilitates the management of stock in central warehouses, as well as field sales points [56]. The dynamic management of prices and sales conditions, and the smooth movement of highly rotating goods in the channel is also crucial. This would not be possible without coordinating flows across all channels.

Network coordination, including its forms and mechanisms, is studied in different configurations in networks of cooperating organisations. The authors emphasise that the effectiveness of the use of combinations of coordination mechanisms depends on the extent to which they are matched to the type of network of interacting organisations [57]. Such a fit should take into account, among other things, the part of the supply chain at which the network is formed. A factor that significantly influences where network relationships are intensified is the degree of product customisation [58]. While products designed according to the customer’s design require complex supply networks and simplified distribution systems, standardised or massively differentiated products require the extension of network relationships at the distribution level. Distribution networks are an example of building relationships between product manufacturing organisations and intermediaries, logistics companies, and final customers. The coordination of the distribution network must be aimed at synchronising processes in such a way that customer orders are reliably fulfilled when and where the customer expects the product [59]. Omni-channel distribution, due to its complexity and the integration of different channels required for its implementation, requires a precise choice of coordination mechanisms, which are sought in the network coordination construct. As we have pointed out, omni-channel distribution requires a focus on customer satisfaction in such a way that regardless of the channel chosen, the customer is equally satisfied with the order. This challenge justifies the high importance placed on network coordination.

Authors [60,61] define network coordination as the effective and efficient use of the resources of all nodes of an inter-organisational network (including infrastructure, knowledge, and other resources), to achieve set goals. Network coordination aims to ensure the coherence of activities, to counteract conflicts by arranging in some purposeful order the tasks carried out by multiple participants, and to adapt participants with different attributes to the established rules through various mechanisms [59]. In line with the concept presented in the paper, we have assumed that forms of network coordination indicate the source of the coordinator’s authority, giving him or her the power to coordinate the network through any set of mechanisms. Some authors [62] list a set of three forms of coordination:

market, hierarchical, and social, which together occur in networks. Another author [63] details these into mechanisms: price (e.g., price, bilateral collateral), non-price (e.g., trust, social standards, decision-making style), and flow (e.g., VMI, QR, CPFR). Hierarchy-driven mechanisms prevail in the enterprise. Going beyond the single organisation and analysing distribution networks, one can see the increasing importance of mechanisms related to the market form of coordination. One and the other mechanisms are strongly intertwined with mechanisms characteristic of the social form of coordination. These three types of groups of mechanisms are most often discussed in the literature in the context of network coordination. Among the mechanisms characteristic of the market form, what is usually mainly described is the price [63], but also formal relationships and bilateral collateral. Among the mechanisms characteristic of the hierarchical form, he identifies structures and control systems resulting from management styles, bureaucratic allocation of resources, budgeting, and organisational integration. A distinguishing feature of the hierarchical form of coordination is the power that one actor acquires over others through knowledge. This is an important point, as there are no organisational structures characteristic of companies in networks. Thus, the source of power is not subordination in the organisational structure but the fact that one organisation has more knowledge and capacity to use it than the other organisations. This organisation naturally becomes the coordinator. Among the mechanisms attributed to social coordination, however, he mentions trust, communication systems, and information exchange as well as social standards [58]. Since distribution networks are systems oriented towards reliably fulfilling customer orders and ensuring that products are available where and when the customer wants to purchase and receive them, we supplemented the indicated forms of coordination with a logistical form. The logistical form of coordination is oriented towards the selection of such coordination mechanisms, which ensure the timely, complete, and damage-free realisation of distribution processes to the place indicated by the customer. This addition to the network coordination construct is the result of the indicated challenges posed by the logistics handling of omni-channel systems.

In omni-channel distribution, flow mechanisms that affect the timeliness and completeness of implemented orders become particularly important. This group of mechanisms is insufficiently discussed in the literature. The set of flow mechanisms will constitute the construct of logistical coordination in the research. As logistical coordination is aimed at reliable process execution (i.e., the timely, damage-free, and complete fulfilment of customer orders), also under the impact of disruptions, it can be assumed that the selection of flow coordination mechanisms simultaneously aims to strengthen the resilience of the distribution system [64]. Thus, such mechanisms are sought that allow for the consistency of operations and continuity of processes, regardless of the factors affecting the flows of finished goods [65]. In research on network coordination, authors point to VMI, CPFR, and others. These are detailed tools in flow management; however, they do not exhaust the impact on the logistical problems that face the coordinator of distribution networks, supply networks, or supply chains. Intuitively, the flow mechanisms identified by network coordination researchers touch on key areas for flow management, including forecasting and resources management. In our proposed construct of logistics coordination in networks of cooperating organisations, we have adopted a broader spectrum, taking into account mechanisms analysed separately by different authors:

- Network participants' resources management from the logistics operator level [66],
- Forecasting network flows [67],
- Organisation of transport and emergency transport [68],
- Logistical information management from the logistics operator level [69],
- Demand management [13,52],
- Managing human resources and infrastructure in the network [70].

The implementation of such assumptions will extend the current theory of network coordination with logistic mechanisms allowing for the coordination of flows in complex distribution systems, which are omni-channel systems.

2.3. Logistics Operator in Multi-Channels

A key component in assessing the effectiveness of physical distribution is the quality of logistics processes including, in particular, reliability [71]. Therefore, cooperative organisations in omni-channel systems seek to collaborate with LSPs, who add value by providing multiple complementary services, as well as sharing physical resources and information to streamline flows throughout the supply chain [7]. Retailers can, for example, shorten the lead time of orders mainly through picking services provided by LSPs [72]. Logistics issues in the context of multi-channel and omni-channel are most often concerned with the interaction in supply chains, warehouse operations and the design of warehouse management solutions, e-fulfilment, and logistics-related customer service issues [73]. Logistics is a critical aspect related to the success of e-commerce operations [74,75], but also to the operation of other forms of distribution like multi-, cross-, and omni-channel [76]. The growth of the 3PL market has been accelerated due to the e-commerce boom and the increase in return logistics operations. There has been a massive influx of third-party logistics to help maintain this highly complex supply chain, offering a wide variety of different services [77]. LSPs also have an impact on reducing environmental impact by increasing the use of environmentally friendly modes of transport, increasing delivery efficiency, and increasing delivery flexibility [78]. Alongside information technology, 3PL is often recognised as one of the necessary elements to achieve rapid multi-channel business growth [79]. However, it is important to note that acquiring logistics operators is equated with a long-term financial decision [5]. For 3PL operators, it is critical to have physical resources such as warehouses or transport fleets [1] which provide them with the ability to run flexible operations. An increasing number of logistics service providers are becoming actively involved in the multi-channel distribution of food products. One of the first logistics service providers to become actively involved in the multi-channel distribution of food products was DHL [80].

The concept of multi-channels and the concept of using an LSP entity to deliver logistics services are mostly separate issues in the literature [81]. This can be seen, among other things, in the development of models for integrating e-commercial platforms into the communication between manufacturer and customer, in which the LSP is treated as a separate entity that is not included in the information flow, but only performs the outsourced logistics services [82]. In our opinion, such an approach is not correct, especially if the distribution network is to fulfil the assumptions arising from omni-channelism and thus ensure the same level of customer satisfaction in each channel [83]. According to some authors, the inclusion of logistics operators in the flows increases the complexity of omni-channel systems [82]; however, the benefits of their use are so significant that their role in such distribution systems is constantly increasing.

In multi-channel systems, it is essential to maintain and make rational use of the knowledge base of customers across channels [84]. End-customer satisfaction is a result of, among other things, the level of logistics service offered by LSPs to network participants [2]. LSPs offer logistics services, but they also provide access to a network of contacts for retailers to leverage their network of relationships to efficiently fulfil orders to customers. They can handle product returns or work with carriers for 'last-mile' deliveries [7]. Some authors place the greatest emphasis on last-mile delivery and see it as a critical point in the performance of multi-channel systems. They also note that systems not focused strictly on the last mile, even if LSPs are present, are less effective than those focused on last-mile optimisation [85]. Among the tasks of 3PLs in the field of multi-channel are also the handling of drop shipping logistics and supporting companies in resource management, e.g., using the VMI model [86]. One of the undisputed critical elements related to the functioning of online sales, from the perspective of logistics processes, is precisely an adequate warehouse management system [7]. The adaptation of LSPs to current trends related to digitalisation is also an important element in multi-channel. Digitalisation is changing the market environment in which companies are moving, most notably in terms of changing working environments, customer experiences, and entire

business models [6]. This is also the case for multi-channel logistics operators. They have to adapt their operations to current trends and to the requirements of their internal customers, which is consequently considered to be an adaptation of the operators' business models to contemporary market requirements. In addition, issues such as, for example, the operation of click-and-mortar shops, i.e., shops where orders can be placed electronically or in person by traditional means, require increased logistics integration. This integration should allow customers to order online and pick up their purchases from the nearest shop or return those products at the most convenient location [5]. One of the logistical issues in cross-channel is the delivery from warehouses adapted to the collection process for small shipments. Warehouses adapted to the pick-up process can be linked to existing warehouses. In the cross-channel area, further distribution channels are usually differentiated in the area of last-mile logistics [80]. LSPs in such a situation should pay special attention to the reverse flow of products [74]. Some authors assign logistics related to delivery and product picking and return a high score in estimating the risks that occur in cross-channels [87]. Such risks can be mitigated by outsourcing logistics operations to logistics operators.

The main challenge for LSPs in the omni-channel era is managing the increasing number of small shipments, fulfilling more frequent orders, shorter lead times, a higher number of SKUs, and synchronising distribution processes across channels [1]. The literature notes that logistics service providers should develop their skills and infrastructure towards enhancing their capabilities in automating consignment sorting processes in the area of warehouse management [74]. Concepts such as fully automated warehouses, carbon-neutral buildings, hybrid or all-electric trucks, robotics, drones, and voice- or optically-guided warehouse operations are increasingly being used by LSPs [1]. LSPs should also invest in software and IT platforms to automate transport planning tasks in terms of considering fleet location, road congestion, and capacity [74]. Some researchers note the possibility of combining technological solutions from, among others, the Internet of Things used at the manufacturer with LSP operations [88]. LSPs should tailor logistics services for specific modes of receipt and also demonstrate the ability to integrate their solutions with customer-friendly solutions such as QR codes [78]. Among the main challenges of LSPs is that they need to satisfy customers with different needs in a variety of channels [2]. The literature also indicates in their research that most LSPs create additional customer value in omni-channel systems [89]. Using dedicated applications and personalised IT systems, LSPs aim to increase the transparency of distribution channel flows, create a customer base with their needs, and increase customer satisfaction by improving the quality of logistics services tailored to specific customers. An IT platform can serve as an application, providing seamless digital communication between companies throughout the supply chain [90]. LSPs are also very often tasked with the design and creation of reverse logistics networks [91] and also with the planning of transport routes [92], especially with an emphasis on last-mile delivery planning [89]. Selected LSP activities in distribution networks with multi-channel are indicated in Table 2.

Authors [93] indicate that selecting LSPs and building relationships with them can be counted among the strategic tasks of an omni-channel architect company. According to a study in the literature [79], companies that have been able to transition to omni-channel sales in recent years have been able to achieve an increase in profits from their operations in the range of 5–15%. Also, in terms of increasing the innovation of omni-channel companies, some authors indicate that the use of LSPs in omni-channels can be counted among a set of best practices [94]. Therefore, the proper integration of LSPs in omni-channel structures, although a complex task, can bring many benefits. There is a research gap in the literature related to the role of logistic operators in coordinating omni-channel logistics. Studies on this topic are scattered across various domains, but this article will consolidate, expand, and attempt to clarify a certain viewpoint presented by its authors.

Table 2. Selected activities carried out by LSPs in distribution networks in which multi-channelism is present.

Selected Activities Carried out by the LSP	
in Multi- and Cross-Channels	in Omni-Channels
• maintaining flexibility in dealing with different distribution channels. • generating added value for the network's internal and end customers. • maintaining and making rational use of the customer knowledge base across channels. • fitting a warehouse management system. • supporting various distribution models (e.g., drop shipping or VMI) with logistics services. • aligning the operator's structures with current market trends related to digitalisation. • handling product returns. • implementation of last-mile logistics. • differentiating distribution in terms of last-mile logistics.	• elements from multi- and cross-channel operation. • handling significantly growing small consignments. • optimising distribution through various channels. • shortening the lead time for orders of an increasing number of SKUs. • designing backflows. • increasing the level of automation in logistics processes. • implementing platforms and software for information exchange. • supporting retailers, creating value for the entire network. • reduction in omni-channel costs. • developing and implementing modern technologies.

3. Materials and Methods

The theoretical background carried out identified gaps in research on the logistical support of omni-channels. In particular, there is a lack of in-depth research on network coordination in such complex distribution systems. Combining the problematics of network coordination in omni-channels with the problematics of the tasks carried out by logistics operators in omni-channels, we posed the following research questions in the paper:

RQ.1: What role can a logistics operator play in the network coordination of omni-channels?

RQ.2: What forms of network coordination can a logistics operator use to ensure reliable omni-channel flows?

RQ.3: Which network coordination mechanisms are the most powerful in building customer satisfaction in omni-channel systems?

The answer to question 1 was sought in the theoretical background in Section 2.2. Questions 2 and 3, on the other hand, were initiated by isolating a set of network coordination mechanisms in Section 2.1 for each form of coordination. The construct of network coordination is made up of four forms: market, hierarchical, social, and logistical, which use distinctive price, non-price, and flow mechanisms (Table 3).

The coordination mechanisms presented in Table 3 were determined through an extensive review of the literature on network coordination within distribution systems, particularly those focusing on omni-channel distribution. This review encompassed both seminal works and recent studies that detail various forms of coordination and their associated mechanisms. We identified four primary forms of network coordination: market, hierarchical, social, and logistical, each characterized by specific coordination mechanisms. Market coordination mechanisms were derived from sources that emphasize pricing strategies, formal relationships, and bilateral security as key components. Price mechanisms influence the behaviour and decisions of network participants through dynamic pricing strategies. Formal relationships are established via contracts and formal agreements that delineate the terms of collaboration and ensure clear expectations between parties. Bilateral security involves mutual protection and risk-sharing measures that foster stable and reliable partnerships. Hierarchical coordination mechanisms were identified by examining the control structures and systems resulting from different management styles. These mecha-

nisms include organisational integration, which emphasizes the coordination of various departments and functions within and across organisations to achieve cohesive outcomes. Bureaucratic allocation of resources, another hierarchical mechanism, involves a structured and rule-based distribution of resources, ensuring that network activities align with organisational goals and policies. Social coordination mechanisms were derived from the literature focusing on trust, social standards, and significant information exchange. Trust is a crucial element that facilitates smooth interactions and reduces the need for constant monitoring. Social standards refer to the norms and values that guide behaviour within the network, promoting cooperative and consistent actions. Information exchange involves the sharing of relevant data and knowledge, enhancing transparency and collaboration among network participants. Logistical coordination mechanisms were identified as essential for the effective management of complex distribution systems like omni-channel networks. These mechanisms include the management of network participants' resources from the logistics operator level, forecasting network flows, organising transport and emergency transport, logistical information management, demand management, and the management of human resources and infrastructure within the network. These logistical mechanisms ensure the timely, complete, and damage-free fulfilment of distribution processes, which is critical for maintaining high customer satisfaction levels in omni-channel systems.

Table 3. The network coordination mechanisms considered in the AHP method.

Forms of Network Coordination		Coordination Mechanisms
market	• Price. • Formal relationships. • Bilateral security.	
hierarchical	• Control structures and systems resulting from management style. • Organisational integration. • Bureaucratic allocation of resources.	
social	• Trust. • Social standards. • Significant exchange of information.	
logistical	• Network participants' resources management from the logistics operator level. • Forecasting network flows. • Organisation of transport and extraordinary transport. • Logistical information management from the logistics operator level. • Demand management. • Management of human resources and infrastructure in the network.	

Further steps in the search for answers to Questions 2 and 3 were carried out using a research procedure that aimed to develop a tool to assess logistics operators in terms of their predisposition to coordinate omni-channels. To achieve this objective, we conducted a hierarchical analysis of the impact of the different mechanisms used by the logistics operator on the reliability of the omni-channel distribution system. Thus, expert research and AHP analysis were used at this stage (Figure 6).

The procedure presented in Figure 6 was developed by the authors, combining established AHP methodology with novel applications specific to network coordination in omni-channel distribution systems and the role of logistics operators. While grounded in the standards of the AHP method and drawing upon research by other scholars, the procedure's uniqueness lies in its tailored application to these specific areas. This innovative approach builds on the traditional AHP framework, which decomposes complex

problems into hierarchical components for pairwise comparison using expert judgments. By adapting these principles to focus on omni-channel strategies and logistics operators, we extended the AHP method's applicability, addressing the unique challenges and dynamics of these domains. In summary, the novelty of our procedure is its specific adaptation of the well-established AHP methodology to the context of network coordination, omni-channel distribution, and logistics operators, providing new insights and enhancing the method's relevance to these fields.

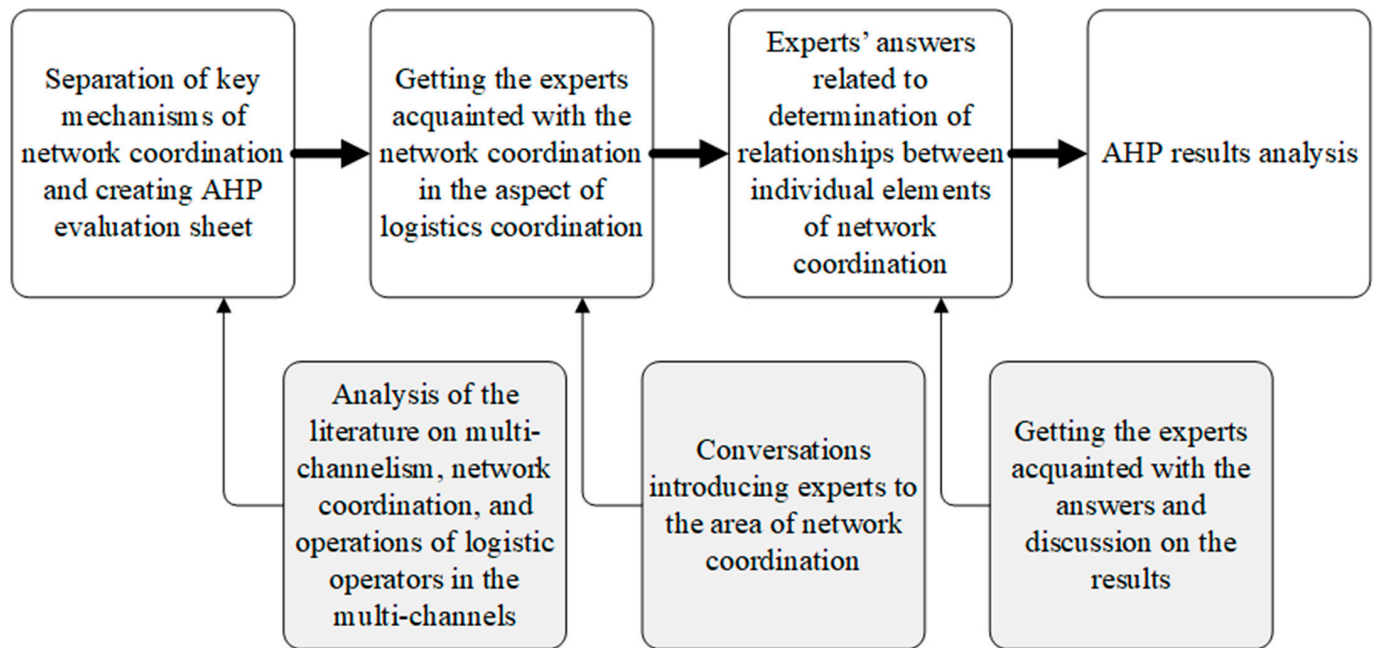


Figure 6. Test procedure.

The selection of experts was determined by the narrow research area requiring knowledge of both omni-channel and the role of logistics operators in building customer satisfaction and enhancing distribution network reliability. Twenty-four experts were invited to participate in the study. The expert self-assessment sheet included both knowledge and experience criteria. It was assumed that an expert is a person who works within the structures of a logistics operator in an independent decision-making position that is related to the implementation of warehouse or transport processes in a multi-channel and has professional experience in this area of more than 5 years. We determined the expert's degree of familiarity with the problem in question on the basis of the expert's self-assessment on a 10-point scale. The expert's task was to objectively indicate their own familiarity with the problem, scoring themselves from 0 to 10, where 0 meant that the expert had no familiarity with the problem and 10 meant that familiarity with the problem belonged to the expert's narrow specialisation. On the basis of the competence index (according to the assumption made, it had to exceed 0.5), we qualified 8 experts for further research. The experts' panel included only senior managers working in 3PL companies. The chosen experts are as follows:

- Expert 1: Senior Logistics Manager, 12 years of experience, specializing in warehouse and transport management including e-commerce operation.
- Expert 2: Operations Director, 15 years of experience, responsible for 3PL strategies, also omni-channel implementation.
- Expert 3: Logistics Analyst, 10 years of experience, expert in supply chain management.
- Expert 4: Logistics Manager, 8 years of experience, specializing in logistics resource management and warehouse processes in the e-commerce area.

- Expert 5: Operations Manager, 11 years of experience, focused on optimizing logistics processes and managing transport in an omni-channel environment.
- Expert 6: Logistics Specialist, 9 years of experience, expert in planning and implementing logistics strategies.
- Expert 7: Logistics Specialist, 14 years of experience, specializing in logistics system integration and supply chain management.
- Expert 8: Process Manager, 10 years of experience, responsible for implementing logistics solutions and managing warehouse operations in 3PL.

Each of the selected experts has extensive experience in logistics outsourcing, particularly in activities related to e-commerce and omni-channel strategies. Their individual experiences may influence their interpretations of specific coordination mechanisms; however, the use of the AHP method, which requires pairwise comparisons of factors, helps minimize subjective differences. The procedure also includes consistency verification (CI and CR), which further enhances the objectivity of the results. Therefore, while the experts' experiences may bring unique perspectives, the AHP methodology and verification process ensure that the results are reliable and representative. Each of the experts was interviewed by the authors of the study and then completed a questionnaire in which they compared in pairs the importance of the different forms and mechanisms of coordination in the coordination of omni-channels.

The assembled experts were introduced to the concept of network coordination in order to clarify the questions that appeared in the survey questionnaire. The survey is one of the most popular and most used research methods [95]. The experts were also introduced to the basic information related to the AHP method—the information was given to them during the introductory interview that preceded their completion of the questionnaire. The expert proceeded to complete the survey after being familiarised with the information mentioned above and had an interviewer available throughout the survey to clarify any doubts. This approach allowed us to obtain correct answers, which were not influenced by dissonance related to the misperception and interpretation of the surveyed factors. On the basis of the responses, we created an AHP evaluation sheet, which primarily served to assess the impact and importance of the different elements of the coordination mechanisms. The analysis included a comparison on a nine-point scale of the impact of the different forms of network coordination and the mechanisms they use. The scale for the importance of assessment is the scale presented in the AHP literature [96].

The AHP method belongs to the group of methods for the multi-criteria evaluation of decision-making problems. It is a hierarchical approach to multi-criteria decision-making that combines quantified with non-quantified and objectively measurable with subjective criteria [96]. The method involves breaking a complex problem into its component parts and then comparing them in pairs using expert knowledge. AHP works particularly effectively when the relationships between the components of a decision are unknown, while the cumulative end result is easy to predict [97]. The AHP method is also used to evaluate individual components, in addition to indicating the abundance of individual scores for each component and inferring from the mean and median of the results obtained [96]. This approach implies the use of two measures, i.e., CI (consistency index) and CR (consistency ratio).

The CI increases as the inconsistency of the estimates increases and is calculated with the following formula:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

CR, in turn, is the ratio of the CI of the matrix containing the expert's assessments of pairwise comparisons to the mean value of the random pairwise comparison consistency indices and is given by the following formula:

$$CR = \frac{CI}{r} = \frac{\lambda_{max} - n}{r(n - 1)} 100\%$$

where

λ_{max} —the eigenvalue of the matrix and is one measure of the consistency of comparisons, reflecting the proportionality of preferences,
 n —the number of elements being compared with each other,
 r —the mean value of the coherence indices of the random pairwise comparisons.

As a rule of thumb, an expert's judgements are assumed to be consistent if the CR is no greater than 0.1 ($CR < 10\%$) [98]. The assumed value of r varies depending on the dimension of the matrix (n). The values of r determined from computer simulation are standard values from the literature [96].

A high CR and CI in the AHP method may be caused by imperfections in the hierarchy of criteria or inconsistency in the decision-making of an expert or group of experts. When there is inconsistency in expert judgements, this may be due to differences in experience or preferences, leading to subjective judgements. On the other hand, inadequacies in the hierarchy of criteria may be due to inaccurate prioritisation of criteria or failure to consider all relevant factors [99]. In order to minimise the impact of these factors on the results, it is important that an expert or group of experts carefully thinks through and agrees on the hierarchy of criteria and makes judgements consistently. After assessing the consistency of the individual experts, it was decided to assign weights to the individual experts' assessments based on the criterion related to the value of the CR index and to reassess the importance of the individual factors in relation to network and logistical coordination. The AHP method, which we chose, has already been used to describe the problematic activities of logistics operators e.g., for sustainable development [82].

4. Results

The experts who took part in the study rated the links between the various forms of network coordination and then the network coordination mechanisms by weight. A heatmap showing the number of occurrences of each rating for each rated element is presented in Figure 7.

The elements of logistics coordination that the experts indicated most often as elements to the right of the heatmap are presented in Figure 3, and at the same time the elements that most often had a strong advantage over the elements compared, were the management of network participants' resources from the logistics operator level and the forecasting of flows in the network. The latter element showed a deeper embeddedness with a greater impact on the other elements. Therefore, it can be concluded that these elements are the elements most often indicated by experts as those with the greatest advantage over the others in the coordination of omni-channels from the position of the logistics operator. Demand forecasting by the operator can bring a number of benefits, such as the fact that operator-generated forecasts can support the demand plans of producers in distribution networks [13] but also increase flexibility in response to fluctuations in demand that would be signalled by a well-structured forecasting system. Resources management in the network from an operator's perspective is also an important element, which is a well-constructed system of resources management of the individual links in the network and will enable a reduction in the overall stock level, as well as a better availability of products from stock. On the other hand, the most frequently selected element that had the least importance in logistical coordination is the one related to the organisation of transport and extraordinary transport. Thus, the experts indicated that, according to past experience, extraordinary transport is not a mechanism commonly used in the coordination of flows in omni-channel systems. Among the mechanisms characteristic of the market, hierarchical and social forms, price, organisational integration, and trust are the most important. Tables 4–8 show the arithmetic averages and medians obtained from the given assessment. The given numerical values were presented as $x(y)$, where x is the value corresponding to the mean of the results obtained; and y is the value corresponding to the median of the results obtained. Results were presented rounded to two decimal places.

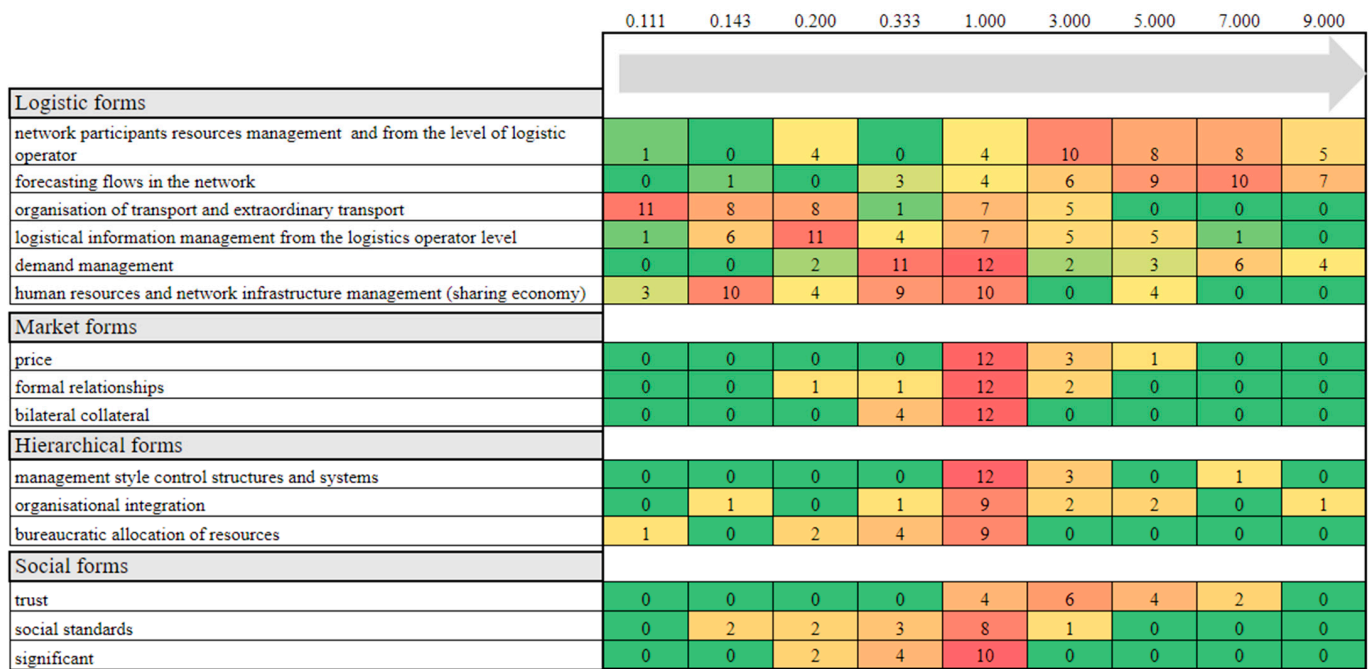


Figure 7. A heatmap for the number of occurrences of elements at the adopted impact scale (green—the factors with the less number of answers, red are the factors with the largest number of answers).

Table 4. Mean magnitudes and median scores associated with determining the advantage between the forms of network coordination assessed.

Network Coordination	Logistical Coordination	Hierarchical Coordination	Social Coordination	Market Coordination
Logistical coordination	1.00 (1.00)	2.00 (1.00)	3.25 (3.00)	2.00 (1.00)
Hierarchical coordination	0.73 (1.00)	1 (1.00)	3.00 (3.00)	2.00 (1.00)
Social coordination	0.38 (0.33)	0.47 (0.33)	1.00 (1.00)	1.42 (1.00)
Market coordination	0.73 (1.00)	0.73 (1.00)	1.09 (1.00)	1.00 (1.00)

Based on the averaged expert responses (Table 5), logistics coordination is deemed more important than other forms of network coordination. Given the survey's focus on the logistics operator's role, this result is expected. Experts recognize the significant role of logistics functions and services in distribution networks. Interestingly, experts prefer the hierarchical form over the social and market forms, with the social form slightly edging out the market form.

Based on the averaged expert responses (Table 6), the importance of various elements in logistics coordination is ranked as follows: network flow forecasting, resource management at the operator level, demand management, logistical information management at the operator level, human resources and network infrastructure management, and the organisation of transport and extraordinary transport.

The experts also determined the importance of the different elements related to market coordination mechanisms (Table 7), ranking them as follows: price, formal relationships, and bilateral collateral.

Based on the experts' averaged assessment (Table 9), it can be concluded that the hierarchy of importance of the different hierarchical coordination mechanisms is as follows: organisational integration, structures and control systems resulting from management style, and the bureaucratic allocation of resources.

Table 5. Mean magnitudes and median scores associated with determining the advantage between the logistical coordination mechanisms assessed.

Forms of Logistical Coordination	Network Participants' Resources Management and from the Logistics Operator Level	Forecasting Network Flows	Organisation of Transport and Extraordinary Transport	Logistical Information Management from the Logistics Operator Level	Demand Management	Management of Human Resources and Infrastructure in the Network (Sharing Economy)
network participants' resources management and from the logistics operator level	1.00 (1.00)	1.94 (1)	7.5 (8.00)	5.00 (5.00)	2.05 (2.00)	5.50 (6.00)
forecasting network flows	2.73 (1.00)	1.00 (1.00)	7.75 (8.00)	5.50 (5.00)	2.42 (3.00)	6.75 (7.00)
organisation of transport and extraordinary transport	0.14 (0.13)	0.13 (0.13)	1.00 (1.00)	0.62 (0.67)	0.85 (0.14)	1.55 (1)
logistical information management from the logistics operator level	0.22 (0.20)	0.20 (0.20)	2.75 (2.00)	1.00 (1.00)	1.10 (0.67)	3.05 (3.00)
demand management	1.65 (0.67)	0.82 (0.33)	6.08 (6.99)	3.33 (2.00)	1.00 (1.00)	2.50 (1.00)
management of human resources and infrastructure in the network (sharing economy)	0.22 (0.17)	0.17 (0.14)	1.75 (1.00)	1.53 (0.33)	0.79 (1.00)	1.00 (1.00)

Table 6. Mean magnitudes and median scores associated with determining the advantage between the market coordination mechanisms assessed.

Forms of Market Coordination	Price	Formal Relations	Bilateral Collateral
price	1 (1)	1.75 (1)	1.5 (1)
formal relations	0.82 (1)	1 (1)	1.5 (1)
bilateral collateral	0.83 (1)	0.83 (1)	1 (1)

Table 7. Mean magnitudes and median scores associated with determining the advantage between the hierarchical coordination mechanisms assessed.

Forms of Hierarchical Coordination	Management Style Control Structures and Systems	Organisational Integration	Bureaucratic Allocation of Resources
management style control structures and systems	1.00 (1.00)	2.00 (1.00)	1.50 (1.00)
organisational integration	0.81 (1.00)	1.00 (1.00)	3.50 (3.00)
bureaucratic allocation of resources	0.83 (1.00)	0.52 (0.33)	1.00 (1.00)

Table 8. Mean magnitudes and median scores associated with determining the prevalence between the social coordination mechanisms assessed.

Forms of Social Coordination	Trust	Social Standards	Significant Exchange of Information
trust	1.00 (1.00)	4.25 (4.00)	2.75 (3.00)
social standards	0.34 (0.27)	1.00 (1.00)	1.25 (1.00)
significant exchange of information	0.55 (0.33)	0.92 (1.00)	1.00 (1.00)

Table 9. CR and CI values for network coordination ($n = 4$; $r = 0.89$).

Expert	CR Value	CI Value
1	0.043	0.038
2	0.200	0.180
3	0.058	0.052
4	0.100	0.090
5	0.127	0.115
6	0.057	0.052
7	0.562	0.506
8	0.057	0.052

According to Table 9, the averaged evaluation of the experts showed the following hierarchy for social coordination mechanisms: trust, social standards, and significant information exchange. In a further analysis, according to the assumptions of the AHP, CR and CI values were calculated for the answers given by each expert. CR and CI values were rounded to three decimal places (Tables 9–11). Green boxes indicate reasonable consistency and red boxes indicate not consistent.

When assessing the forms of network coordination (Table 9), i.e., logistical, market, hierarchical, and social coordination, the highest consistency in responses was shown by expert No. 1 and the lowest by expert No. 7. The experts, in this case, gave mostly consistent answers (62.50% of experts with a CR indicator expressing the consistency of answers).

In the case of the assessment of logistical coordination (Table 10), only one expert (expert 4) showed consistency in the responses. A high CR in the AHP method indicates a lack of consistency in the assessments of an expert or group of experts and may mean that the hierarchy of criteria is imperfect. However, this does not mean that the expert's assessment is completely invalid. The expert's assessment may still have value but should be carefully analysed in the context of the performance of other experts and in the context of the hierarchy of criteria. A high CR may suggest that some of the expert's assessments may be more subjective or flawed, leading to uncertain results.

With regard to the market, hierarchical, and social form (Table 11), the answers with the highest consistency were shown by expert No. 5, whose assessments were all consistent, while on the other hand, the expert whose assessments in this respect were the least consistent was expert No. 6 (all assessments were characterised by an excessively high CR indicator). In general, a high CR indicator can be seen in the experts' assessments. A high CR indicator may suggest that it is worth re-examining the hierarchy of criteria or reflecting carefully on the results, but it does not mean that the expert's assessment is completely worthless. An expert's subjective assessment can be considered good when it is based on sound knowledge and experience in the field and is consistent with the hierarchy of criteria and the objectives of the analysis. The baseline results were further evaluated by means of a weighting assessment, where the importance of each assessment was averaged. This modified the baseline structure of the averaged scores shown at the beginning of the analysis. The weights were determined from the calculated consistency coefficients for the individual experts and were assigned based on an arbitrarily created scoring scale (Table 12), which was the starting point for developing the weights of the individual expert assessments.

Table 10. CR and CI values for logistical coordination ($n = 6$; $r = 1.25$).

Expert	CR Value	CI Value
1	0.178	0.221
2	0.170	0.211
3	0.215	0.267
4	0.065	0.081
5	0.407	0.505
6	0.240	0.298
7	0.186	0.230
8	0.170	0.211

Table 11. CR and CI values for market, hierarchical, and social forms ($n = 3$; $r = 0.52$).

Expert	Market Form		Hierarchical Form		Social Form	
	CR Value	CI Value	CR Value	CI Value	CR Value	CI Value
1	0.025	0.015	0.259	0.150	0.117	0.068
2	0.000	0.000	0.000	0.000	0.117	0.068
3	0.000	0.000	0.117	0.068	0.000	0.000
4	0.117	0.068	0.401	0.233	0.070	0.041
5	0.000	0.000	0.000	0.000	0.000	0.000
6	0.117	0.068	0.117	0.068	0.401	0.233
7	0.000	0.000	0.516	0.299	0.025	0.015
8	0.000	0.000	0.025	0.015	0.025	0.015

The assigned scores based on the consistency of the experts' responses for each factor and the assigned weights are shown in Table 13.

Regarding the consistency of the assessments, expert No. 8 received the highest weight due to the most consistent responses, while expert No. 7 showed the least consistency. These calculated weights were used to recalculate the averaged results from the experts' answers, producing a weighted average. Figures 8–13 display the importance ratings of individual factors, averaged using these consistency-based weights.

Table 12. Adopted assessment scale for experts.

Size Range of CR for Individual Elements		Assessment
from	to	
0.000	0.050	5
0.050	0.100	4
0.100	0.150	3
0.150	0.180	2
0.180	0.200	1
0.200	∞	0

Table 13. Assessment of experts' responses for consistency of their responses.

Expert	Number of Decision Matrices with $CR < 0.1$	Number of Points Network Coordination	Number of Points Logistical Coordination	Number of Points Market Coordination	Number of Points Hierarchical Coordination	Number of Points Social Coordination	Total Points	Assessment Weight *
1	2	5	1	5	0	0	13	0.101
2	2	0	1	5	5	5	18	0.140

Table 13. Cont.

Expert	Number of Decision Matrices with CR < 0.1	Number of Points Network Coordination	Number of Points Logistical Coordination	Number of Points Market Coordination	Number of Points Hierarchical Coordination	Number of Points Social Coordination	Total Points	Assessment Weight *
3	2	4	0	5	3	3	17	0.132
4	3	4	4	3	0	0	14	0.109
5	3	3	0	5	5	5	21	0.163
6	1	4	0	3	3	3	14	0.109
7	2	0	1	5	0	0	8	0.062
8	4	4	1	5	5	5	24	0.186

$$* \text{ grade weight} = \frac{\text{expert's grade}}{\text{sum of grades of all experts}}$$

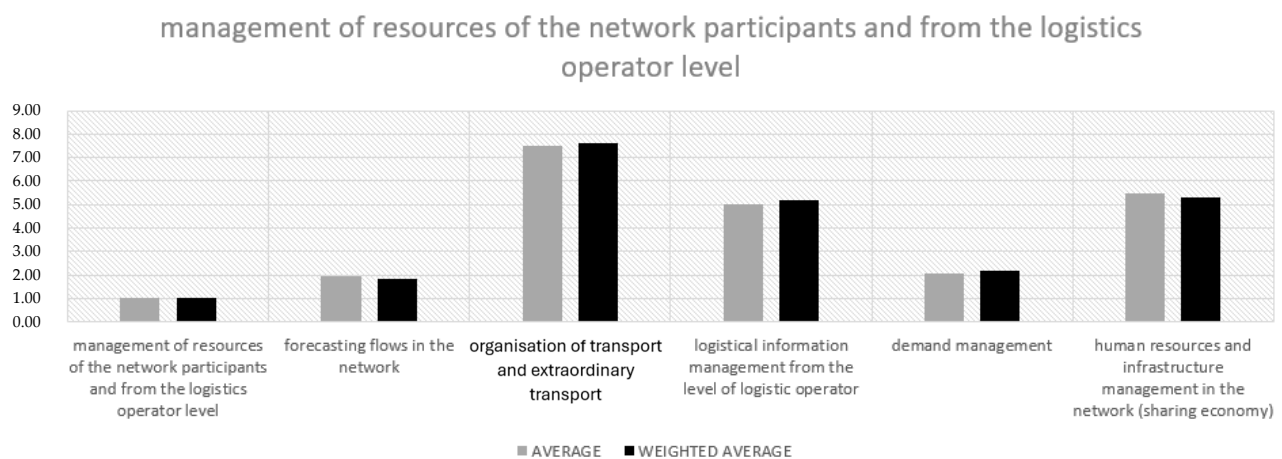


Figure 8. The importance of the element ‘management of participant resources in the network from the logistics operator level’ in relation to the other elements of logistics coordination in the averaged assessment and after applying the weighting assessment.

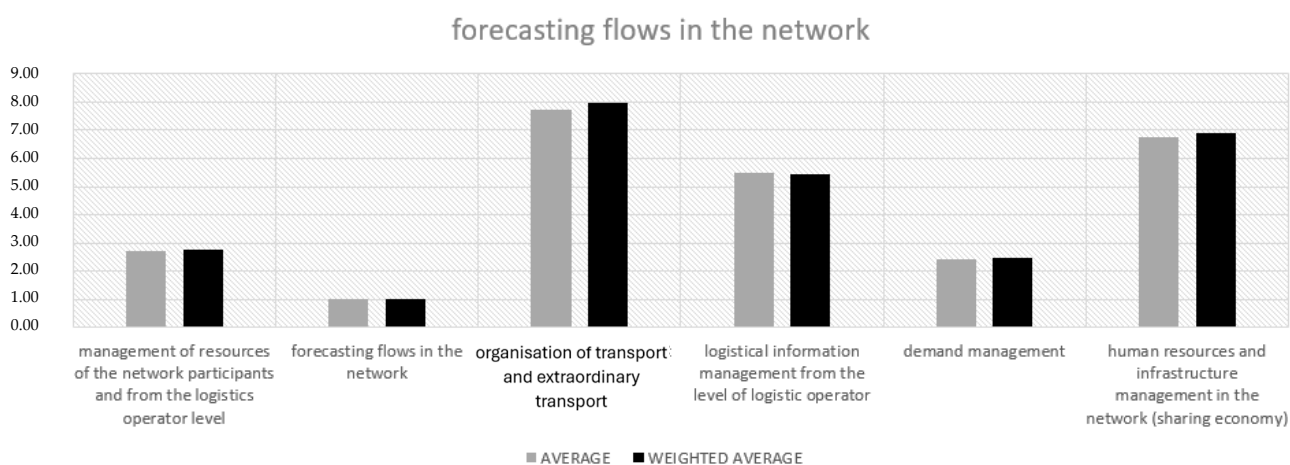


Figure 9. The importance of the element ‘forecasting flows in the network’ in relation to the elements of logistics coordination in the averaged assessment and after applying the weighting assessment.

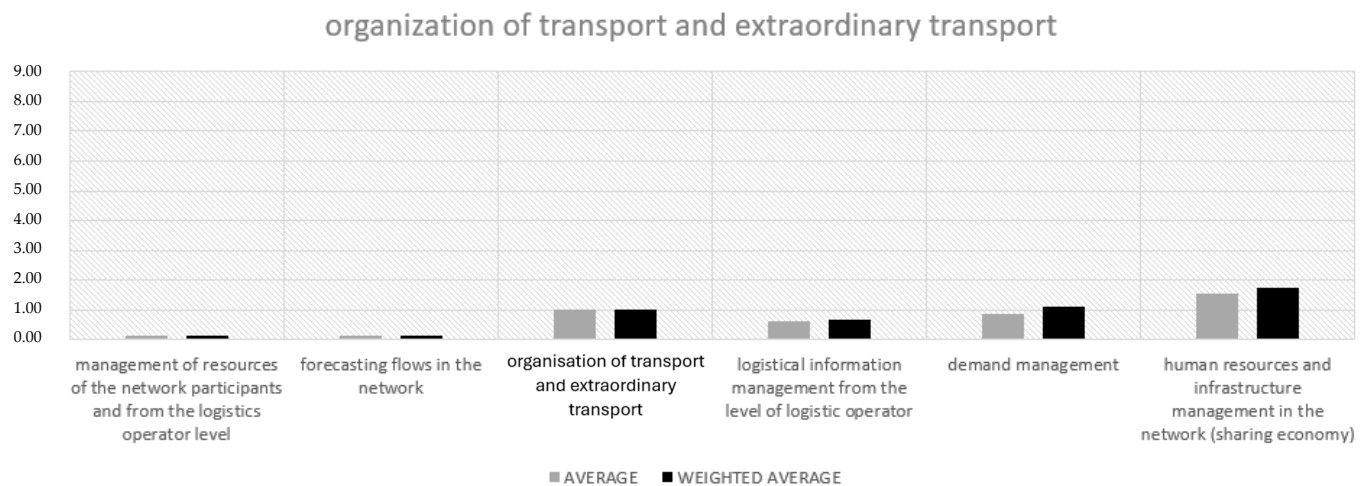


Figure 10. The importance of the element ‘organisation of transport and extraordinary transport’ in relation to the other elements of logistics coordination in the averaged assessment and after application of the weighting assessment.

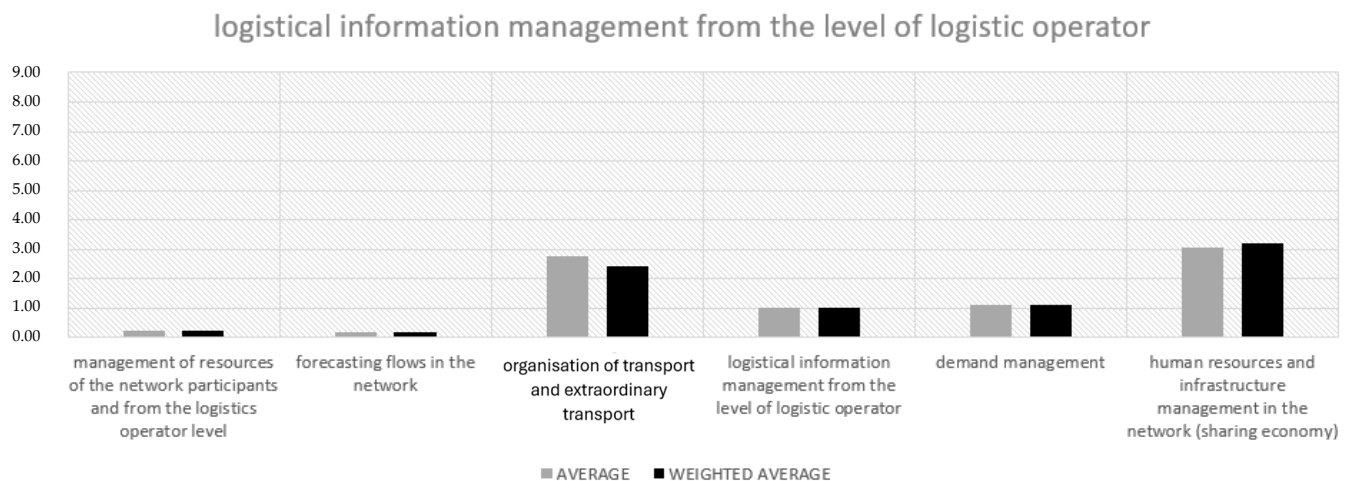


Figure 11. The importance of the element ‘logistical information management from the level of logistics operator’ in relation to the other elements of logistics coordination in the averaged assessment and after applying the weighting assessment.

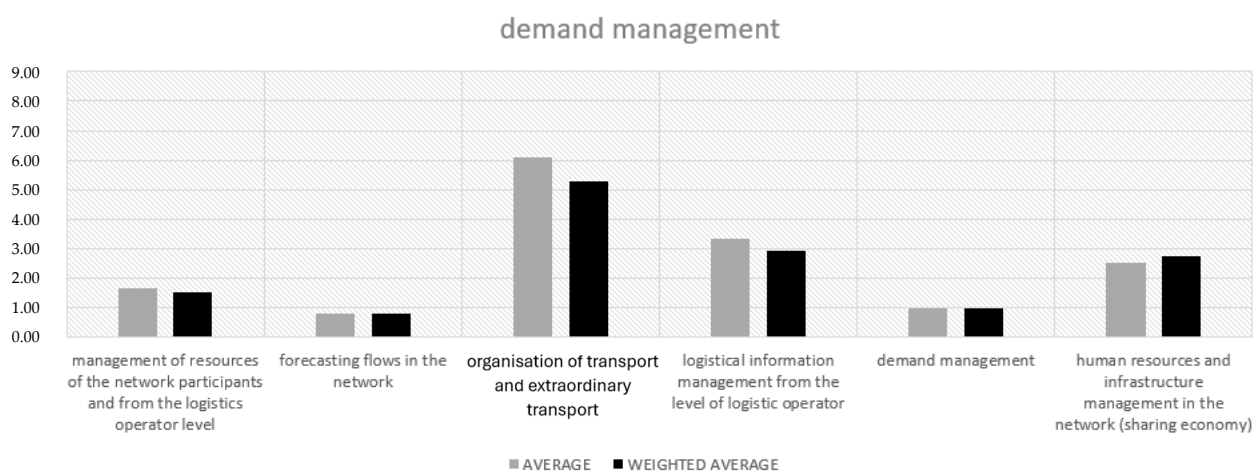


Figure 12. The importance of the element ‘demand management’ in relation to the other elements of logistics coordination in the averaged assessment and after applying the weighting assessment.

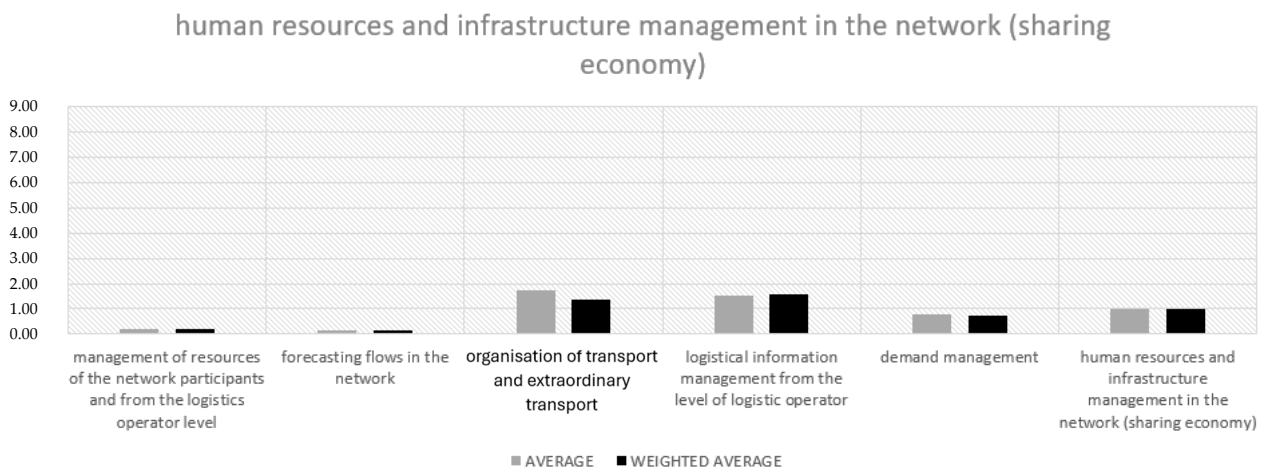


Figure 13. The importance of the element ‘management of human resources and infrastructure in the network’ in relation to the other elements of logistics coordination in the averaged assessment and after applying the weighting assessment.

The management of network participants’ resources from the operator level has great advantages over elements related to the organisation of transport and extraordinary transport, the management of human resources and infrastructure in the network, and the management of logistical information from the logistics operator level.

The forecasting of flows in the network has great advantages over mechanisms related to the organisation of transport and emergency transport, the management of human resources and infrastructure in the network, and the management of logistical information from the level of the logistics operator.

The organisation of transport and emergency transport has a slight advantage over resource management, however, it continues to be the element that is positioned lowest in the hierarchy.

The management of logistical information from the logistics operator level has a moderate advantage over the organisation of transport and extraordinary transport and the management of human resources and infrastructure in the network.

The demand management element has a strong advantage over the organisation of transport and extraordinary transport and a moderate advantage over logistical information management from the logistics operator level and the management of human resources and infrastructure in the network.

The element ‘human resources and infrastructure management in the network’ has a slight advantage over transport and extraordinary transport organisation, information management from the logistics operator level, and human resources and infrastructure management in the network. The final assessment of the individual forms of logistics coordination and the individual mechanisms was based on the results of the AHP method carried out, where the weights were calculated based on the local weights for the individual elements of the forms of coordination and the weights of the individual forms (Table 14).

The analysis reveals the following hierarchy in logistical coordination, highlighting the dominance of certain elements: forecasting network flows and managing stocks from the logistics operator level (both significantly more important than others); demand management and logistical information management from the operator level (both similarly rated); and, lastly, human resources and network infrastructure management (sharing economy) and organising transport and extraordinary transport. For market-based coordination mechanisms, the discrepancies between element weights are smaller, with the hierarchy as follows: price, formal relationships, and bilateral collateral. For hierarchical coordination mechanisms, the criteria are organisational integration, structures and control systems from management style, and bureaucratic resource allocation, with the first two elements similarly weighted. In social coordination mechanisms, trust is rated highest, followed by

social standards and significant information exchange, with the latter two rated similarly. The final weights and the overall hierarchy of criteria for network coordination are shown in Figure 14.

Table 14. The final evaluation of the hierarchy of expert-assessed elements of network coordination from a logistical coordination perspective.

Criterion	Criterion Weight	Sub-Criterion	Sub-Criterion Weight	Final Weight
Forms of logistical co-ordination	0.41	network participants' resources management and from the logistics operator level	0.28	0.11
		forecasting network flows	0.32	0.13
		organisation of transport and extraordinary transport	0.06	0.02
		logistical information management from the logistics operator level	0.10	0.04
		demand management	0.17	0.07
		management of human resources and infrastructure in the network (sharing economy)	0.06	0.02
Market forms	0.14	price	0.40	0.06
		formal relations	0.33	0.05
		bilateral collateral	0.27	0.04
Hierarchical forms	0.32	management style control structures and systems	0.38	0.12
		organisational integration	0.42	0.13
		bureaucratic allocation of resources	0.20	0.06
Social forms	0.13	trust	0.60	0.08
		social norms	0.20	0.03
		significant exchange of information	0.19	0.02

The most important elements in network coordination by the form of coordination are organisational integration (hierarchical form, weight of 0.1342), forecasting of network flows (logistic form, weight of 0.1312), structures and control systems resulting from management style (hierarchical form, weight of 0.1216), and management of network participants' resources from the logistics operator (logistic form, weight of 0.1148).

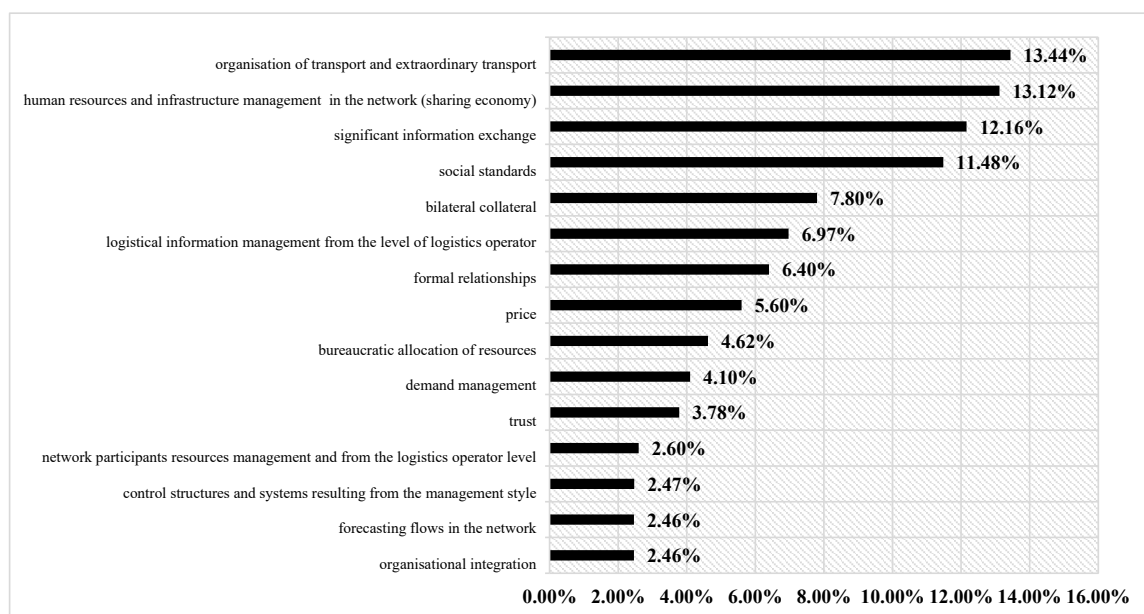


Figure 14. The hierarchy of criteria in the network coordination framework taking into account the form of logistical coordination.

5. Discussion

The coordination mechanisms identified in the research, which logistics operators can apply as a personalised combination consisting of market, social, hierarchical, and logistical coordination mechanisms, are an extension of other authors' research in both the area of network coordination and the role of the logistics operator in omni-channel systems. Many researchers point to the relationship between the development of omni-channel systems [100–103] and the increasing role of logistics operators in ensuring the reliability of flows in such complex distribution systems [48]. The mechanisms identified in our study allow us to address the challenges posed by the development of omni-channel. The results presented so far by other authors have focused in particular on pointing out the importance of LSPs in integrating omni-channel operations and reducing their operating costs [16,104,105]. Thus, the authors point to the relationship between selected flow mechanisms and the reliability of flows in distribution systems, without discussing the role of the logistics operator in network coordination. Publications on network coordination, on the other hand, do not delve deeper into logistics coordination [63,106,107], which we have expanded in our research as a set of flow mechanisms. The conceptualisation of logistics coordination is an important contribution to the study of network coordination, especially in supply, distribution, procurement, and production networks.

The role of the logistics operator in omni-channel network coordination, as we have shown, is not limited to logistics coordination based on flow mechanisms but points to the need to use mechanisms of various forms of coordination. We continued to identify as important mechanisms those based on price and also non-price mechanisms, including in particular formal relationships, structures, and control systems resulting from management style as well as organisational integration and above all trust. All of these factors have also been shown to be important in studies by other authors studying network coordination [61, 63]. Interestingly, on the basis of the research conducted, the mechanism with the least importance among the mechanisms of the logistics coordination form is the one related to organising transport and extraordinary transport. Transport is one of the most important functions in the supply chain, and its role is particularly important in last-mile logistics, i.e., the final stage of delivering goods to the end customer [108]. Nowadays, with the development of e-commerce and online sales, transportation in last-mile logistics has become extremely important, as this is where end-customers have direct contact with the goods and the delivery service [109]. In our opinion, this is related to the global framing of the transport issue and the lack of targeting of the question precisely under the specifics of transport in the reality of last-mile logistics.

The methodology we used is not new and refers to the research of other authors. Due to its qualities, the AHP method is often used to assess multiple factors influencing the problem under investigation. Research using the AHP method has been conducted for omni-channel issues [110–114], logistics operator selection [115–117], and also the analysis of network coordination mechanisms [118–120]. Thus, various authors addressing the issues we have addressed have drawn on similar methodologies. Our practical contribution to this body of the literature is the development of a tool that is dedicated to participants in omni-channel distribution. We have named this tool the 'Multicriteria assessment sheet of the coordination competence of logistics operators for omni-channel systems' (Figure 15). This tool links the role of the logistics operator in such systems to the challenges posed to the logistics operation of such systems and also to the network coordination mechanisms.

The developed tool is at the same time a response to the needs of organisations expanding their omni-channel systems and looking for a service provider that is able to coordinate such networks. Indeed, with data on the coordination mechanisms used by potential logistics operators using the developed tool, it is possible to select the operator that is best suited to omni-channel network coordination. Based on AHP analysis there was a proposition of evaluation of logistics services providers [86], but firstly this issue could be extended by coordination mechanisms. Despite the very different mechanisms included in the developed tool, in order to standardise the calculations, we proposed the

same assessment system. Each criterion is evaluated on a 10-degree scale. We have adopted the following scoring:

- The operator does not use the mechanism.
- 1–4: the operator uses the mechanism only to a limited extent.
- 5–6: the operator uses the mechanism but not comprehensively (selected range of instruments and/or for a selected area of the network).
- 7–9: the operator uses the mechanism to a significant extent.
- 10: the operator applies the mechanism fully and comprehensively.

LOGISTICS OPERATOR ATTRIBUTES	Forms of network coordination (A)	Weight (B)	Operator assessment (from 0 to 10) (C)	Weighting assessment (D)	Final assessment (E)
	organisational integration	0.1344			
	forecasting flows in the network	0.1312			
	control structures and systems resulting from the management style	0.1216			
	network participants resources management and from the level of logistics	0.1148			
	trust	0.0780			
	demand management	0.0697			
	bureaucratic allocation of resources	0.0640			
	price	0.0560			
	formal relationships	0.0462			
	logistical information management from the level of logistics operator	0.0410			
	bilateral collateral	0.0378			
	social standards	0.0260			
	significant exchange of information	0.0247			
	organisation of transport and extraordinary transport	0.0246			
	human resources and infrastructure management in the network (sharing ec	0.0246			
$column (D) = (B) * (C)$ $column (E) = sum of values fr(D)$					

Figure 15. Multi-criteria evaluation sheet for coordination competence of logistics operators for omni-channel systems.

This is the initially proposed concept for evaluating criteria, which is being used in the testing of this tool. Ultimately, we plan to detail the AHP evaluation sheet itself with one more level to assess mechanisms. This level will include a set of specific instruments that can be used for coordination through a specific mechanism. This concept requires separate research and will be pursued in the next stage of the tool's development.

The main limitation of the study is the small number of experts who took part in the survey. In the survey, we set high requirements for the competence of the experts, in which we combined both knowledge and experience in the work of the logistics operator and the omni-channel logistics service. These requirements gave us a high degree of confidence in the results obtained; however, they limited the potential set of experts. In addition, the mechanisms identified are universal, which is both an advantage and a disadvantage of this research. The tool can be used by omni-channel irrespective of the geographical area; however, in order to obtain even more accurate results in the future, we want to extend the research to include mechanisms related to the impact also on last-mile transport, which is strongly dependent on solutions in individual countries. Thus, we believe that it is worthwhile to investigate whether the importance of individual network coordination mechanisms will vary from country to country.

6. Conclusions

As demonstrated in our research, a logistics operator aiming to effectively perform the role of a flow coordinator in an omni-channel network must possess a set of tools outlined within the mechanisms of logistics coordination. We have proposed that logistics coordination should be treated as one of the forms of network coordination. The framework of logistics coordination developed by us extends the previously identified flow coordination

mechanisms within the network. This is justified by the requirements currently imposed on flow coordinators in omni-channel systems. The analysis conducted by the authors revealed a significant cognitive gap associated with the operational mechanisms of logistics operators within the context of intricate network coordination structures in omni-channel systems. Research on this subject has thus far been carried out separately for each of these domains, resulting in a lack of a coherent and holistic approach to the problem. As a result, the authors identified a deficit in existing literary positions that could genuinely present the essential characteristics required for logistics operators to achieve effective network coordination within diverse networks and supply chains. To address this existing knowledge gap, the authors opted for extensive research, integrating theoretical analysis with empirical field studies. Through this balanced approach, they aimed to comprehend deeper aspects of logistics operators' functioning mechanisms within the context of modern omni-channel network structures. The theoretical analysis facilitated the extraction of key theoretical frameworks underpinning the functioning of omni-channel logistic systems, while empirical studies provided real-world data and examples that either confirmed or complemented the theoretical assumptions. The authors endeavoured to contribute to the advancement of knowledge in the realm of logistics operator activities in omni-channel networks by identifying missing pieces in the literature and subsequently filling these gaps through comprehensive theoretical and empirical investigations. Such an approach allowed for a more coherent and comprehensive perspective on the subject of network coordination, as well as the formulation of concrete conclusions and recommendations for business practices in the context of omni-channel networks and supply chains.

The research carried out using the AHP method allowed the development of a multi-criteria evaluation tool for the selection of a logistics operator for omni-channel system coordination. The presented multi-criteria evaluation sheet makes it possible to compare multiple logistics operators for a better fit to perform the function related to network coordination in omni-channel systems. In this evaluation sheet, the evaluation is achieved by means of the forms of logistical, social, hierarchical, and market coordination identified in the paper. Each of these forms is assigned weights determined by the authors on the basis of the AHP analysis carried out and additional analyses to determine the importance of the different elements of the mentioned forms of coordination. The AHP method, used in the research, is a mathematical tool that allows for the hierarchical comparison and weighting of different criteria. Thus, the authors were able to determine exactly which factors are most important in the evaluation of logistics operators for coordination in omni-channel systems. The results of this research and the developed multi-criteria evaluation tool for logistics operators can be very useful for companies that want to optimise their logistics processes in omni-channel systems. By doing so, they will be able to better match the choice of logistics operator to perform the network coordination function in omni-channel systems, thus improving their competitiveness. This tool can also be used by logistics operators, who can carry out a self-assessment and determine the development directions they want to take in omni-channel services.

The limitations of the tool indicated in the discussion relate in particular to the omission of the last-mile issue from the survey. We believe that this is an extremely important element that should be included in the tool developed in the future. Indeed, logistics operators may have different capacities to cooperate with cities in the implementation of last-mile transport. Developing the right approach to include this element in the assessment of logistics operator competence requires separate research on this issue. The research must take into account the different organisational and legal arrangements for city logistics and the cooperation of freight transport stakeholders with the city. The challenge will be to integrate this part of the research into the methodology already developed to date for assessing logistics operators. According to the authors, however, this will allow a full assessment of the ability of logistics operators to coordinate omni-channels and to compare operators on the basis of their specificities. Such an approach, in addition to creating a full evaluation sheet for comparing operators, can also bring tangible practical benefits.

Companies operating omni-channel systems can support their decision-making process related to the selection of a logistics service provider by including the aforementioned tool in their selection assessment. One significant area of exploration is the integration of last-mile delivery capabilities into the existing multi-criteria evaluation tool. Future studies could focus on developing specific metrics and criteria for assessing logistics operators' competencies in managing last-mile logistics, especially in urban environments. This would involve detailed analyses of city logistics frameworks, regulatory environments, and the capabilities of logistics operators to collaborate with municipal authorities and other stakeholders in freight transport. Future research could also investigate the impact of emerging technologies on logistics coordination in omni-channel systems. Technologies such as artificial intelligence, blockchain, and the Internet of Things (IoT) offer the potential to enhance coordination mechanisms by providing real-time data, improving transparency, and enabling more efficient resource management. Examining how these technologies can be integrated into logistics coordination frameworks and assessing their impact on performance and customer satisfaction would be valuable. Another promising research direction is the exploration of sustainable logistics practices within omni-channel networks. As environmental concerns become increasingly critical, understanding how logistics operators can implement sustainable practices, such as green transportation methods, energy-efficient warehousing, and waste reduction strategies, will be essential. Future studies could develop and test evaluation criteria for sustainability and examine the trade-offs between operational efficiency and environmental impact.

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References

1. Baglio, M.; Perotti, S.; Dallari, F.; Creazza, A. How can logistics real estate support third-party logistics providers? *Int. J. Logist. Res. Appl.* **2022**, *25*, 1334–1358. [\[CrossRef\]](#)
2. Chen, M.C.; Hsu, C.L.; Lee, L.H. Investigating pharmaceutical logistics service quality with refined Kano's model. *J. Retail. Consum. Serv.* **2020**, *57*, 102231. [\[CrossRef\]](#)
3. Wieland, A.; Handfield, R.B.; Durach, C.F. Mapping the Landscape of Future Research Themes in Supply Chain Management. *J. Bus. Logist.* **2016**, *37*, 205–212. [\[CrossRef\]](#)
4. Stank, T.P.; Pellathy, D.A.; In, J.; Mollenkopf, D.A.; Bell, J.E. New Frontiers in Logistics Research: Theorizing at the Middle Range. *J. Bus. Logist.* **2017**, *38*, 6–17. [\[CrossRef\]](#)
5. Chiu, H.-C.; Hsieh, Y.-C.; Roan, J.; Tseng, K.-J.; Hsieh, J.-K. The challenge for multichannel services: Cross-channel free-riding behavior. *Electron. Commer. Res. Appl.* **2011**, *10*, 268–277. [\[CrossRef\]](#)
6. Châlons, C.; Dufft, N. The role of IT as an enabler of digital transformation. In *The Drivers of Digital Transformation: Why There's No Way Around the Cloud*; Springer: Cham, Switzerland, 2017; pp. 13–22.

7. Rabinovich, E.; Knemeyer, A.M. Logistics Service Providers in Internet Supply Chains. *Calif. Manag. Rev.* **2006**, *48*, 84–108. [\[CrossRef\]](#)
8. Wiedmer, R.; Griffis, S.E. Structural characteristics of complex supply chain networks. *J. Bus. Logist.* **2021**, *42*, 264–290. [\[CrossRef\]](#)
9. Wang, Q.; Huo, B.; Zhao, X. What Makes Logistics Integration More Effective? Governance from Contractual and Relational Perspectives. *J. Bus. Logist.* **2020**, *41*, 259–281. [\[CrossRef\]](#)
10. Xue, X.; Wang, Y.; Shen, Q.; Yu, X. Coordination mechanisms for construction supply chain management in the Internet environment. *Int. J. Proj. Manag.* **2007**, *25*, 150–157. [\[CrossRef\]](#)
11. Salih Börtçine, A.; İsmail, İ. Corporate and supply chain network governance of third party logistics service providers: Effects on buyers' intention to continue the relationship. *Manag. Mark.* **2017**, *12*, 227–296. [\[CrossRef\]](#)
12. Kmiecik, M. Conception of logistics coordination in the distribution networks. *Logist. Res.* **2022**, *15*, 1–16.
13. Kmiecik, M. Supporting of manufacturer's demand plans as an element of logistics coordination in the distribution network. *Prod. Eng. Arch.* **2023**, *29*, 69–82. [\[CrossRef\]](#)
14. Van der Westhuizen, C.; Niemann, W. Strategic supply chain alignment: The role of third-party logistics service providers during disruption recovery. *J. Transp. Supply Chain Manag.* **2022**, *16*, 738. [\[CrossRef\]](#)
15. Özcan, S.; Yumurtacı Hüseyinoğlu, I.Ö. Managing disruptions and strategy development during Covid-19 pandemic: The perspective of third-party logistics service providers (3PLs). *Int. J. Logist. Res. Appl.* **2023**, 1–27. [\[CrossRef\]](#)
16. Zhang, J.; Farris, P.W.; Irvin, J.W.; Kushwaha, T.; Steenburgh, T.J.; Weitz, B.A. Crafting Integrated Multichannel Retailing Strategies. *J. Interact. Mark.* **2010**, *24*, 168–180. [\[CrossRef\]](#)
17. Multaharju, S.; Hallikas, J. Logistics service capabilities of logistics service provider. *Int. J. Logist. Syst. Manag.* **2015**, *20*, 103. [\[CrossRef\]](#)
18. Arruda, H.; Silva, E.R.; Lessa, M.; Proença, D., Jr.; Bartholo, R. VOSviewer and bibliometrix. *J. Med. Libr. Assoc. JMLA* **2022**, *110*, 392. [\[CrossRef\]](#) [\[PubMed\]](#)
19. Van Eck, N.J.; Waltman, L. Citation-based clustering of publications using CitNetExplorer and VOSviewer. *Scientometrics* **2017**, *111*, 1053–1070. [\[CrossRef\]](#)
20. Van Eck, N.J.; Waltman, L. Text mining and visualization using VOSviewer. *arXiv* **2011**, arXiv:1109.2058.
21. Grange, R.; Heaslip, G.; McMullan, C. Coordination to choreography: The evolution of humanitarian supply chains. *J. Humanit. Logist. Supply Chain Manag.* **2020**, *10*, 21–44. [\[CrossRef\]](#)
22. Fritz, M.; Hausen, T. Electronic supply network coordination in agrifood networks: Barriers, potentials, and path dependencies. *Int. J. Prod. Econ.* **2009**, *121*, 441–453. [\[CrossRef\]](#)
23. Bhatnagar, R.; Teo, C.C. Role of logistics in enhancing competitive advantage: A value chain framework for global supply chains. *Int. J. Phys. Distrib. Logist. Manag.* **2009**, *39*, 202–226. [\[CrossRef\]](#)
24. Perdana, T.; Tjahjono, B.; Kusnandar, K.; Sanjaya, S.; Wardhana, D.; Hermiatin, F.R. Fresh agricultural product logistics network governance: Insights from small-holder farms in a developing country. *Int. J. Logist. Res. Appl.* **2022**, *26*, 1761–1784. [\[CrossRef\]](#)
25. Marques, D.S.P.; Paulillo, L.F.D.O.; Vian, C.E.D.F. Ethanol trading groups and network governance. *Gest. Prod.* **2012**, *19*, 825–840. [\[CrossRef\]](#)
26. Wong, C.W.; Lai, K.-H.; Ngai, E. The role of supplier operational adaptation on the performance of IT-enabled transport logistics under environmental uncertainty. *Int. J. Prod. Econ.* **2009**, *122*, 47–55. [\[CrossRef\]](#)
27. Alamdari, A.M.; Jabarzadeh, Y.; Samson, D.; Sanoubar, N. Supply chain risk factors in green construction of residential mega projects—Interactions and categorization. *Eng. Constr. Arch. Manag.* **2023**, *30*, 568–597. [\[CrossRef\]](#)
28. Jahre, M.; Jensen, L.-M. Coordination at the 10-year mark of the JHLSCM—from global response to local preparedness. *J. Humanit. Logist. Supply Chain Manag.* **2021**, *11*, 585–598. [\[CrossRef\]](#)
29. Averkuna, M.F.; Karlova, O.A. Economic-Mathematical Modeling of Logistic Coordination of Financial Flows in Cities and Metropolitan Areas. *Int. J. Econ. Res.* **2017**, *14*, 213–219.
30. Salaun, V.; Fulconis, F.; Fabbe-Costes, N. What mechanisms at the heart of Pulsating Temporary Organization? The case of the festival du Bout du Monde. *Rev. Fr. Gest.* **2016**, *42*, 83–99. [\[CrossRef\]](#)
31. Davis, L.B.; Samanlioglu, F.; Qu, X.; Root, S. Inventory planning and coordination in disaster relief efforts. *Int. J. Prod. Econ.* **2013**, *141*, 561–573. [\[CrossRef\]](#)
32. Kohn, J.W.; McGinnis, M.A.; Kara, A. A structural equation model assessment of logistics strategy. *Int. J. Logist. Manag.* **2011**, *22*, 284–305. [\[CrossRef\]](#)
33. Williams, K.A.; Sullivan, F.; Suner, S.; Shapiro, M.; Kobayashi, L.; Woolard, R.; Hill, W.; Seekell, C. Rhode Island disaster initiative. *Int. J. Risk Assess. Manag.* **2008**, *9*, 394–408. [\[CrossRef\]](#)
34. Chatfield, A.T.; Bjørn-Andersen, N. The Impact of IOS-Enabled Business Process Change on Business Outcomes: Transformation of the Value Chain of Japan Airlines. *J. Manag. Inf. Syst.* **1997**, *14*, 13–40. [\[CrossRef\]](#)
35. Nyhuis, P.; Nickel, R.; Busse, T. Logistisches Controlling der Materialverfügbarkeit mit Bereitstellungsdiagrammen. *Z. Wirtsch. Fabr.* **2006**, *101*, 265–268. [\[CrossRef\]](#)
36. Eriksson, E.; Norrman, A.; Kembro, J. Understanding the transformation toward omnichannel logistics in grocery retail: A dynamic capabilities perspective. *Int. J. Retail. Distrib. Manag.* **2022**, *50*, 1095–1128. [\[CrossRef\]](#)
37. Abramova, E.R.; Protsenko, I.O.; Terenina, I.V. The influence of coordination mechanisms on the procurement performance indicators of supply chains participants. *Int. J. Supply Chain. Manag.* **2020**, *9*, 695–702.

38. Ramjaun, T.I.; Rodrigues, V.S.; Kumar, M. Horizontal supply chain collaboration amongst small enterprises: Insights from UK brewery networks. *Prod. Plan. Control.* **2022**, *35*, 206–224. [\[CrossRef\]](#)
39. He, L.; Xue, M.; Gu, B. Internet-of-things enabled supply chain planning and coordination with big data services: Certain theoretic implications. *J. Manag. Sci. Eng.* **2020**, *5*, 1–22. [\[CrossRef\]](#)
40. Ryciuk, U. Supply chain governance mechanisms: A review and typology. In *Eurasian Business Perspectives, Proceedings of the 23rd Eurasia Business and Economics Society Conference, Madrid, Spain, 27–29 September 2017*; Springer International Publishing: Cham, Switzerland, 2020; pp. 145–159.
41. Statsenko, L.; Gorod, A.; Ireland, V. A supply network governance framework: A case study of the South Australian mining industry. *J. Glob. Oper. Strat. Sourc.* **2018**, *11*, 55–78. [\[CrossRef\]](#)
42. Sholihah, S.A.; Samadhi, T.A.; Cakravastia, A.; Bahagia, S.N. Coordination Model in Hinterland Chain of Hub-and-Spoke Export Trade Logistics. *J. Ind. Eng. Manag.* **2018**, *11*, 776–793. [\[CrossRef\]](#)
43. Octavia, T.; Halim, C.; AWidyadana, I.G.; Palit, H. Coordination of humanitarian logistic model plan for natural disaster in East Java, Indonesia. *Int. J. Supply Chain. Manag.* **2016**, *5*, 52–60.
44. Spillan, J.E.; McGinnis, M.A.; Kara, A.; Yi, G.L. A comparison of the effect of logistic strategy and logistics integration on firm competitiveness in the USA and China. *Int. J. Logist. Manag.* **2013**, *24*, 153–179. [\[CrossRef\]](#)
45. McGinnis, M.A.; Spillan, J.E.; Virzi, N. An empirical study comparing Guatemalan and United States logistics strategies. *Int. J. Logist. Manag.* **2012**, *23*, 77–95. [\[CrossRef\]](#)
46. Mehta, S.; Saxena, T.; Purohit, N. The New Consumer Behaviour Paradigm amid COVID-19: Permanent or Transient? *J. Health Manag.* **2020**, *22*, 291–301. [\[CrossRef\]](#)
47. Van Hoek, R.; Gibson, B.; Johnson, M. Talent management for a post-COVID-19 supply chain—The critical role for managers. *J. Bus. Logist.* **2020**, *41*, 334. [\[CrossRef\]](#)
48. Verhoef, P.C.; Kannan, P.; Inman, J.J. From Multi-Channel Retailing to Omni-Channel Retailing. *J. Retail.* **2015**, *91*, 174–181. [\[CrossRef\]](#)
49. Rigby, D. The Future of Shopping. *Harv. Bus. Rev.* **2011**, *89*, 65–76.
50. Zoltners, A.A.; Sinha, P.; Lorimer, S.E. Sales Force Effectiveness: A Framework for Researchers and Practitioners. *J. Pers. Sell. Sales Manag.* **2008**, *28*, 115–131. [\[CrossRef\]](#)
51. Chiang, W.-Y.K.; Chhahed, D.; Hess, J.D. Direct Marketing, Indirect Profits: A Strategic Analysis of Dual-Channel Supply-Chain Design. *Manag. Sci.* **2003**, *49*, 1–20. [\[CrossRef\]](#)
52. Szozda, N. *Zarządzanie Produktem w Łańcuchu Dostaw w Dobie Transformacji Cyfrowej*; Wydawnictwo Uniwersytetu Ekonomicznego we Wrocławiu: Wrocław, Poland, 2023.
53. Cummins, S.; Peltier, J.W.; Dixon, A. Omni-channel research framework in the context of personal selling and sales management. *J. Res. Interact. Mark.* **2016**, *10*, 2–16. [\[CrossRef\]](#)
54. Sopadjieva, E.; Dholakia, U.M.; Benjamin, B. A Study of 46,000 shoppers shows that omnichannel retailing works. *Harv. Bus. Rev.* **2017**, *3*, 1–2. Available online: <https://hbr.org/2017/01/a-study-of-46000-shoppers-shows-that-omnichannel-retailing-works> (accessed on 31 December 2020).
55. Ishfaq, R.; Darby, J.; Gibson, B. Adapting the retail business model to omnichannel strategy: A supply chain management perspective. *J. Bus. Logist.* **2023**, *45*, e12352. [\[CrossRef\]](#)
56. Szozda, N.; Świerczek, A. Transformacja cyfrowa struktur omnikałowych w dystrybucji produktów. *Gospod. Mater. Logist.* **2021**, *2021*, 2–12. [\[CrossRef\]](#)
57. Fugate, B.; Sahin, F.; Mentzer, J.T. Supply Chain Management Coordination Mechanisms. *J. Bus. Logist.* **2006**, *27*, 129–161. [\[CrossRef\]](#)
58. Kramarz, M. Problem odporności w koordynacji sieci dystrybucji. *Stud. Ekon.* **2018**, *351*, 34–45.
59. Twaróg, S.; Kramarz, M. Koordynacja sieciowa—Model badań nad koordynacją sieci zdominowanych i równorzędnych partnerów. *Przedsięb. Zarz.* **2017**, *18*, 309–322.
60. Young, M.; Dulewicz, V. Similarities and Differences between Leadership and Management: High-Performance Competencies in the British Royal Navy. *Br. J. Manag.* **2008**, *19*, 17–32. [\[CrossRef\]](#)
61. Hoetker, G.; Mellewigt, T. Choice and performance of governance mechanisms: Matching alliance governance to asset type. *Strat. Manag. J.* **2009**, *30*, 1025–1044. [\[CrossRef\]](#)
62. Heide, J.B. Plural Governance in Industrial Purchasing. *J. Mark.* **2003**, *67*, 18–29. [\[CrossRef\]](#)
63. Czakon, W. Network governance dynamics impact on intellectual property management: The case of a franchise system. *Int. J. Intellect. Prop. Manag.* **2009**, *3*, 23. [\[CrossRef\]](#)
64. Novak, D.C.; Wu, Z.; Dooley, K.J. Whose resilience matters? Addressing issues of scale in supply chain resilience. *J. Bus. Logist.* **2021**, *42*, 323–335. [\[CrossRef\]](#)
65. Kramarz, M. Logistics Coordination in Building the Resilience of the Distribution Network. *Organ. Manag./Zesz. Nauk. Politech. Śląskiej Ser.* **2023**, *170*, 233. [\[CrossRef\]](#)
66. Kmiecik, M.; Wolny, M. Forecasting Needs of the Operational Activity of a Logistics Operator. *Logforum* **2022**, *18*, 197–212. [\[CrossRef\]](#)
67. Kramarz, M.; Kmiecik, M. Quality of Forecasts as the Factor Determining the Coordination of Logistics Processes by Logistic Operator. *Sustainability* **2022**, *14*, 1013. [\[CrossRef\]](#)

68. Kramarz, M.; Kramarz, W. Managing the flow components in supply chains. *Metalurgija* **2019**, *58*, 158–160.
69. Choy, K.; So, S.; Lau, H.; Kwok, S. Development of an integrated logistics information system for third party logistics facilitators. *Int. J. Bus. Perform. Manag.* **2006**, *8*, 170–193. [\[CrossRef\]](#)
70. Asnordin, N.A.; Sundram VP, K.; Noranee, S. The Influence of Professional Human Resource and Firm Infra-structure towards Supply Chain Performance. *Int. J. Acad. Res. Bus. Soc. Sci.* **2020**, *10*, 718–732.
71. Sousa, R.; Voss, C.A. Service Quality in Multichannel Services Employing Virtual Channels. *J. Serv. Res.* **2006**, *8*, 356–371. [\[CrossRef\]](#)
72. Wollenburg, J.; Holzapfel, A.; Hübner, A.; Kuhn, H. Configuring retail fulfillment processes for omni-channel customer steering. *Int. J. Electron. Commer.* **2018**, *22*, 540–575. [\[CrossRef\]](#)
73. Mishra, R.; Singh, R.K.; Koles, B. Consumer decision-making in omnichannel retailing: Literature review and future research agenda. *Int. J. Consum. Stud.* **2021**, *45*, 147–174. [\[CrossRef\]](#)
74. Banerjee, M. Development of omnichannel in India: Retail landscape, drivers and challenges. In *Exploring Omnichannel Retailing: Common Expectations and Diverse Realities*; Springer: Cham, Switzerland, 2019; pp. 115–137.
75. Yurt, O.; Sorkun, M.F.; Hsuan, J. Modularization of the front-end logistics services in e-fulfillment. *J. Bus. Logist.* **2023**, *44*, 583–608. [\[CrossRef\]](#)
76. Ishfaq, R.; Davis-Sramek, B.; Gibson, B. Digital supply chains in omnichannel retail: A conceptual framework. *J. Bus. Logist.* **2022**, *43*, 169–188. [\[CrossRef\]](#)
77. Wang, Y.; Yu, Z.; Shen, L.; Fan, R.; Tang, R. Decisions and Coordination in E-Commerce Supply Chain under Logistics Outsourcing and Altruistic Preferences. *Mathematics* **2021**, *9*, 253. [\[CrossRef\]](#)
78. Rai, H.B.; Mommens, K.; Verlinde, S.; Macharis, C. How Does Consumers' Omnichannel Shopping Behaviour Translate into Travel and Transport Impacts? Case-Study of a Footwear Retailer in Belgium. *Sustainability* **2019**, *11*, 2534. [\[CrossRef\]](#)
79. Gupta, V.K.; Dakare, S.; Fernandes, K.J.; Thakur, L.S.; Tiwari, M.K. Bilevel programming for manufacturers operating in an omnichannel retailing environment. *IEEE Trans. Eng. Manag.* **2021**, *70*, 3958–3975. [\[CrossRef\]](#)
80. Saskia, S.; Mareš, N.; Blanquart, C. Innovations in e-grocery and Logistics Solutions for Cities. *Transp. Res. Procedia* **2016**, *12*, 825–835. [\[CrossRef\]](#)
81. Mikhaylyk, M.; Baginova, V.; Mamaev, E. Empirical markers in the concept of digital logistics of multichannel supply chains. *E3S Web Conf.* **2019**, *91*, 08056. [\[CrossRef\]](#)
82. Wang, C.-N.; Nguyen, N.-A.; Dang, T.-T.; Lu, C.-M. A Compromised Decision-Making Approach to Third-Party Logistics Selection in Sustainable Supply Chain Using Fuzzy AHP and Fuzzy VIKOR Methods. *Mathematics* **2021**, *9*, 886. [\[CrossRef\]](#)
83. Esper, T.L.; Castillo, V.E.; Ren, K.; Sodero, A.; Wan, X.; Croxton, K.L.; Knemeyer, A.M.; DeNunzio, S.; Zinn, W.; Goldsby, T.J. Everything Old is New Again: The Age of Consumer-Centric Supply Chain Management. *J. Bus. Logist.* **2020**, *41*, 286–293. [\[CrossRef\]](#)
84. Jeanpert, S.; Paché, G. Integration process in multichannel management: From consumer decisions to supply chain strategy. *Supply Chain Forum Int. J.* **2016**, *17*, 231–245. [\[CrossRef\]](#)
85. Lim, S.F.W.T.; Winkenbach, M. Configuring the Last-Mile in Business-to-Consumer E-Retailing. *Calif. Manag. Rev.* **2019**, *61*, 132–154. [\[CrossRef\]](#)
86. Gupta, A.; Singh, R.K.; Mangla, S.K. Evaluation of logistics providers for sustainable service quality: Analytics based decision making framework. *Ann. Oper. Res.* **2021**, *315*, 1617–1664. [\[CrossRef\]](#)
87. Bezes, C. Comparing online and in-store risks in multichannel shopping. *Int. J. Retail. Distrib. Manag.* **2016**, *44*. [\[CrossRef\]](#)
88. Golinska-Dawson, P.; Werner-Lewandowska, K.; Kolinska, K.; Kolinski, A. Impact of Market Drivers on the Digital Maturity of Logistics Processes in a Supply Chain. *Sustainability* **2023**, *15*, 3120. [\[CrossRef\]](#)
89. Ramanathan, R.; George, J.; Ramanathan, U. The role of logistics in e-commerce transactions: An exploratory study of customer feedback and risk. In *Supply Chain Strategies, Issues and Models*; Springer: London, UK, 2014; pp. 221–233.
90. Naumov, V.; Naumova, E.; Shteyngart, E.; Ostrovskaya, N. Methodological principles of forming multichannel digital communication in the supply chains. *E3S Web Conf.* **2020**, *157*, 05010. [\[CrossRef\]](#)
91. Angel, A.; Tan, A. Designing reverse logistics network in an omnichannel environment in Asia. *LogForum* **2018**, *14*, 519–533.
92. Montreuil, B. Omnichannel Business-to-Consumer Logistics and Supply Chains: Towards Hyperconnected Networks and Facilities. In *Proceedings of the 14th IMHRC Proceedings, Karlsruhe, Germany, 12–16 June 2016*.
93. Frei, R.; Jack, L.; Krzyzaniak, S.-A. Mapping Product Returns Processes in Multichannel Retailing: Challenges and Opportunities. *Sustainability* **2022**, *14*, 1382. [\[CrossRef\]](#)
94. Fleischer, W.; Graf, C.; Lange, T. *Supply Chain of the Future: Key Principles in Building an Omnichannel Distribution Network*; McKinsey & Company: Chicago, IL, USA, 2020.
95. Schoenherr, T.; Ellram, L.M.; Tate, W.L. A Note on the Use of Survey Research Firms to Enable Empirical Data Collection. *J. Bus. Logist.* **2015**, *36*, 288–300. [\[CrossRef\]](#)
96. Saaty, T. *Decision Making for Leaders: The Analytic Hierarchy Process for Decisions in a Complex World*; University of Pittsburgh, RWS Publications: Pittsburgh, PA, USA, 2001.
97. Tułeczki, A.; Król, S. *Modele Decyzyjne z Wykorzystaniem Metody AHP w Obszarze Transportu*; Politechnika Krakowska: Kraków, Poland, 2007; pp. 172–174.
98. Teknomo, K. Analytic hierarchy process (AHP) tutorial. *Revoledu.com* **2006**, *6*, 1–20.

99. Parlińska, M.; Pietrych, Ł. AHP jako metoda ekonomii eksperymentalnej. *Stud. Inform. Pomerania* **2016**, *42*, 51–59. [[CrossRef](#)]
100. Murfield, M.; Boone, C.A.; Rutner, P.; Thomas, R. Investigating logistics service quality in omni-channel retailing. *Int. J. Phys. Distrib. Logist. Manag.* **2017**, *47*, 263–296. [[CrossRef](#)]
101. Fairchild, A.M. What is the Role of Third Party Logistics (3PL) Partners in an Omni-Channel Strategy? *Int. J. Oper. Res. Inf. Syst.* **2016**, *7*, 22–32. [[CrossRef](#)]
102. Kembro, J.H.; Norrman, A. Warehouse configuration in omni-channel retailing: A multiple case study. *Int. J. Phys. Distrib. Logist. Manag.* **2020**, *50*, 509–533. [[CrossRef](#)]
103. Liu, Y.; Song, G. Role of Logistics Integration Capability in Enhancing Performance in Omni-Channel Retailing: Supply Chain Integration as Mediator. *Sustainability* **2023**, *15*, 9053. [[CrossRef](#)]
104. Sundgren, C. Supply chain structures for distributing surplus food. *Int. J. Logist. Manag.* **2020**, *31*, 865–883. [[CrossRef](#)]
105. De Carvalho, J.L.G.; Campomar, M.C. Multichannel at retail and omni-channel: Challenges for Marketing and Logistics. *Bus. Manag. Rev.* **2014**, *4*, 103–113.
106. Czakon, W. Network cooptation. In *The Routledge Companion to Cooptation Strategies*; Routledge: London, UK, 2018; pp. 47–57.
107. Deflorin, P.; Scherrer, M.; Schillo, K. The influence of IIoT on manufacturing network coordination. *J. Manuf. Technol. Manag.* **2021**, *32*, 1144–1166. [[CrossRef](#)]
108. Fransoo, J.C.; Lee, C. The Critical Role of Ocean Container Transport in Global Supply Chain Performance. *Prod. Oper. Manag.* **2013**, *22*, 253–268. [[CrossRef](#)]
109. Lu, L.; Zhao, X.; Wang, Z. Research on the Optimization of Last Mile Delivery of E-commerce Logistics. In Proceedings of the 2nd International Conference on Management Science and Industrial Engineering, Osaka, Japan, 7–9 April 2020; Springer: Berlin/Heidelberg, Germany, 2018; pp. 582–589.
110. Wulf, J. Development of an AHP hierarchy for managing omnichannel capabilities: A design science research approach. *Bus. Res.* **2020**, *13*, 39–68. [[CrossRef](#)]
111. Domański, R. How to measure omnichannel? Marketing indicator-based approach-theory fundamentals. *Logforum* **2021**, *17*, 373–385. [[CrossRef](#)]
112. Prabhuram, T.; Rajmohan, M.; Tan, Y.; Johnson, R.R. Performance evaluation of Omni channel distribution network configurations using multi criteria decision making techniques. *Ann. Oper. Res.* **2020**, *288*, 435–456. [[CrossRef](#)]
113. Leung, K.H.; Mo, D.Y. A fuzzy-AHP approach for strategic evaluation and selection of digital marketing tools. In Proceedings of the 2019 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), Macao, China, 15–18 December 2019; pp. 1422–1426.
114. Kim, R.B.; Matsui, T.; Park, Y.; Okutani, T. Perceived Consumer Value of Omni-Channel Service Attributes in Japan and Korea. *Eng. Econ.* **2019**, *30*, 621–630. [[CrossRef](#)]
115. Ye, G.; Wu, J. Selection of a Logistics Service Provider Based on Analytic Hierarchy Process (AHP) Approach: A case study of Swedish Coffee Manufacturer. Bachelor's Thesis, University of Gävle, Gävle, Sweden, 2014.
116. Boakai, S.; Samanlioglu, F. An MCDM approach to third party logistics provider selection. *Int. J. Logist. Syst. Manag.* **2023**, *44*, 283. [[CrossRef](#)]
117. Qureshi, M.R.N.M. A Bibliometric Analysis of Third-Party Logistics Services Providers (3PLSP) Selection for Supply Chain Strategic Advantage. *Sustainability* **2022**, *14*, 11836. [[CrossRef](#)]
118. Kumar, M.; Garg, D.; Agarwal, A. An integrated approach of fuzzy AHP and fuzzy TOPSIS in modelling contractual design of supply chain inventory coordination mechanism. *Int. J. Manag. Decis. Mak.* **2019**, *18*, 407. [[CrossRef](#)]
119. Lu, L.; Yupeng, L.; Kongxin, H. Meteorological satellite stakeholder relationship network based on social network analysis. *J. Syst. Eng. Electron.* **2021**, *32*, 907–926. [[CrossRef](#)]
120. Zeppetella, L.; Gebennini, E.; Grassi, A.; Rimini, B. A decision framework for upgrading ERP systems. In Proceedings of the Summer School Francesco Turco, Naples, Italy, 13–15 September 2016; pp. 13–15.

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