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Oleg Zagurskyi, Tadeusz Pokusa, Marian Duczmal, Mikola Ohiienko,
Svitlana Zagurska, Liudmyla Titova, Ivan Rogovskii, Alona Ohiienko

LOGISTICS CENTERS: STATUS AND DEVELOPMENT TRENDS

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Authors of Monograph
Oleg Zagurskyi, Tadeusz Pokusa, Marian Duczmal, Mikola Ohiienko, Svitlana Zagurska, Liudmyla Titova, Ivan Rogovskii, Alona Ohiienko

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PREFACE

A developed logistics and transport system determines the level of economic development of the country, and the promotion of the concept of supply chains and the implementation of scientific results developed in this field into the practice of production, trade and transport enterprises at the global, international, national and regional levels actualize the need to deepen research into the formation and functioning of logistics centers with the aim of developing theoretical-methodological, institutional, normative-legal and methodical support for their activities. In recent years, global practice and domestic business have shown a steady trend towards increasing the volume and improving the quality of logistics services. In this connection, the need to create a modern logistics infrastructure, one of the objects of which is a logistics center, is growing.

The development of logistics infrastructure is of particular importance for Ukraine in connection with the change in its political and economic strategy aimed at joining the EU, the process of forming modern product supply chains. Despite the difficulties faced by the transport and logistics sector of Ukraine due to the full-scale invasion of Russia, in July 2022 the EU included Ukrainian logistics routes in the Trans-European Transport Network. This will allow the development of multimodal transportation, reduce logistics costs, and also contribute to the attraction of European investments for the modernization of this sector of the country's economy. For the efficient operation of the logistics and transport system of Ukraine, the development of a system of innovative logistics centers, the projects of which will be presented at the event, is extremely important.

- restoration of logistics capacities to meet the needs of trade and production;

– development of logistics hubs near borders and large airports;

– automation in the logistics industry;

- development of land logistics partnership with EU countries.

The term "logistics center" itself is quite common, and sometimes any large warehouse complex with a standard list of services is understood by it. However, the modern realities of the development of the domestic logistics infrastructure dictate new requirements for both the semantics and the content of the term "logistics center". Today, it is a more perfect organization, characterized by the expansion of the range of services and has its own distinctive features. Many residents are located on its territory, which provide the entire complex of logistics services related to transportation, distribution, warehousing, cargo processing, supply, inventory management and other related services. Many structures are involved in the complex process of planning, construction and operation of the logistics center: governmental, federal, regional, municipal, as well as private investors, developers and logistics operators. The main task of the logistics center is the effective integration and coordination of the activities of all internal participants, as well as external producers and consumers.

The creation of a modern network of logistics centers will allow the domestic economy to solve many urgent tasks:

a) relieve the tension of city traffic, because transport accessibility is necessary for the efficient operation of logistics centers, and they are located outside the territory of cities and convenient entrances to them are organized;

b) increase the efficiency of land use, as valuable urban land is freed up for new social construction;

c) reduce the amount of emissions into the atmosphere due to a decrease in the participation of freight transport in urban traffic;

d) to strengthen the country's competitiveness on world commodity markets;

e) to solve the problems of employment of the population thanks to the creation of a significant number of new jobs;

f) solve the issue of migration of the working population, which prefers to find work closer to the place of residence.

The foreign practice of organizing logistics centers shows that the state is primarily interested in their creation, as a result of which it is ready to provide the necessary area for development, provide the land with the necessary infrastructure, and invest funds in construction. However, there is still no program for the development of logistics centers in Ukraine, and the creation of large warehouse complexes is completely left to private entrepreneurship. Private companies are often driven only by the interest of obtaining a quick profit and strive to create modern multimodal complexes that require high volumes of investments with a long payback period.

The realities of the modern economic and political development of Ukraine, especially the future post-war development, actualize the need for the creation and development of modern logistics centers on the basis of public-private partnership, as focal companies that manage commodity and material and related flows on the way to promote products along new transport routes.

CHAPTER 1
THEORETICAL AND METHODOLOGICAL DETERMINANTS OF DEVELOPMENT OF LOGISTICS CENTERS

1.1 Conceptual and terminological apparatus of the concept of logistics centers

In today's economy, due to diverse customer needs, strict environmental requirements of society and a large number of global competitors, market competition is becoming increasingly fierce. One of the important factors that allows companies not only to survive, but also to achieve success is the efficiency of their logistics. The management of the logistics system includes several interrelated activities (warehousing, inventory handling, information services and transportation) and any decisions that can affect a large number of interested parties, both positively and negatively. The efficiency and stability of the logistics system determine the long-term competitiveness and success of enterprises. Therefore, both academic circles and practitioners are studying new methods of increasing the economic, environmental and social sustainability of the goods distribution system.

The design of the spatial distribution structure is of strategic importance for companies, as it allows to ensure the necessary level of customer service and to reduce logistics costs as much as possible. Decisions regarding the spatial structure of distribution relate to the location of distribution channels, that is, the spatial location of the transportation and storage system, as well as the location of distribution centers.

Goods distribution centers, or as it is more commonly used in the logistics field, logistics centers, are the basic infrastructural element of supply chains. Examining them from a scientific point of view, we note that there is currently no unambiguous interpretation of the term "logistics center". The authors of

textbooks, monographs and articles on logistics do not give the same definition to this term, and many of them try to avoid it altogether.

In a broad sense, "logistics center" means a certain territory specially organized for logistics operations, within which:

– all types of operations related to door-to-door cargo delivery (transportation, storage and cargo processing, distribution and redistribution of goods) in international and domestic connections take place;

- all activities are carried out by many logistics operators on a commercial basis.

Operators can be owners or tenants of buildings or structures (warehouses, distribution centers, warehouses, offices, freight forwarding services, etc.) built on this territory. Logistics centers should also be provided with all the means necessary to carry out the above-mentioned processes.

It is very important that the logistics center is managed by one neutral legal entity (usually a public-private partnership company) to ensure synergy and commercial cooperation. Finally, the logistics center must meet European standards and quality indicators in order to provide a basis for effective commercial and sustainable logistics and transport decisions.

The term "logistics center" is often the subject of confusion because. some authors understand it as a logistics center for companies involved in activities related to transportation and logistics[1], and others as functional equivalents of cargo villages in Europe, Japan, Singapore, China or the USA[2].

[1]Tompkins, J., Smith, JD The Warehouse Management Handbook. Tompkins Press. 1998. 702.; Meidute I. Comparative analysis of the definitions of logistics centers. TRANSPORT. 2005, Vol XX, No. 3, 106-110.; Dyczkowska, JA; Reshetnikova, O. Logistics Centers in Ukraine: Analysis of the Logistics Center in Lviv. Energies 2022, 15, 7975.https://doi.org/10.3390/en15217975.;Çavuşoğlu D., Zorba Y., and Esmer S. “A Set of Criteria for Logistics Center Development: A Fuzzy Analytic Hierarchy Process.” Journal of ETA Maritime Science, 2022. vol. 10(1), 47-60.; Rimienė, K. and Grundey, D. 'Logistics center concept through evolution and definition', Engineering Economics, 2007, Vol. 4, No. 54, 87-95.

[2]Kauf S., Laskowska-Rutkowska A., The location of an international logistics center in Poland as a part of the One Belt One Road Initiative. LogForum 2019, 15 (1), 71-83,http://doi.org/10.17270/J.LOG.2019.311; Aigang, H, "Study on the marketing strategy of Tianjin port logistics center" World Maritime University Dissertations. 2006. 225.; Sheffi Y."Logistics-Intensive Clusters: Global Competitiveness and Regional

The reasons for these terminological contradictions are: the relative immaturity of the research area; variety of functions that change in connection with the development of world logistics.

A wide variety of logistics concepts in the scientific literature has led to the appearance of many terms similar to the concept of "logistics center", these are:

– freight villages[3];

– logistics platform (Plates-formes Logistiques/Multimodales[4];

– Interporti[5];

– goods movement center (Gueterverkehrszentren (GVZ))[6];

– logistics park (Logistics park)[7];

– cargo platform (Platform freight terminal)[8];

Growth,"International Series in Operations Research & Management Science, in: James H. Bookbinder (ed.),Handbook of Global Logistics, edition 2013. 127, 463-500.

[3]Jiani Wu, Hans-Dietrich Haasis, The freight village as a pathway to sustainable agricultural products logistics in China, Journal of Cleaner Production, Volume 196, 2018, 1227-1238.; Okan Aksoy, Bahar Özyörük, The importance of freight villages: An implementation in TCDD, Applied Mathematical Modelling, Volume 39, Issue 19, 2015, 6043-6049.; Oláh, J., Nestler, S., Nobel, T., Popp, J. Evolution of Freight Villages and Dry Ports from the Macro Logistics Perspective Based on European Benchmarking 2020", Periodica Polytechnica Transportation Engineering, 2021, 49(4), 382-393.https://doi.org/10.3311/PPtr.16659.; Mary Catherine Osman, Maria Huge-Brodin, Jonas Ammenberg & Jenny Karlsson Exploring green logistics practices in freight transport and logistics: a study of biomethane use in Sweden, International Journal of Logistics Research and Applications, 2022, DOI:10.1080/13675567.2022.2100332

[4]Rosenberg, LN; Balouka, N.; Herer, YT; Dani, E.; Gasparin, P.; Dobers, K.; Rüdiger, D.; Pättiniemi, P.; Portheine, P.; van Uden, S. Introducing the Shared Micro-Depot Network for Last-Mile Logistics. Sustainability 2021, 13, 2067.https://doi.org/10.3390/su13042067.;Said Ahmed. Optimization of goods transport for multimodal logistic platforms. Automatic Control Engineering. Université de Lille, 2021. English. ffNNT. 110.; Maria Alejandra Acevedo Cote; Daniela Fernanda Sánchez Polanco; Javier Arturo Orjuela-Castro. Logistics Platforms - Trends And Challenges. Acta logistica Acta logistica ogistica -International Scientific Journal about Logistics International Scientific Journal about Logistics International Scientific Journal about Logistics Volume: 8 2021. 1001-1012.;Sanchez Polanco, Daniela Fernanda,Acevedo Cote, María Alejandra,Orjuela Castro, Javier Arturo. Evaluating third party logistics. Challenges and trends. Tecnura. 2023, vol. 27, No. 75, 10-10.

[5]Varese, E.; Bux, C.; Amicarelli, V.; Lombardi, M. Assessing Dry Ports' Environmental Sustainability. Environments 2022, 9, 117.https://doi.org/10.3390/environments9090117; Lam Canh Nguyen & Theo Notteboom. The relations between dry port characteristics and regional port-hinterland settings: findings for a global sample of dry ports, Maritime Policy & Management, 2019, 46:1, 24-42, DOI:10.1080/03088839.2018.1448478

[6]Peter Kemper, Markus Fischer, Modeling and Analysis of a Freight Terminal with Stochastic Petri Nets, IFAC Proceedings Volumes, Volume 33, Issue 9, 2000, 267-272.; Varese, E.; Marigo, DS; Lombardi, M. Dry Port: A Review on Concept, Classification, Functionalities and Technological Processes. Logistics 2020, 4, 29.https://doi.org/10.3390/logistics4040029;

[7]Iveta Kubasakova, Jaroslava Kubanova, Rudolf Kampf, The Storage Area of Logistic Objects in 2020 and its Operators, Infrastructure and Services, Transportation Research Procedia, Volume 53, 2021, 305-313.; Jiehui Jiang, Dezhi Zhang, Qiang Meng, Impact analysis of investment coordination mechanisms in regional low-carbon logistics network design, Transportation Research Part D: Transport and Environment, Volume 92, 2021, 102735.; Sun, X., Yu, H., Solvang, WD et al. The application of Industry 4.0 technologies in sustainable logistics: a systematic literature review (2012–2020) to explore future research opportunities. Environ Sci Pollut 2022, Res 29, 9560-9591. https://doi.org/10.1007/s11356-021-17693-y

- cargo coordination center (Centro integrado de mercancias)[9];

– transport center (Centro de transporte)[10];

– logistics square (Plaza logistica)[11];

– Rail Service Center (RSC)[12];

– transport center (Transport center)[13];

– distribution center (Distribution center)[14];

- the terminal[15]

- storage[16]

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[8]Natalia Kapkaeva, Anastasia Gurzhiy, Svetlana Maydanova, Anastasia Levina, Digital Platform for Maritime Port Ecosystem: Port of Hamburg Case, Transportation Research Procedia, Volume 54, 2021, 909-917.; Kine, HZ; Gebresenbet, G.; Tavasszy, L.; Ljungberg, D. Digitalization and Automation in Intermodal Freight Transport and Their Potential Application for Low-Income Countries. Future Transp. 2022, 2, 41-54.https://doi.org/10.3390/futuretransp2010003.; Jain, A.; van der Heijden, R.; Marchau, V.; Bruckmann, D. Towards Rail-Road Online Exchange Platforms in EU-Freight Transportation Markets: An Analysis of Matching Supply and Demand in Multimodal Services. Sustainability 2020, 12, 10321.https://doi.org/10.3390/su122410321.; Postan, M., Savelieva, I., & Stadnik, V. Development of a method for determination of ship's loading time distribution under irregular cargo arrival. Eastern-European Journal of Enterprise Technologies, 2019, 6(3 (102), 49-56. https://doi.org/10.15587/1729-4061.2019.183828.

[9]Christopher Mejía Argueta, Osman Camilo Soto Cardona, Harol Mauricio Gámez Albán, Jenny Patricia Moreno Moreno, Análisis del tamaño de empaque en la cadena de valor para minimáriz costos logísticos: un case de estudio en Colombia, Estudios Gerenciales, Volume 31, Issue 134, 2015, 111-121.; Commercial Logistics and Facilitation of Sustainable Goods Transport in Support of the 2030 Agenda for Sustainable Development. Comercio Sexto periodo de sesiones Ginebra, 21 a 23 de noviembre de 2018. https://unctad.org/system/files/official-document/cimem7d17_es.pdf

[10]Rojas Quezada C., Martínez Bascuñán M., De la Fuente Contreras H., Schäfer Faulbaum A., Aguilera Saéz F., Fuentes Mella G., Peyrín Fuentes C. y Carrasco Montagna Cruz J. Accesibilidad a equipamientos según mobilidad y modos de transporte en una ciudad media, Los Angeles, Chile. Anales de Geografía de la Universidad Complutense, 2019, 39(1), 177-200.https://doi.org/10.5209/aguc.64682.

[11]Patricia Cano Olivos, Fernando Orue Carrasco, José Luis Martínez Flores, Yésica Mayett Moreno, Gabriel López Nava, Modelo de gestion logística para pequeñas y medianas empresas en México, Contaduría y Administración, Volume 60, Issue 1, 2015, Pages 181-203.

[12]Patricia Perennes, Open Access for Rail Passenger Services in Europe: Lessons Learned from Forerunner Countries, Transportation Research Procedia, Volume 25, 2017, Pages 358-367.; Nikola Bešinović Resilience in railway transport systems: a literature review and research agenda, Transport 2020, Reviews, 40:4, 457-478, DOI:10.1080/01441647.2020.1728419

[13]Bardal A. and Sigitova M. Localization of Transport and Logistics Centers in the Region. IOP Conf. Series: Materials Science and Engineering 753 (2020) 072021 IOP Publishing doi:10.1088/1757-899X/753/7/072021.

[14]Alexander TC Onstein, Ishani Bharadwaj, Lóránt A. Tavasszy, Dick A. van Damme, Abdel el Makhloufi,

From XXS to XXL: Towards a typology of distribution center facilities, Journal of Transport Geography, Volume 94, 2021, 103128.; Rajesh Kr Singh, Nikhil Chaudhary, Nikhil Saxena, Selection of warehouse location for a global supply chain: A case study, IIMB Management Review, Volume 30, Issue 4, 2018, 343-356.

[15]Ilona Urbanyi-Popiołek, Magdalena Klopott, Container Terminals and Port City Interface – A Study of Gdynia and Gdańsk Ports, Transportation Research Procedia, Volume 16, 2016, 517-526.; Raimondas Šakalys, Nijolė Batarlienė, Research on Intermodal Terminal Interaction in International Transport Corridors, Procedia Engineering, Volume 187, 2017, 281-288.

[16]Falovich V.A. Supply chain warehousing: between costs and benefits. Bulletin of Lviv Polytechnic National University "Logistics", 2014, 811, 438-445.; JPvan den Berg, WHM Zijm, Models for warehouse management: Classification and examples, International Journal of Production Economics, Volume 59, Issues 1–

Having analyzed all the definitions listed above, we note that the main reasons for such a variety of terms are, first of all, different political, social, institutional, regional and geographical aspects. According to their functions, they can all be divided into four groups: warehouse, distribution center, terminal, and logistics center, the main difference of which is in the performed functions and volumes of services that provide added value (Figure 1.1).

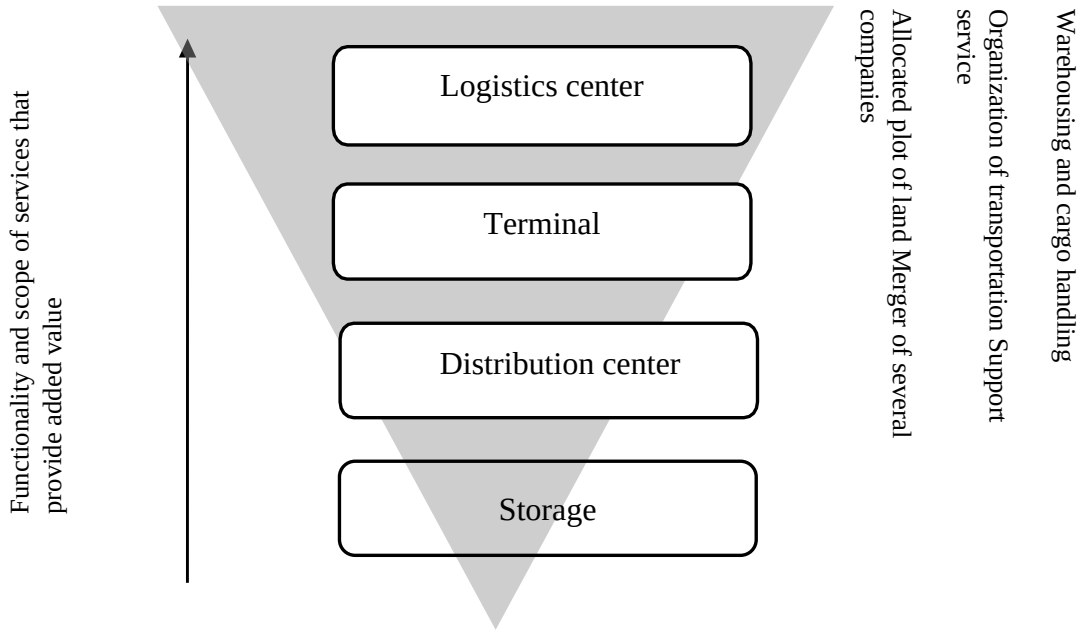

Fig. 1.1 – Functional-criteria hierarchy of the concepts "warehouse", "distribution center", "terminal" and "logistics center"

Source: compiled by the authors on the basis of the considered literary sources

Where the "logistics center" is the highest link of the distribution logistics network, which, in our opinion, should be understood as the union of several companies in a certain territory that provide complex logistics (warehousing, cargo processing and distribution), transport and auxiliary

3, 1999, 519-528.; Saderova, J.; Rosova, A.; Sofranko, M.; Kacmary, P. Example of Warehouse System Design Based on the Principle of Logistics. Sustainability 2021, 13, 4492.https://doi.org/10.3390/su13084492.; Rajesh Kr Singh, Nikhil Chaudhary, Nikhil Saxena, Selection of warehouse location for a global supply chain: A case study, IIMB Management Review, Volume 30, Issue 4, 2018, 343-356.; Davarzani, H., Norrman, A. Toward a relevant agenda for warehousing research: literature review and practitioners' input. Logistics. Res. 8, 1 (2015).https://doi.org/10.1007/s12159-014-0120-1.

services. The activity of the logistics center should be based on the full interaction of counterparties and supported by a single information platform. It is desirable that the logistics center has access to various types of transport. It is also worth noting that this logistics facility serves the entire supply chain, and not individual customers, thereby creating added value for the products moving along it.

The generalization of approaches to the characteristics of logistics centers made it possible to formulate the following main features:

- location in a certain territory (with the exception of virtual logistics platforms);
- unification of several commercial companies to provide logistics services;
- openness (accessibility) of the logistics center to all companies wishing to conduct their commercial activities there;
- the activity is regulated by the managing organization, preferably a 4PL or 5 PL provider (with the exception of network logistics centers);
- the presence of a synergistic effect from the interaction of participants in the logistics center;
- availability of a full list of logistics services not below the level of 3PL providers;
- modern logistics infrastructure and technologies (warehouse complexes and office premises not lower than class "A");
- availability of additional services (for example, gas stations, car washes, cafes, consulting and research activities);
- share distribution of costs (for service development, information technologies, training of specialists, etc.);
- participation of the state in the design and construction of the logistics center, as well as in its management (preferred);

- location in major transport hubs;
- the logistics center should be a means of interaction between local transport and long-distance transportation;
- access to various types of transport (preferred);
- the area of the territory of the logistics center should be about 100 hectares (preferably).

For national logistics systems, logistics centers provide the following advantages:

- logistics centers are connecting points of logistics systems of different countries and carry out efficient delivery of large volumes of goods over long distances (Figure 1.2);
- contribute to the increase of multi- and intermodal transportation, reducing excessive traffic on roads;
- increases the interaction of regions, thereby increasing their economic potential;
- contribute to the consolidation of several cargo flows into a large flow and direct it to another node of the network;
- improve the quality of providing logistics services of the national logistics system.

Among European countries, the leader in the development of transport and logistics infrastructure is Germany, which has formed a network of logistics centers of state importance. In it, logistics centers are managed by special monitoring bodies created by project participants, and the state and municipal bodies invest in the development of municipal roads and intermodal transport.

Another example of the effective implementation of the concept of logistics centers is the USA, where logistics centers, or "logistics houses", have a highly developed logistics infrastructure, a network of railways with high productivity, which optimally interact with air transport. The USA has a

network of logistics centers located in strategically favorable locations. It is represented by large sea and air ports, road and railway tracks, waterways, pipelines, cargo terminals, customs authorities and other objects of the national transport system. Logistics service here is highly developed, fast and flexible[17].

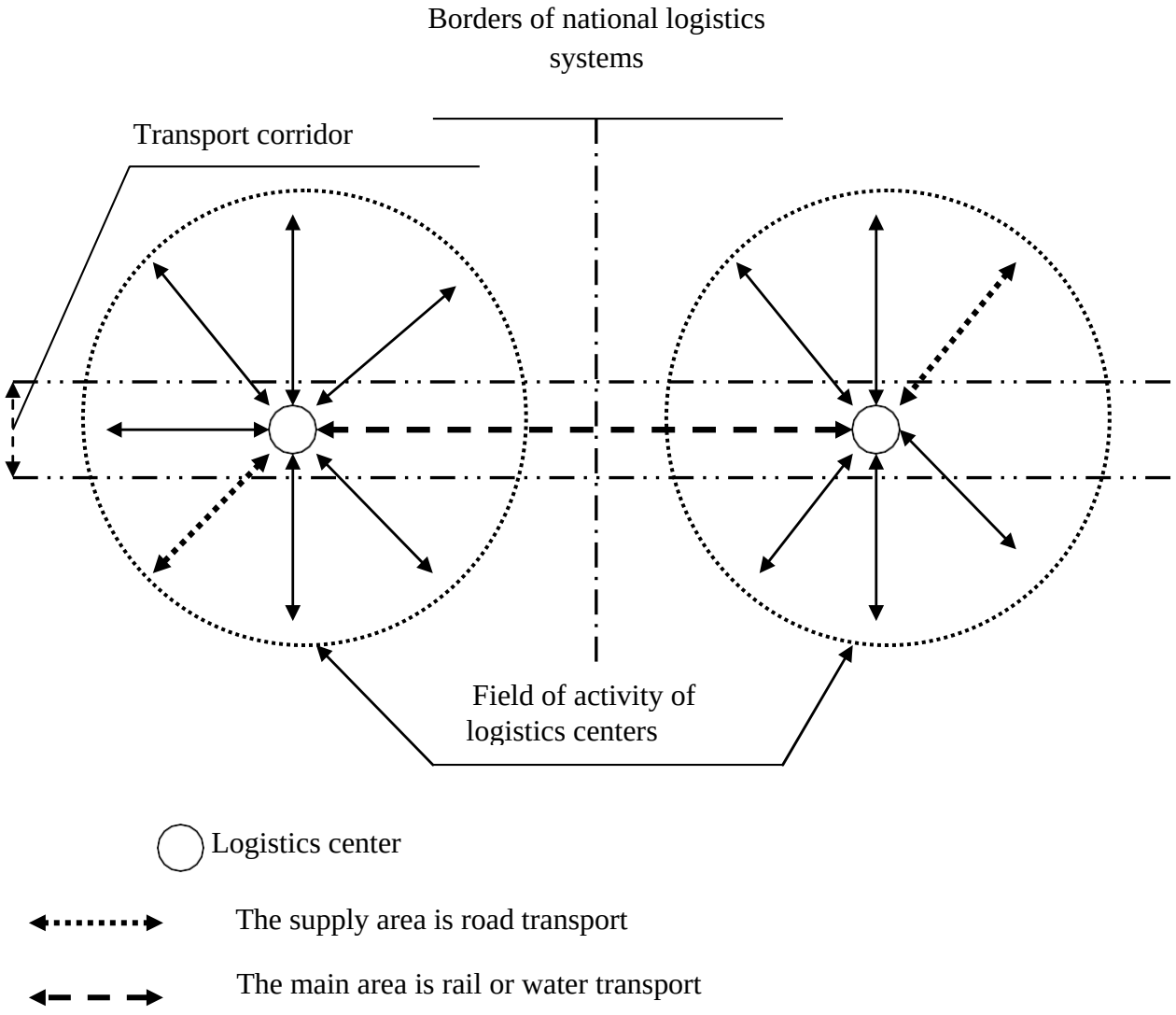

Fig. 1.2 – Schematic representation of connections between national transport systems through logistics centers

Source: compiled by the authors on the basis of the considered literary sources

[17]Clarence Woudsma, Paul Jakubicek, Laetitia Dablanc, Logistics Sprawl in North America: Methodological Issues and a Case Study in Toronto, Transportation Research Procedia, Volume 12, 2016, 474-488.

In Holland, the activity of logistics centers accounts for approximately 40% of the revenue of the country's transport complex. The main logistics centers here are the ports of Rotterdam, Amsterdam and Venlo, but the first two are not as developed as the logistics centers of the countries previously discussed. The functions of transport hubs are performed by distribution parks (Distriparks). The 500-hectare Port of Venlo is the only logistics center built with significant state participation. However, the port does not have a managing company, its functions are performed by the municipal administration.

In Great Britain, unlike previous countries, there are still no large logistics centers and all projects here are private. They were originally created by the British Rails company (British Railways), and after its privatization, by the subsidiary company Railfreight Distribution. Accordingly, there is no state policy regarding the development of logistics centers in Great Britain either, the state does not seek to invest funds in the development of transport and logistics infrastructure. The exception is several logistics centers in Daventry, which have a large management company. The average area of UK logoparks is 93 hectares (from 25 to 264 hectares).

In addition to the above, there are a number of other countries whose logistics center development practice deserves attention. The largest freight village Nordic Transport Center (NTC) is located in Denmark (city of Aalborg), with an area of about 200 hectares, which is one of the largest projects of logistics centers implemented in Europe. In Austria, there is a program for the development of transport and logistics infrastructure. Under which the state helps to optimize supply chains to improve transport connections with regions, increase the efficiency of transport and logistics infrastructure, organize mixed transport, etc. In Greece, projects of logistics centers are implemented mainly at the initiative of the Greek Association of Transport Chambers. The investor is EU funds and the national government of Greece.Thus, a whole network of logistics centers has been created in Western Europe, which contribute to the optimization of its

internal and international economic exchange. The payback period of such logistics centers here is on average 6-10 years.

Table 1.1 – The largest logistics centers in the world

Mark / LC, Country	**Roissy-SOGARIS, France**	**GVZ Bremen, Germany**	**InterportoBologna, Italy**	**Plataforma Logistica de Zaragoza, Spain**	**Alliance Texas, USA**	**CenterPointIntermodal Center, USA**
Size, ha	54	472	420	1312	7285	2631
Transport infrastructure	Intermodal terminal, railway, a/d, nearby airport	Intermodal terminal, railway, a/d, river port, near airport	Intermodal terminal, railway, a/d	Intermodal terminal, railway, a/d, airways	Intermodal terminal, railway, a/d, airways	Intermodal terminal, railway, a/d
Operation and management	SOGARIS	GVZ Bremen	InterportoBologna SPA	PLAZA SA	Hillwood, a Perot Com-pany	CenterPoint Properties
Project	PPP	PPP	PPP	PPP	Private	Private
State participation	Regional and local self-government	Central and regional government	Central, regional and local government	Regional and local government	Local government	Local government
Number tenants	100	150	107	250	350	No data available
Number of employees, people	2500	8000	2500	12000	35000	8000
Additional Services	Customs, post office, health care, public transport, restaurant, cafe, gas station and so on	Parking, customs services, gas station	Customs, post office, public transport, banks, bar, restaurant	Offices, Research Institute in logistics industry, shopping center, hotel	Office and residential, hospitals, hotel, as well as education, retail, etc	Offices, business parks

Source: official sites of logistics centers

It should be noted that the importance of Eastern European countries is growing in the logistics business, primarily due to the expansion of the European Union and the entry of multinational companies into the markets. The logistics market in Eastern Europe is characterized by wide regional differences. While the Czech Republic, Slovakia, Slovenia, Hungary and Poland have made good progress, Romania, Bulgaria and Croatia are far behind. A special role in the development of EU logistics centers is played by the Europlatform (Europlatforms EEIG), which was created in 1991. The European Association of Freight Villages (logistics centers) has 62 companies representing 10 countries (Germany, France, Italy, Spain, Denmark), Portugal, Hungary, Greece, Luxembourg and Ukraine). Europlatform manages the activities of logistics centers throughout Europe, and also develops the concept of logistics centers in general for the world. In recent years, many large-scale logistics centers have been built by commercial companies. Table 1.1 illustrates examples of the largest logistics centers that have achieved significant success in the development of the concept of international logistics centers.

As for logistics centers in Asia, they are currently being created mainly on the territory of the seaport, in the areas of nearby factories or airports. In Japan, logistics centers are located along international transport corridors, which allows to increase the volume of cargo transportation and the possibility of intermodal transportation.

Large ports in Asia are now setting themselves the task of increasing the functionality of their hubs. Services are expanding in such large ports as Shanghai and Tianjin (PRC), Gwangyang and Busan (Korea), Bangkok (Thailand), Singapore. Shanghai and Singapore are leading international logistics centers in Southeast Asia. Singapore conducts all international trade through logistics centers. Other major centers are located in Malaysia and Thailand. The development of logistics centers in Asia takes place on the basis of local specifics and tasks defined by the state.

A study of the trends in the creation of logistics centers in Ukraine showed that the predominant developers are private structures with foreign capital. Thus, the NAI Pickard company, which is part of the NAI group of companies (the sixth largest group of real estate agencies in the world), built 260,000 m2 of warehouse space in Ukraine back in 2008. Kuehne + Nagel has built 35,000 m2 of its own warehouses in Ukraine, although it is a logistics company and usually does not own warehouses. However, the company had to build warehouses in Ukraine, because it was not possible to rent modern high-tech warehouses.

The need for logisticians in warehouses naturally arouses interest in this segment and in development companies. The British Operator Raven & russia has been investing about $600 million in the construction of Ukrainian logistics complexes since 2008. Their clients are foreign logistics operators, as well as Ukrainian supermarkets: Velika Kishenya, Furshet, etc. Among the clients of Raven & russia, which offers warehouses of the "big box retail unite" format (warehouses in which trade is carried out), are METRO, Auchan, "Epicentr", "New Line" and others. In 2014, the following were put into operation: the second stage of the San Factory (7,000 m^2), the 293 multi-temperature warehouse complex RLC (63,000 m^2), the warehouse complex for own use by the Raben company (3 stage, 20,000 m^2), the warehouse complex "Etalon" (2nd stage, 6 thousand m2) and a part of the warehouse complex for FM Logistic's own use (14,000 m^2). Of these, according to Colliers International, most of the warehouse space (69%) was projects with an offer on the open market[18].

One of the prospects for the development of the logistics center market remains the construction according to the BTS (built-to-suit) scheme – the construction, reconstruction or modernization of the owner's facilities according to the needs of a specific tenant under a contract, according to which the tenant

[18]There is nowhere else to take land. The market is worth it. BUSINESS — news of Ukraine. URL: http://business-x.biz/zemli-bilshe-vzyati-niderinok-sto%D1%97t-biznes-novini-ukra%D1%97ni-73926/

undertakes to pay for the necessary work and conclude a new lease agreement with the owner. Experts note that developers of logistics real estate quickly oriented themselves and switched to construction for a specific consumer instead of projects for the open market, so they even managed to reduce the vacancy of warehouse space.

Before the war, in 2022, Ukraine planned to complete the construction and put into operation almost 100,000 m^2 of warehouse space, in particular:

– the first stage of the M06 logistics complex of the Amstar company (32,000 m^2);

– industrial park E40 of the Dragon Capital company (21,000 m^2);

– the second stage of the logistics center RLC II (24,000 m^2);

– two small warehouses with an area of about 10,000 m^2 each[19].

Modern projects for the development of logistics centers in connection with the war are mainly implemented in the western regions of the country. Soon the bypass road of Lviv near the village of Zimna Voda, the first and second phases of the technology park with an area of 68,000 m^2 and 43,000 m^2 of warehouses, respectively, were put into operation. The third phase is also planned; it will take several more years. If everything planned is built, the center can become the largest in the country. The Ukrainian development company Alterra Group is constantly increasing the pace of construction of the Lviv logistics center PORT with an area of 47,000 m^2.

1.2 Classification, typology and hierarchy of logistics centers

The best method for studying the activities of logistics centers is their classification. Namely, multi-faceted faceted classification, which allows dividing the object under investigation into appropriate types and thereby reveals its essence and content.

[19]Dyczkowska, JA; Reshetnikova, O. Logistics Centers in Ukraine: Analysis of the Logistics Center in Lviv. Energies 2022, 15, 7975. https://doi.org/10.3390/en15217975

Thus, the experience of creating large logistics centers in the European Union made it possible to divide all logistics centers into five categories:

1) main logistics centers of pan-European significance.
2) the main logistics centers are partly of pan-European significance.
3) secondary logistics centers of regional significance.
4) national auxiliary logistics centers.
5) regional / local auxiliary logistics centers.

Table 1.2 – Categories of the European logistics center

No	Criteria	LC category				
		1	**2**	**3**	**4**	**5**
1	Location in the Trans-European Network (TEN) Corridor Zone	Kh	Kh			
2	Top-class highways	Kh				
3	Railways of the highest class	Kh				
4	Number of types of transport	3	2	2	1	1
5	Scale of activity	IN	WITH	WITH	M	M
6	Volumes of goods distribution	IN	WITH	WITH	M	M
7	Legal entity status	Kh	Kh	Kh	Kh	Kh
8	Consistency of the district	Kh		Kh	Kh	
9	Service availability	Kh	Kh	Kh	Kh	Kh
10	Network interaction	Kh	Kh	Kh	Kh	Kh
11	Interaction between logistics centers	Kh	Kh	Kh		
12	Environmental protection	Kh	Kh	Kh		
13	Membership in the national organization of logistics centers	Kh	Kh	Kh		
14	Membership in EUROPLATFORMS	Kh	Kh			
15	Association with larger logistics centers			Kh	Kh	Kh
16	Accessibility	Kh	Kh	Kh	Kh	Kh
17	Intra-European and international connections	Kh	Kh			
18	National message	Kh	Kh	Kh	Kh	Kh

X – the presence of a criterion; B is large; C – average; M is small.

Source: Krekora P, Nyszk W. Selected logistics centers in the European Union. Security and Defense Quarterly. 2014;3(2):63-80. doi:10.5604/23008741.1152570.

The Finnish company Pöyry Infra Oy, specializing in issues of transport systems, proposed the following classification of logistics centers in Eastern Europe (2009):

- Logistics centers with a full range of services (serve international transportation). These facilities are located in areas with railway access tracks and provide high-level services (maintenance, offices, storage, container transportation, customs, etc.).
- Small logistics centers with an adapted area, where several companies provide basic logistics services (carrying different levels of transportation).
- Logistics centers serving one or more industries (food industry services, automotive, electronics, medicine, industries requiring cold storage, and others). They organize both international and local supplies.
- Logistics centers serving rail and container transportation, organizing international deliveries. They have an intermodal terminal, equipment for loading containers, a large length of railway access tracks, and are located close to the port.
- Logistics centers providing modern value-added services. They organize international, local, national and regional transportation.
- Logistics centers of city logistics. They organize the distribution and transportation of goods in the city. Local and regional transportation services are provided[20].

In foreign and domestic scientific works, a lot of attention is paid to the typology and hierarchy of logistics centers, the main approaches are presented in the Tables 1.3 and 1.4, which show that the first attempts to divide logistics centers into types were made back in the 1990s.

[20]Classification of Logistic centers in Eastern Europe and Russia. Pöyry. URL:http://www.poyry.com/sites/default/files/imce/Classification_of_logistics_center s_0.pdf.

Table 1.3 – Typology and hierarchy of logistics centers in foreign literature

Year, author	Sign	Types of logistics centers
1999, Weymans B. and co-authors[21]	Terminal size	1. Main Port Terminal (XXL) 2. International Terminal (XL) 3. National Terminal (L) 4. Regional terminal (M) 5. Local terminal (S)
2001, Liner S. and Harrison R.[22]	Transport served by domestic terminals	1. A port on inland waterways 2. Air cargo port 3. Maritime loading inland port (dry port) 4. Trade and transport center of the inner port
2007, Rimien K. and Grundy D.[23]	The role of logistics centers in the supply chain	1. Level - warehouse, distribution center 2. Level - transport terminal, logistics center, cargo village 3. The level is a logistics node
2009, ESCAPE UN[24]	Design, functions and role in the supply chain	1. Cargo village 2. Dry port 3. Intermodal terminal 4. Ground container warehouse 5. Container site
2010, Fechner I.[25]	Types of logistics nodes of the national logistics network	1. Seaport Airport 2. Inner port (dry port) 3. Logistics center 4. Warehouse center 5. Transshipment terminal 6. Sorting complex 7. Packing and sorting complex 8. Inland water port 9. Warehouse complex
2011, Higgins, K. and Ferguson, M.[26]	Standardized typology and hierarchy of logistics centers	1. Warehousing and distribution cluster (Container yard/Warehouse=>Ground container warehouse/Distribution center) 2. Freight Transportation and Distribution Cluster (Intermodal Terminal => Inland Port => Cargo Village) 3. Cluster Gateway, i.e. the place of transportation docking (Main port terminal)

[21] Wiegmans, Bart W., et al. "Container Terminals And Utilization Of Facilities." International Journal of Transport Economics / Rivista Internazionale Di Economia Dei Trasporti, vol. 31, no. 3, 2004, 313-39.

[22] Leitner SJ and Harrison R. The Identification And Classification Of Inland Ports. Performing Organization Report No. Research Report 0-4083-1. Center for Transportation Research The University of Texas at Austin. 134.

[23] Rimiene K., and Grundey D. Logistics Center Concept Through Evolution and Definition. Engineering Economics, Vol. 4, No. 54, 2007, 87-95.

[24] Transport and Communications Bulletin for Asia and the Pacific No. 78 Development of Dry Ports United Nations publication 2009 https://www.unescap.org/sites/default/d8files/bulletin78_Fulltext.pdf

[25] Fechner, I. Role of logistics centers in national logistics system. LogForum. 2010. No. 2. URL:http://www.logforum.net/pdf/6_2_2_10.pdf

[26] Higgins CD, Ferguson MR An Exploration of the Freight Village Concept and its Applicability to Ontario. Hamilton: McMaster University, 2011. 195.

Continuation of the Table 1.3

2012, Rodrigue Zh.-P.[27]	Functions	1. Gateway 2. Cargo distribution cluster or logistics zones (port-oriented logistics zone, inland port, logistics park, cargo village) 3. Transfer hub 4. Intermodal terminal 5. Satellite terminal (remote terminal)
2019, Geitz, A., Launey, P., and Beziat, A[28].	The degree of integration of logistics	1. Virtual logistics center 2. Physical logistics center 3. Network logistics center

Source: compiled by the authors on the basis of the considered literary sources

Table 1.4 – Typology and hierarchy of logistics centers

Year, author	Sign	Types of logistics centers
2008, E. Krykavskyi and co-authors[29]	Area and radius of action logistics center	1. International (100–150 ha, 500–800 km) 2. Regional (20–50 ha, 50–80 km) 3. Local and industry
2010, Pasichnyk A., Kutyrev V.[30]	Range of clients	1. Logistics centers of a certain company that provides transport services (the production facilities available at the enterprise are used) 2. A logistics center that has a certain production base as a terminal (capacity for receiving, sending, processing and delivering goods andcontainers, warehouse facilities, fleet) 3. Regional logistics center (located in places of accumulation, sorting or overloading of goods and performs particularly important tasks, ensures accelerated passage of goods) 4. A logistics center of functional importance, which belongs to several companies and carries out one type of transport activity 5. A logistics center specializing in transportation by a certain type of transport

[27]Rodrigue, J.-P. Freight Terminal Hierarchy and Added Value. URL:http://people.hofstra.edu/geotrans/eng/ch4en/conc4en/terminaladdedvalluehierar chy.html

[28]Heitz, A., Launay, P., & Beziat, A. Heterogeneity of logistics facilities: an issue for a better understanding and planning of the location of logistics facilities. European Transport Research Review, 2019, 11(5). https://doi.org/10.1186/s12544-018-0341-5.

[29]E. V. Krykavskyi Logistics center is a nodal object of logistics networks. Logistics: problems and solutions. 2008. No. 5. 38-39.

[30]Pasichnyk A. M., Kutyrev V. V. Transport and customs logistics centers in Ukraine: problems and development prospects. url. www.irbis.nbu.com. ua/.../cgiirbis_64.exe

Continuation of the Table 1.4

		6. A comprehensive logistics center that provides services to all companies by all types of transport
2012, Stutynska I.[31]	Classiness of warehouse spaces	1. International (class A) 2. National (class A) 3. Regional (class A and B) 4. Local (classes A, B, C, D) 5. Centers of companies (classes A, B, C, D)

Source: compiled by the authors on the basis of the considered literary sources

Of particular interest is the hierarchy of large logistics facilities according to their geographical coverage and capacity, which was proposed in 1999 by Wemans B., Mazurel E. and Niikamp P.[32].

The authors included the main port terminals of XXL size, which are large transport hubs, airports, deep-sea seaports that provide global transport networks, to the higher level.

They are followed by XL-sized international terminals, which are continental-level airports and seaports with a smaller scale of operations.

National level networks are served by national terminals (L), which combine rail, road and inland water transport networks in their activities.

The same networks, but of a regional scale, serve regional terminals (M).

Objects with the smallest size carry out small-scale operations and organize the work of road transport only and are the final point of the transport network. This approach shows the great importance of transport hubs in creating world supplies through terminal networks of various ranks.

Liner S. and Harrison R.[33](2001), conducting a study of the operation of inland ports (dry ports), divided logistics centers into four categories depending on the main type of transport they serve:

[31]Strutynska I. Classification signs in the activity of logistics centers. Socio-economic problems and the state. 2012. No. 2. 299-307.

[32] Wiegmans B., Masurel E. and Nijkamp P. Intermodal Freight Terminals: An Analysis of the Terminal Market. Transportation Planning and Technology, Vol. 23, No. 2, 1999, 105-128.

[33]Leitner SJ and Harrison R. The Identification And Classification Of Inland Ports. Performing Organization Report No. Research Report 0-4083-1. Center for Transportation Research The University of Texas at Austin. 134.

A port located on inland waterways- mainly used for transportation of bulk goods.

Air cargo port- a specialized cargo port, on the territory of which customs, warehouse facilities, sometimes even industrial centers function. Usually, expensive or perishable goods are transported using this facility.

*Primorye internal loading port*serves as a point for deconsolidation of goods on domestic routes, is located near a seaport (50-250 km from the main port), with which it is connected by road, rail or waterways.

*Trade and transport center of the inland port*located at the junction of several modes of transport, where there is a large free area. These objects are intended for trade, contribute to the creation of added value to goods. They can serve both the city and the entire region.

A similar study was conducted in 2009 by T. Notteboom and Zh.-P. Rodrigue.[34],dividing intermodal terminals into three types according to their location and functions: port terminals, rail terminals and distribution centers.

Later, in 2007, Rimien K. and Grundy D.[35]proposed a three-level classification, dividing logistics centers into six types according to their role in the supply chain. The authors assigned objects to a certain level depending on their similarity to each other. The first level includes logistics facilities with the smallest sphere of activity, the second - with the average, and the third - with the highest.

The peculiarity of this hierarchy is that there is no clear boundary between the concepts analyzed by the authors. Warehouses act as an intermediate storage point between suppliers and manufacturers, helping to smooth out fluctuations in demand. Or they can be a more complex object for distribution, maintenance and provision of value-added services. Distribution

[34]Notteboom, TE and Rodrigue, JP Inland Terminals, Regions and Supply Chains. Open Journal of Applied Sciences, 2009, Vol.9 No.4, April 12, 1-39.

[35]Rimiene., K., and D. Grundey. Logistics Center Concept Through Evolution and Definition. Engineering Economics, Vol. 4, No. 54, 2007, 87-95.

centers also belong to this type of objects, but in addition to storing goods, they manage the flow of goods. Despite all that, according to the authors, in modern literature, distribution centers are also referred to places located at nodal points of the transport system, where cargo flows are grouped or separated, this approach brings the term "distribution center" closer to the definition of "terminal" or "logistics center".

Transport terminals, according to the authors, are concentration points in which cargo flows either complete their journey or form flows for further movement to their final destination. Transport terminals can vary from simple terminals to terminals with advanced capabilities to provide a range of additional services, these terminals are similar in functionality to logistics centers or cargo villages.

Logistics centers are designed for the best management of all types of activities related to cargo movement, they carry out cargo consolidation, organize intermodal transportation, and contribute to the development of the regional economy. Logistics centers, distinguished by their scale and wide functionality, are cargo villages. They offer a wide range of services, developed infrastructure, are distinguished by high integration to facilitate the management of product flows, as well as significant influence in the organization of regional trade flows.

Logistics hubs (gateways, seaports, air cargo ports, major terminals) are large points that have access to different modes of transport and handle cargo from different directions.

In 2009, the Economic and Social Commission for Asia and the Pacific, based on the experience of logistics infrastructure development, developed a comprehensive typology that divided intermodal logistics centers according to their design, functions and roles, ranging from simple container yards to cargo villages.

The Institute of Logistics and Supply Chain Management (ILSCM) at the University of Victoria in Melbourne (Australia) conducted an in-depth study on the topic of logistics centers and logistics cities. Initially, in 2007, researchers divided logistics centers into four types:

– cargo village;

– internal port;

– cargo hub;

– logistics city.

And in 2010, the presented typology was transformed taking into account the development of ideas in logistics. According to the authors, the smallest logistics center in terms of size and level of service provision is a city cargo terminal, i.e. a place equipped for transshipment and storage of transport units. This object has direct connections from many directions, which allows for the transportation of goods using various types of transport.

*Cargo hub*is a node used for the collection, sorting, transshipment and distribution of goods for a particular area, includes at least one cargo terminal. Provides value-added services, organizes transportation at the regional and international levels.

*Logistics village*has the same meaning as proposed by Rymien K. and Grundy D. It differs from a freight hub by involving industrial activity, which creates advantages in terms of savings and cost reduction. The largest logistics center, according to ILSCM, is a logistics city, which is a city area with suburbs that carry out logistics activities and support services provided by transport infrastructure and logistics hubs. The distinguishing characteristics of this territorial association are that the logistics city provides the benefits derived from population aggregation by creating a common infrastructure (utilities, public transport or education), the availability and diversity of the workforce, as well as a developed market.

A similar hierarchy was presented in 2010 by Sengpyel K., according to which logistics centers can be divided into five types. At the first level, simple operations such as transshipment, transportation and storage are carried out - operations carried out by the cargo terminal. They are followed by a cargo hub and a logistics village (similar to ILSCM).

These three types have clear boundaries, and the fourth and fifth levels (logistics city and interregional logistics cluster), presented by the author, have blurred boundaries. According to the author, these logistics clusters differ in size, number of logistics cores and logistics structures. For example, a logistics city may include a metropolitan area, and an interregional logistics cluster may include different metropolitan areas.

Another interesting typology was presented in 2010 by the Polish author Fechner I.[36], which identified 10 types of logistics hubs of the national logistics network.

According to the author, there are main logistics nodes (sea port, airport, inland port, logistics center, warehouse center, transshipment terminal, sorting complex, packaging and sorting complex) that process large cargo flows, and auxiliary nodes in the form of warehouses and terminals that designated service of individual enterprises (inland water port, warehouse complex).

A logistics center differs from a warehouse center in the possibility of intermodal transport service. The warehouse complex is a closed structure, that is, it is limited to a room intended for storing stocks.

However, the most interesting work, in our opinion, is the standardized typology and hierarchy of logistics centers proposed by Higgins K. and Ferguson M.[37]in 2011. In which they analyzed different approaches and combined the hierarchies developed by Waymans B. with co-authors, Liner S.

[36]Fechner I. Role of logistics centers in national logistics system. LogForum. 2010. No. 2. URL:http://www.logforum.net/pdf/6_2_2_10.pdf

[37]Higgins CD, Ferguson MR An Exploration of the Freight Village Concept and its Applicability to Ontario. Hamilton: McMaster University, 2011. 195.

and Harrison R. and Grundy D., UN ESCAP and Notteboom T. with Rodrigue J.-P. Higgins K. and Ferguson M. presented a standardized hierarchy and identified three levels of logistics centers, which included five types of logistics centers (Figure 1.3).

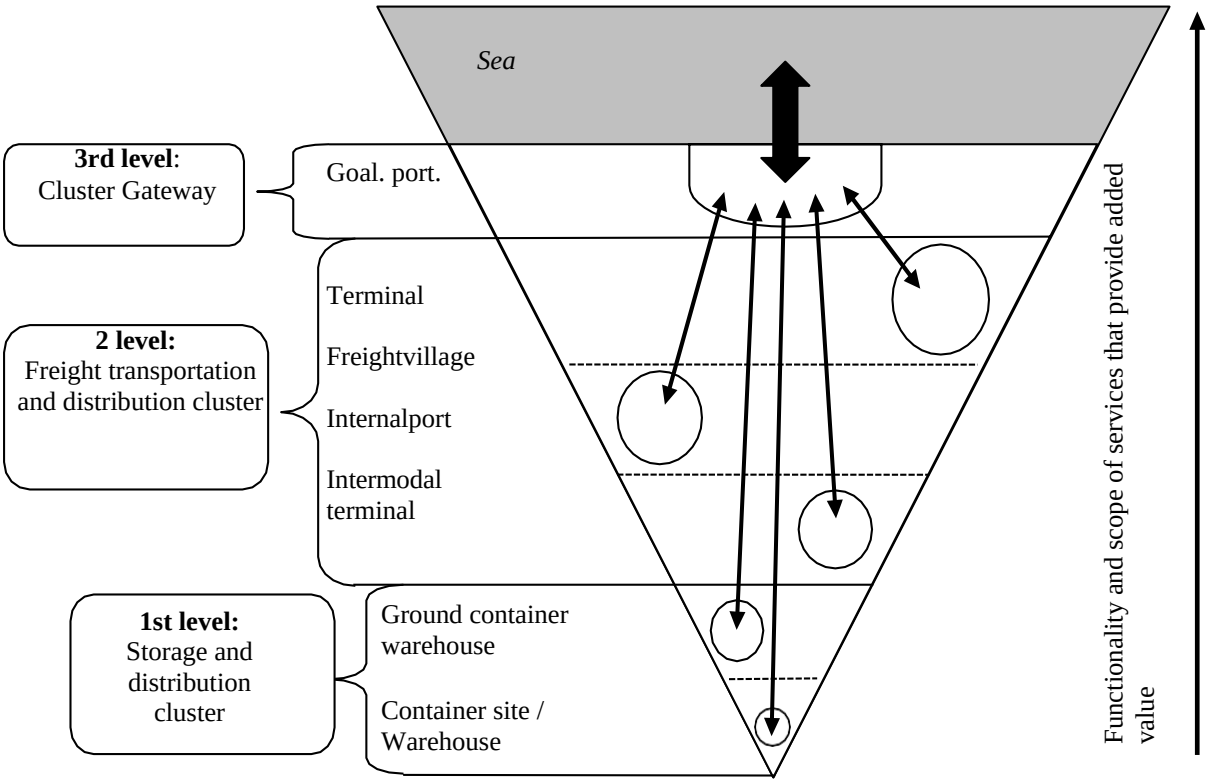

Fig. 1.3 – Standardized hierarchy of logistics centers

Source: Higgins, CD Ferguson MR An Exploration of the Freight Village Concept and its Applicability to Ontario. Hamilton: McMaster University, 2011. 195.

Figure 1.3 shows that an important role in the hierarchy of logistics centers is played by their proximity to the sea. Accordingly, schematically, a typical supply chain, according to the presented hierarchy, may look as shown in Fig. 1.4.

In 2012, Rodrigue Zh.-P.[38] presented its updated hierarchy of cargo terminals, which is based on the logistic zoning of intermodal cargo flows.

[38]Rodrigue J.-P. Freight Terminal Hierarchy and Added Value. URL:http://people.hofstra.edu/geotrans/eng/ch4en/conc4en/terminaladdedvalluehierar chy.html

According to the author, the functional integration of cargo distribution is divided into three levels:

1. Logistics zones (carrying activities on a free plot of land located near the road infrastructure).

2. Logistics clusters (concentration of freight activity in a specific area located around a transport terminal or station).

3. Logistics fields (the area around an intermodal terminal or station with the highest level of integration with seaports, railway stations or airports may also include free trade zones).

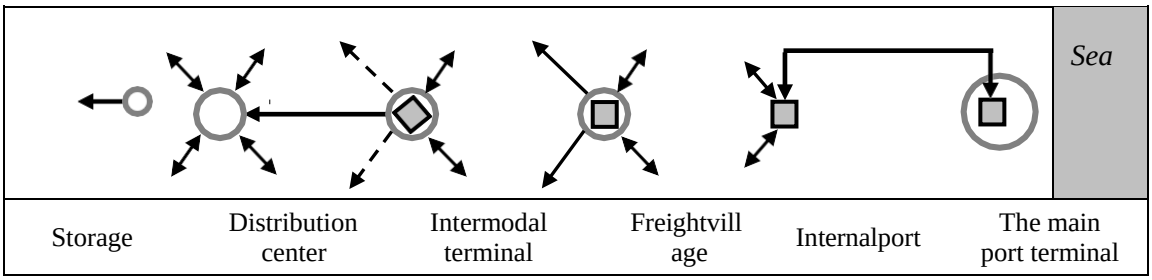

Fig. 1.4 – A typical international supply chain

Source: built on Higgins, CD Ferguson MR An Exploration of Freight Village Concept and its Applicability to Ontario. Hamilton: McMaster University, 2011. 195.

There are four types of logistics zones according to their relationship to terminals:

– port-oriented logistics zones;

– internal (river) ports;

– logistic parks

– cargo villages.

Port-oriented logistics zones, which are located together with the port terminal, and inland ports (dry ports), which are located next to the intermodal railway terminal (in some cases with the barge terminal), have a direct interaction with the intermodal terminal. Various actors, such as local authorities, railway operators and commercial developers, are involved in the

regulation of these logistics zones. Intermodal logistics centers have relative proximity to an intermodal terminal (port or railway).

Logistics parks may not be located in the immediate vicinity of the terminal, but may operate on free land with access roads. Cargo villages, in addition to activities carried out by logistics centers, provide a range of additional services for logistics providers (hotels, offices, restaurants and others).

Logistics zones occupy one of the places in the hierarchy of cargo terminals proposed by Rodrigue Zh.-P. (Fig. 1.5).

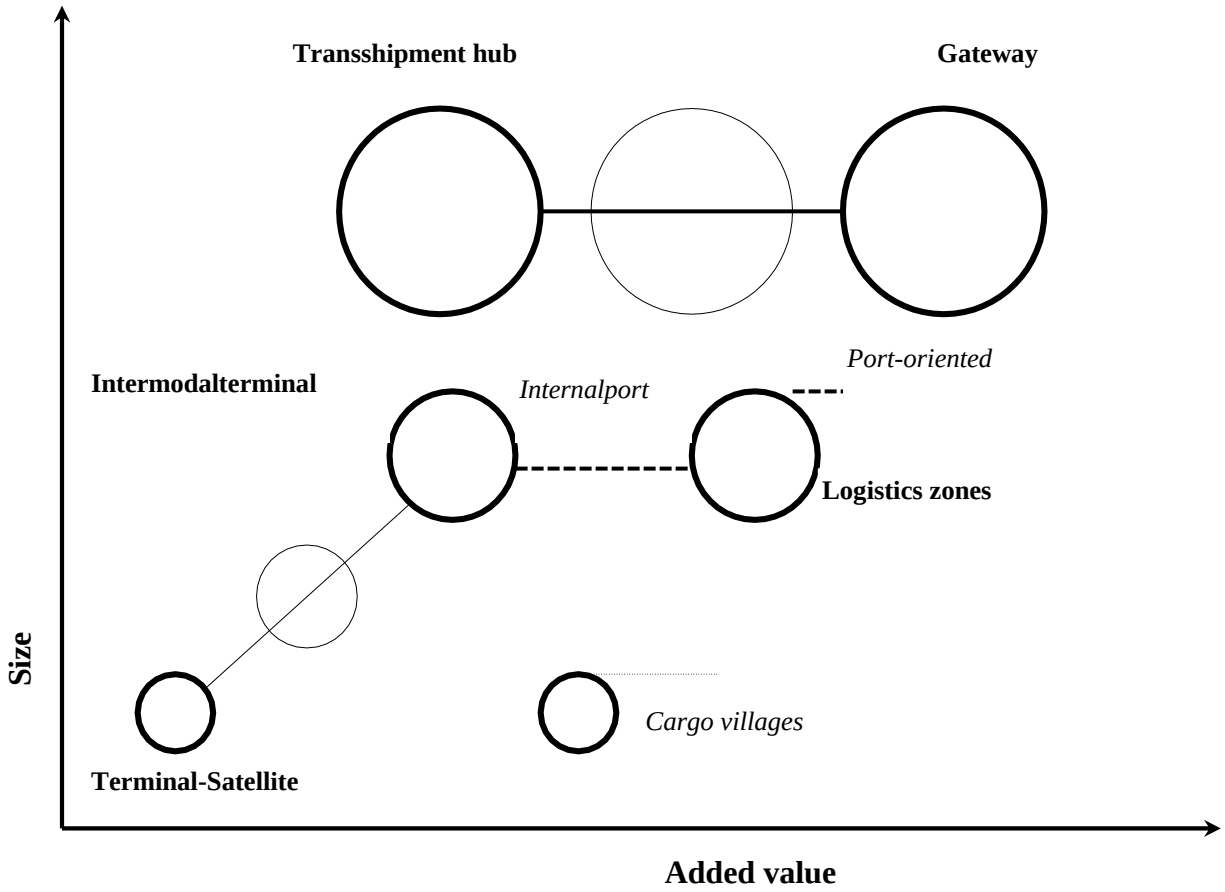

Fig. 1.5 – Hierarchy of cargo terminals

Source: Rodrigue J.-P. Freight Terminal Hierarchy and Added Value. URL:http://people.hofstra.edu/geotrans/eng/ch4en/conc4en/terminaladdedvalluehierarchy.html

*Terminal-Satellite*carries out specialized transport and distribution activities, performs specific functions, for example, transshipment, is often located near the main transport hub (Gateway). An intermodal terminal is a means of transferring goods between different modes of transport.

*Transfer hub*is a port terminal specializing mainly in transshipment of container cargo from one transport network to another. Due to the limited activity, transshipment hubs provide a lower level of added value than logistics zones.

*Gateway(*by analogy with Higgins K. and Ferguson M. Main Port Terminal, Riemien K. and Grundy D. Logistics Hub) is a world-class intermodal transport hub. Contains the entire range of additional services related to transportation. Gateways mainly focus on cargo transfers between maritime and inland transport systems.

The sign "the degree of integration of logistics" deserves special attention. In this case, the types of logistics centers reflect the stages of development[39] (Figure 1.6).

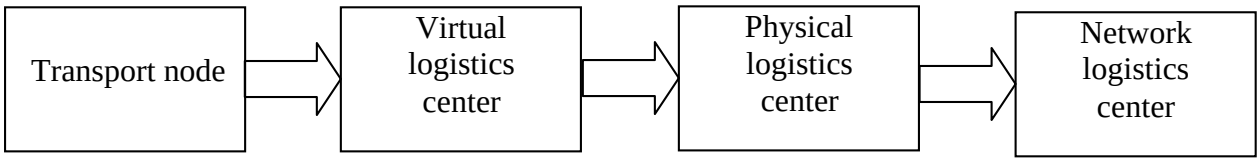

Fig. 1.6 – Stages of development of logistics centers

Source: compiled by the authors based on Heitz A., Launay P. & Beziat, A. Heterogeneity of logistics facilities: an issue for a better understanding and planning of the location of logistics facilities. Eur. Transp. Res. 2019. Rev. 11, 5. https://doi.org/10.1186/s12544-018-0341-5

[39]Heitz, A., Launay, P. & Beziat, A. Heterogeneity of logistics facilities: an issue for a better understanding and planning of the location of logistics facilities. Eur. Transp. Res. Rev. 11, 5 2019. https://doi.org/10.1186/s12544-018-0341-5.

Transport node(zone, cluster) is a docking point for various types of transport that organizes transshipment of cargo. Such nodes include intermodal cargo terminals and ports.

The virtual logistics center does not have a dedicated territory, does not provide logistics and transport services, it is designed to coordinate the actions of physical logistics centers and companies that carry out their activities in them, organization of marketing operations, etc.

Physical (real) logistics centers fully correspond to the definition of a logistics center given by us earlier.

Network logistics centers (some authors call them regional) represent a network of physical logistics centers and service companies that closely cooperate and carry out activities according to uniform principles. Such network integration increases the competitiveness of each element of the network at the national and international level.

Similar networks are divided into three types according to the growth of concentration and centralization of management: freely organized (type "A"), networks of conceptual interaction (type "B") and hierarchical networks (type "C").

A network of type "A" is built on the basis of self-sufficiency of participants, type "B" on the basis of close interaction of participants, and network of type "C" is led by a dominant company that determines the principles of activity of other participants.

Therefore, after analyzing the research of foreign and domestic scientists, we propose to take into our own classification only those features that reflect the concept of "logistics center" and exclude from the classification those that divide logistics centers into types that do not exist in their pure form. For example, there is no purely informational or purely technological logistics center. Also, in our opinion, the stages of development of logistics centers should not be included in the classification.

Therefore, from the signs indicated in the domestic literature, it is worth highlighting:

– the feature – "participation of modes of transport", since it is the presence of two or more modes of transport that is the main difference between logistics centers and distribution centers and warehouses;

– a feature – "type of ownership", since it is very important whose initiative the project of logistics centers is implemented: the state or a private investor.

– the characteristic – "type of processed goods", since most logistics centers were originally built with industrial centers and parks in mind;

– a feature – "attitude to the port", since it is possible to distinguish external logistics centers that exist on the basis of sea ports and process import-export and transit flows, as well as internal ones that ensure the integrity of the country's economic space.

In addition, logistics centers can be divided according to the composition of the terminals included in them, since the specialization of residents located on the territory of the logistics center requires the presence of certain infrastructure and equipment.

Foreign classification allows us to add the feature "by the scale and administrative level of the territory served"[40] sizes of logistics centers. And also introduce another feature "area size and function"[41], since the authors in their research focus mainly on hierarchy and typology.

Medium and small logistics centers have a size of less than 100 hectares, usually formed in free territories near port terminals or in areas with a high

[40]Asrin Karimi, Khalid Abdul Rahim, Classification of External Stakeholder Pressures in Green Supply Chain Management, Procedia Environmental Sciences, Volume 30, 2015 27-32.

[41] Akkerman, F.,Lalla-Ruiz, E.,Mes, M.andSpitters, T.(2022), "Cross-Docking: Current Research Versus Industry Practice and Industry 4.0 Adoption" 69-104.https://doi.org/10.1108/S1877-636120220000028007;Bondarouk, T.andOlivas-Luján, MR(Ed.) Smart Industry – Better Management (Advanced Series in Management, Vol. 28), Emerald Publishing Limited, Bingley, 2022, 191-198.

population density, which is related to their relatively small size. Large logistics centers range in size from 100 to 800 hectares.

Table 1.5 – Classification of logistics centers according to the author's definition of a logistics center

No	Classification sign	Types of logistics centers
1	By scale and administrative level of service territory	1. International (XXL) 2. State (XL) 3. Regional (L) 4. District (M) 5. Urban and local (S)
2	By type of property	1. Private 2. Public-private 3. Public-private partnerships 4. State 5. Association of commercial structures
3	By types of transport participating	1. Railway and water 2. Railway and automobile 3. Railway, road and water 4. Railway-car-water-air 5. Air and automobile
4	According to the size of the territory and the performed functions	1. Small and medium (less than 100 ha): – logistics park; – intermodal terminal; - freight hub. 2. Extra large (over 800 hectares): – logistic city; - gateway.
5	By types of processed goods	1. Universal containers 2. Tarno-artificial loads 3. Bulk cargoes 4. With special modes of storage and transportation 5. Specialized in industries (grain, coal, oil, forestry, auto parts and others)
6	In relation to the the port	1. External (border) 2. Internal
7	By the nature of the specialization of terminals as part of logistics centers and the degree of integration with industrial enterprises served	1. With specialized terminals for storage and processing of forest and construction cargoes, food products, pharmaceutical products, oil cargoes 2. With a wholesale trade center 3. With a training center 4. With a rehabilitation and wellness complex 5. As part of the industrial and logistics park

Source: compiled by the authors

Most of the large logistics centers are located in suburban areas, especially near the points of convergence of intercity roads. Such large areas usually require proximity to intermodal and adjacent rail terminals.

There are also very large logistics centers (more than 800 hectares), they are created according to mega-projects that began to be implemented only during the last decade. They are located far from city centers and in close proximity to intermodal terminals. Such logistics centers are created by developers who closely cooperate with large carriers (especially with railways). The construction of such logistics centers is associated with large capital investments, extra-large logistics centers require active logistics activities, otherwise their creation will not be economically justified.

Thus, we propose to classify logistics centers according to the author's definition according to seven characteristics (Table 1.5), which include only those that correspond to the modern understanding of the logistics center and the definition proposed by the authors.

1.3 Structuring and functional support of logistics centers

The analysis of the semantics of the terms "warehouse", "distribution center", "logistics center" and "terminal", as well as the study of the classification of logistics centers in foreign and domestic literature showed that there are many objects that fit the definition of "logistics center" , distinguish between their size, location, functionality and level of service provision.

To determine the functions performed by logistics centers, we took as a basis the previously conducted analysis of the standardized hierarchy of K. Higgins and M. Ferguson (Table 1.3, Fig. 1.3) and the hierarchy of cargo terminals by Rodrigue J.-P. (Table 1.3, Fig. 1.5).

Yes, the warehouse can be of different sizes: from small warehouses with an area of several hundred square meters to large warehouse complexes, the area

of which can exceed 100,000 m^2. Accordingly, the following functions of the composition can be distinguished:

– leveling the intensity of material flows in accordance with consumer demand;

– transformation of the assortment within the material flow in accordance with the customer's orders;

– ensuring the concentration and storage of stocks;

– smoothing the asynchrony of the production process;

– unitization of the batch of shipment and provision of services.

Thus, the modern warehouse offers the client various solutions in the field of warehousing, cargo handling, marking, packaging and information service. The warehouse can provide trade and intermediary and distribution services, in this case it becomes a distribution center, the main function of which, in addition to storing goods, is the transformation of cargo flows.

In Europe, a distribution center that, in addition to warehousing services, also provides transport and forwarding services, as well as offers a wide range of related services, belongs to a cargo terminal. That is, the main function of the terminal is the transformation of parameters of cargo flows of various types of transport[42]. Initially, each type of transport was served by its own cargo terminal, later warehouses, office buildings, platforms for various cargo operations and other objects began to be included in their composition. The development of multi- and intermodal transportation and the emergence of logistics operators and providers (3PL services) contributed to the organization of intermodal terminals (public and private). An intermodal terminal is a transport hub, i.e. a node in which cargo flow is consolidated or distributed, and can provide the following services:

– operational logistics (3PL-level services): transportation and

[42]Zhong, G.; Fei, Y.; Yi, J.; Feng, D.; Feng, O. Capacity Evaluation Method of Ship Terminal Area Based on Network Maximum Flow. Sustainability 2022, 14, 10470. https://doi.org/10.3390/ su141710470

forwarding, loading and unloading services, warehousing and cargo processing, customs clearance and insurance, packing and repacking of cargo units;

– trade and intermediary and distribution services (resale services, banking services, agency (brokerage) operations, marketing and intermediary services, etc.);

– non-logistic services related to cargo distribution.

Thus, modern terminals grew out of the system of warehouses of various classes and became part of larger transport and logistics associations (logistics centers, cargo villages, places, etc.).

The terms "inland port" ("dry port"), "port-oriented logistics zones", "logistics park", "transshipment hub" and "cargo village" are united by the general concept of "logistics center", which is the only integrator of cargo activity terminal, logistics providers and other companies operating in a certain area.

The functionality of the logical center is wider than that of the intermodal terminal included in its structure. In the European Union, a general organizational structure of logistics centers was developed. The composition of logistics center participants depends on its size, location and purpose of operation. This structure is presented in Figure 1.7.

The activities of incoming business units, transport companies and non-logistics companies providing auxiliary services are based on the full interaction of participants, which leads to the emergence of a synergistic effect. Such localization helps coordinate the work of all market participants. The figure also shows that warehouse complexes and cargo terminals are part of the logistics center.

Thus, the main objective of the logistics center is to focus several companies on one territory to provide complex logistics, transport and support services. The cargo delivery process is carried out according to a new

progressive scheme, in which several counterparties interact through one integrating person – the logistics center.

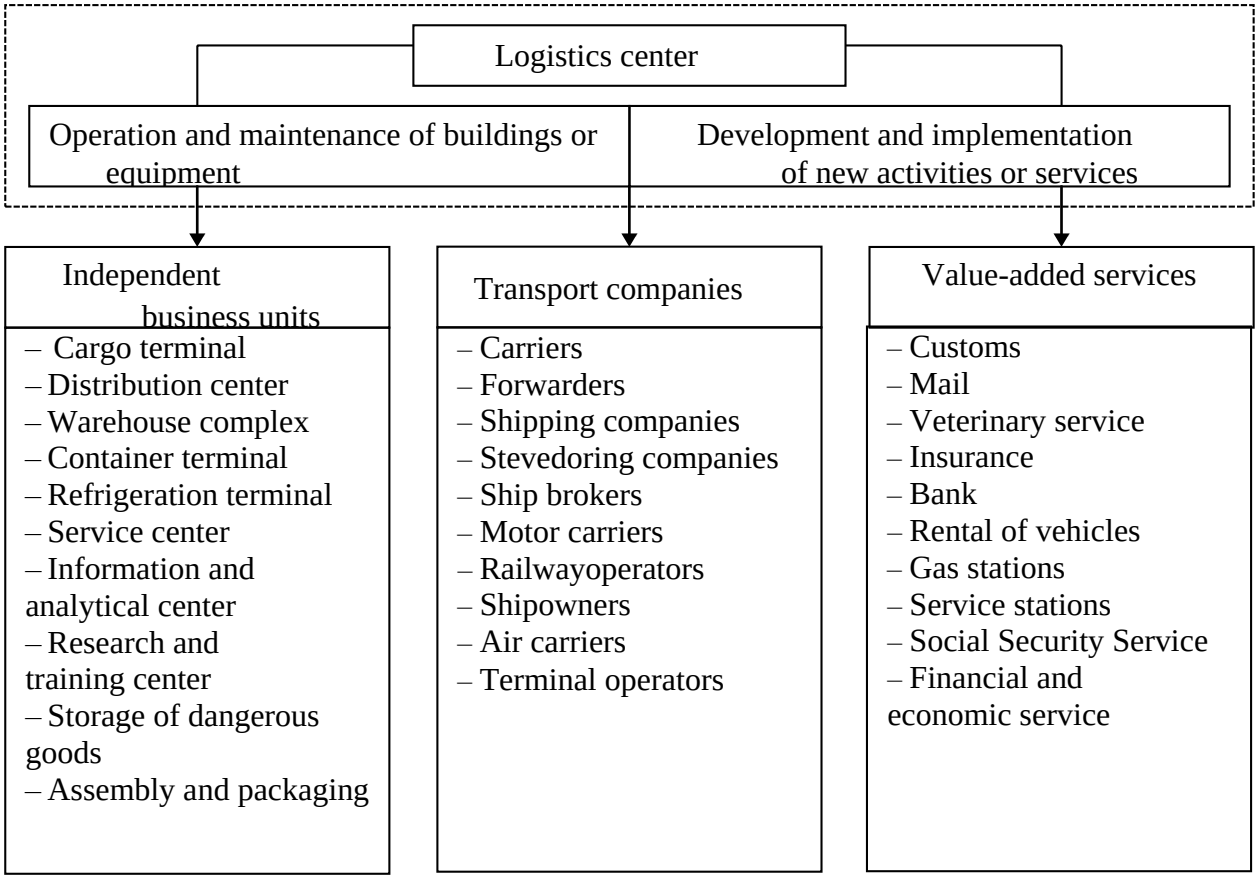

Fig. 1.7 – Typical structure of a logistics center

Source: Service Concept Report for Logistic Centers / NeLoC. - Aalborg, 2004. 55.

For effective functioning, all activities in the middle of the logistics center must be regulated by a special organization (focal company). This organization should ideally be a supply chain integrator, i.e. a 4PL provider. The focal company performs the following tasks: leasing the territory, attracting investors, designing and developing the logistics center, security of complexes, organization of operational activities, infrastructure support, etc.[43].

The focal company's main sources of income are sales/leasing of land plots for purpose-built construction (70-100% of income). There are other

[43]Zagurskyi O.M. Supply chain management: education. manual Bila Tserkva: "Bilotserkivdruk" LLC, 2018. 416.

sources of income, such as the collection of tax on the turnover of the operator, the collection of commission fees for containers and cargo trucks passing through the territory of the logistics center, the provision of information and analytical services and participation in the share capital of the container terminal operator[44].

Thus, the main functions of the logistics center itself are (some of them can be outsourced):

– creation, support and development of infrastructure within the allocated territory, facility security management;

– development of logistics solutions (coordination of operators' activities, construction of warehouse complexes and their delivery to operators, etc.);

– marketing and public relations (promoting the brand, attracting operators, developing the role of a logistics center in international trade).

The functional support of the activity of logistics centers closely corresponds to the complex of services provided by them. In addition to basic operational services, the logistics center also provides advanced services that appeared with the development of integrated logistics. The main service provided by logistics centers is provided by 3PL and 4PL providers. 4PL-level services include planning and optimization of supply chains and routes, integration of information systems, management of customer logistics processes, and others.

For the effective provision of operational logistics services, the logistics center carries out information and analytical and consulting activities (designing optimal solutions based on the integration and coordination of participants and counterparties, consulting clients) and value-added services.

[44] Zagurskyi O., Pokusa T.,Duczmal M.,Ohiienko M., Zagurska S.,Titova L., Rogovskii I.Ohiienko A.Supply chain logistics service system: methods and models of its optimization. Monograph. Opole: The Academy of Management and Administration in Opole, 2022; 192.

Freight villages (FV) in Europe and the USA are considered full synonyms of a logistics center, but they differ in the scope of their activities. There are also similar terms: "Integrated Logistics Center" (ILC), Goods Movement Center (GVZ) and others.

The cargo village is an integrated cluster of large-scale logistics and service activities. An intermodal terminal is located on its territory or nearby. Similar logistics centers create alliances of companies providing logistics services. In addition, they are located in the immediate vicinity of a large city, which provides an effective solution to urban problems.

Cargo villages provide a wide range of support services: 24-hour security, telecommunications, cafes and restaurants, kindergartens, education, offices and conference rooms, hotels, business services (banking, post office), public transport, etc.

A vivid example of a cargo village is AllianceTexas, which is the largest project implemented by the American company Hillwood, founded by R. Perot. The area of the mixed-use complex is about 7,285 hectares, it is located 50 minutes north of Dallas and 20 minutes south of Fort Worth, Texas. The main activities of AllianceTexas are carried out by the integrated logistics center "Alliance Global Logistics Hub", a corporate center and a residential microdistrict. The multimodal inland port Alliance Global Logistics Hub interacts with a cargo airport, an intermodal terminal, has access to two first-class railroads (Union Pacific (UP) and Burlington Northern Santa Fe (BNSF)), highways and a foreign trade zone (FTZ). More than 260 companies operate in AllianceTexas, including 3PL operators (BNSF Railway,

Another illustrative example of a cargo village is Europe's largest logistics platform Logistics Platform of Zaragoza (PLAZA) with an area of 1,312 hectares, located in Spain. It occupies a central position between six urban areas in southwestern Europe (Bordeaux, Toulouse, Bilbao, Madrid, Valencia and Barcelona). The territory of the logistics center is divided into

several sectors: airport, railways, industrial logistics, business park, service, commercial and social sectors. The logistics platform was designed to improve the functionality of distribution chains and increase the efficiency of logistics operators and transport companies.

Logistics centers serving international transportation have the highest functional level. Weymans and co-authors use the concept of "main port terminal" (XXL), Rimjen K. and Grundy D. – "logistics hub", ILSCM Institute – "logistics city", Sengpiel K. – "interregional logistics center" to denote similar clusters cluster", Fechner I. – "sea port" and "airport", Higgins K. and Ferguson M. - "main port terminal", Rodrigue J.-P. – "Gateway".

Rodrigue Zh.-P. Gateways contrast with hubs. According to the author, hubs have a transmodal functionality (carrying out activities in one transport mode), Gateways – intermodal (in several modes, for example, transportation from sea to land). The latter usually connect several transport corridors and are formed at the junction of various transport systems, therefore, they have a more stable position. Sometimes the Gateway can also be a hub, the author divides it into three types:

1) Land gateway – performs a simple transit function and is a mandatory crossing point, sometimes it also carries out production activities.

2) Maritime gateways – large seaports with high throughput, providing connections with railway stations and highways. In Europe, there is a tendency to create satellite terminals or inland ports in the area of seaports. This is due to port congestion or lack of space for logistics activities.

3) Air gateways –cargoan international-class airport connecting large metropolises with regional air lines and highways.

A sea port, concentrating cargo flows, forms adjacent industries around itself, and thereby turns into a port cluster, contributes to increasing the competitiveness of a transport hub. Van den Berg and Van Klink (1995)

documented the function and role in the development of ports fromstage of the first generation to the fourth generation [45]:

– first-generation ports (perform the functions of a stevedore terminal: transshipment and storage);

– second-generation ports (in addition to loading and unloading operations, they provide a wide range of industrial and commercial services);

– third-generation ports (they also provide logistics services: distribution, information support and forwarding services, services for processing all types of transport);

– fourth-generation ports (locate industrial enterprises, terminals and logistics centers on their territory, i.e. are port clusters)[46].

Table 1.5 – 10 largest seaports in the world in 2022

Port	Volume 2020 (Million TEU)	Volume 2019 (Million TEU)	Volume 2018 (Million TEU)	Volume 2017 (Million TEU)	Volume 2016 (Million TEU)	Website
1	Shanghai, China	43.5	43.30	42.01	40.23	37.13
2	Singapore	36.6	37.20	36.6	33.67	30.9
3	Ningbo-Zhoushan, China	28.72	27.49	26.35	24.61	21.6
4	Shenzhen, China	26.55	25.77	27.74	25.21	23.97
5	Guangzhou Harbor, China	23.19	23.23	21.87	20.37	18.85
6	Busan, South Korea	21.59	21.99	21.66	20.49	19.85
7	Qingdao, China	22.00	21.01	18.26	18.3	18.01
8	Hong Kong, SAR, China	17.95	18.30	19.6	20.76	19.81
9	Tianjin, China	18.35	17.30	16	15.07	14.49
10	Rotterdam, The Netherlands	14.35	14.82	14.51	13.73	12.38

Source: The Top 50 Container Ports. https://www.worldshipping.org/top-50-ports

[45] van den Berg, L. and van Klink, HA From City-Port to Port-Network, Tinbergen Institute, Discussion Paper no. TI95. 48. 1995.

[46]Montwiłł A. The Role of Seaports as Logistics Centers in the Modeling of the Sustainable System for Distribution of Goods in Urban Areas, Procedia - Social and Behavioral Sciences, 2014, Volume 151, 257-265.

NShanghai in China is the world's largest port in terms of tonnage (Table 1.6).

Table 1.6 – Shanghai port working areas and their specialization

Name, size	Specialization
Yangshangang Port (container terminal), 1372 ha	Loading and unloading and warehouse works, towing vessels, dock maintenance, etc
Pudong International Container Terminal, 50 ha	Processing of various types of cargo (has refrigeration units and warehouses for storing dangerous goods)
Zhanghuaban Port Terminal, more than 78 hectares, Jungonglu Port Terminal, 25.1 hectares, Baoshan Port Terminal, 27 hectares	Loading and unloading and warehouse work
Lun U Port Terminal, 74 ha	Processing, storage of export-import cargo, dismantling of containers and other services
Luojin Bulk Terminal, 50 ha	Processing of bulk cargoes, mainly Zaliznyaka
Zhuzemen Coal Terminal, 57.35 ha	Transshipment of hard coal
Haitun Automobile Terminal, 26.5 ha	Reception and shipment of cars
Minshen port terminal, 17.4 ha	Transshipment, loading/unloading of goods, storage of imported grain and oil cargoes, fodder crops, rice
Guntsin port terminal	Minerals, industrial raw materials, transportation of collective cargo
Gaoyanlu Port Terminal	Transshipment of bulk imports export cargoes
Xinhua Port Terminal	Transshipment of loose chemical fertilizers, steel
Duncan port terminal	Transshipment of cargo, salt

Source: Official websites of companies

It is followed by Singapore, Ningbo (China), Shenzhen (China), Guangzhou (China), Busan (South Korea), Qingdao (China), Hong Kong (China), Tianjin (China) and Rotterdam (Netherlands). And every year, European and US ports give way to Asian ones.

Table 1.7 – The largest airports in the world by volume of cargo transportation

Place			airport	Volume of transportation in 2022, metric tons	% change compared to 2021	% change compared to 2020
2022	**2021**	**2020**				
1	2	1	HONG KONG SAR, HK (HKG)	5,025,495	12.5	4.5
2	1	2	MEMPHIS, Tennessee, USA (MEM)	4,480,465	-2.9	3.6
3	3	3	SHANGHAI, China (PVG)	3,982,616	8.0	9.6
4	4	6	ANCHORAGE, AK, USA (ANC**)	3,555,160	12.6	29.5
5	6	5	INCHEON, KR (ICN)	3,329,292	18.0	20.4
6	5	4	LOUISVILLE, KY, USA (SDF)	3,052,269	4.6	9.4
7	7	9	TAIPEI, TV (TPE)	2,812,065	20.0	28.9
8	8	13	LOS ANGELES, CA, USA (LAX)	2,691,830	20.7	28.7
9	11	10	TOKYO, Japan (SRV)	2,644,074	31.1	25.7
10	9	8	DOHA, QA (DOH)	2,620,095	20.5	18.2

Source: The top 10 busiest airports in the world revealed.

https://aci.aero/2022/04/11/the-top-10-busiest-airports-in-the-world-revealed

Later, this classification was expanded. S. Pettit and A. Beresford (2009)[47], P. Verhoeven (2010)[48], Flynn M.P. Lee and T. Notteboom (2011)[49] for the customer-oriented port, oriented to society, the "fifth generation port" (5GP) was singled out, and A. Kalishevskyi suggested separating it into a separate category and adding it to the classification"sixth generation port" (6GP). In his opinioncriteria for 6GP include: port capacity to handle 50,000 TEU[50] vessels with a depth of 20 meters; semi- or full automation of the container terminal and powerful transport connections with the hinterland, minimizing negative external effects[51].

Airports with the development of international trade also began to form a port cluster, combining postal and cargo complexes, business centers, cargo terminals, logistics centers and other organizations on their territory. Thus, the concept and functionality of the airport, which began to exist as a logistics hub, subsequently changed.

Air cargo volumes at the top 10 airports, which together account for about 25% (34.2 million metric tons) of global volumes in 2022, grew 12.4% in 2022 compared to 2021 (or 15.0% forcompared to the results of 2020). The increase can be attributed to increased demand for consumer goods and pharmaceuticals online.

Hong Kong International Airport (HKG, 5.0 million metric tons, +12.5%) regained the top spot, while Memphis International Airport (MEM,

[47]Pettit SJ and Beresford AKC Port Development: From Gateways to Logistics Hubs, Maritime Policy & Management, 2009, 36(3), 253-67.

[48]Verhoeven P. A Review of Port Authority Functions: Towards a Renaissance? Maritime Policy & Management, 2010, 37(3), 247-70.

[49]Flynn M., Lee PTW and Notteboom T. The Next Step on the Port Generations Ladder: Customer-Centric and Community Ports. In Notteboom, T. (Ed.) Current Issues in Shipping, Ports and Logistics, University Press Antwerp, Brussels, 2011. 497-510.

[50]TEU (from Englishtwenty-foot equivalent unit) is a conventional unit for measuring the capacity of cargo vehicles. It is used when describing the capacity and throughput of container ships and container terminals. Based on the volume of a 20-foot (6.1 meter) intermodal ISO container - a standard-sized metal box that can be transported by various modes of transport: road, rail and sea.

[51] Kaliszewski A. Fifth and sixth generation ports (5Gp, 6Gp) – Evolution of economic and social roles of ports, translated from Polish: “Porty piątej oraz szóstej generacji (5GP, 6GP) – Ewolucja ekonomicznej i społečnoj roli portów”. Studia I Materiały Instytutu Tra. 2017, 32.

4.5 million metric tons, -2.9%) returned to second place, after himfollowed by Shanghai Pudong International Airport (GDP, 4.0 million metric tons, +8.0%) in third place. As estimated by ACI World[52], more than 69 million aircraft flights were made in 2022, an increase of more than 12% compared to 2021.

The 10 largest airports account for about 8% of global traffic (5.3 million flights), and the increase is 33.9%. year-on-year, which is still a 16.1% drop from 2020. Atlanta Hartsfield-Jackson International Airport (ATL, 708,000 flights, +29.1%) leads, followed by Chicago O'Hare International Airport (ORD, 684,000, +27.1%) and Dallas/Ft. -Werth (DFW, 652 thousand, +26.7%). The top 10 airports for aircraft traffic are all in the United States.

Table 1.8 – Logistics companies operating on the territory of HKIA

Name, size	Specialization
Asian Cargo Terminal (AAT), 8 ha	Loading and unloading and warehousing operations (has refrigeration and freezing units and warehouses for storing dangerous goods), offers universal cargo service
DHL logistics center, 3.5 ha	Loading and unloading and warehouse work (the first large-scale automated hub in the Asia-Pacific region)
Hong Kong Cargo Terminal (HACTL), 17 ha	Loading and unloading and warehouse work (works with perishable and dangerous goods, valuable goods, pets and others)
Cathay Cargo Terminal Pacific, 11 ha	Uses modern material processing systems
Air mail center, 2 ha	Equipped with a modern mail sorting system
Sea cargo terminal (MCT)	Organization of multimodal transportation, has the possibility of mooring ships up to 400 m
Transport and expedition center (AFFC), 6 ha	Warehousing, consolidation, distribution and other logistics services
Trade port logistics center, 1.4 ha	Performs a wide range of specialized logistics services such as inventory management, order processing and delay assembly

Source: HKIA official websitehttp://www.hongkongairport.com

[52] The top 10 busiest airports in the world revealed. https://aci.aero/2022/04/11/the-top-10-busiest-airports-in-the-world-revealed/

Hong Kong International Airport (HKIA) is a logistics hub that combines air, land and water transport.

In order to develop infrastructure, create an "effect of scale" and increase the level of logistics services, the airport involves well-known logistics operators in joint business (Table 1.8).

Based on the above, it can be concluded that Gateways are the main interface between sea/air and domestic logistics, as the main logistic hubs of international supply chains. Such largest logistics clusters require large amounts of investment in infrastructure, occupy huge territories for the implementation of terminal operations and act as the main gateway in international supply chains.

CHAPTER 2
APPROACHES TO FORMATION AND FUNCTIONING LOGISTICS CENTERS

2.1 Choosing the location of the logistics centers

Allocating a certain territory for transportation, logistics and distribution of goods involves spatial planning and infrastructure rationalization. The goal of optimizing the territory and effective routing of the logistics system is to build an infrastructure based on the operator's needs, sustainable use of resources and environmental protection (moving the corresponding intensive transport from residential areas to logistics center zones).

Solving the routing problem of a logistics system is essentially a trade-off between benefits and costs. In order for it to function optimally, or close to it, it is necessary to find a balance between the benefits and costs of business and consumers of supply chains.

Accordingly, the decisions regarding the geographical location of the logistics center itself and its structural elements are extremely important, because their impact on the indicators of its activity is long-term. And if a mistake is made during the construction of production or logistics facilities, and this or that facility is placed in an unfortunate place, then to correct the situation (moving to a new, better place), a large amount of material, financial, labor and other resources will be needed, which will lead to to the loss of customers, time, freezing of capital and, accordingly, a decrease in the competitiveness of enterprises, industries, countries, etc.

Many authors believe that the best place for a logistics center is where you can reduce all costs – for transport, for land/rent, etc.[1]. Summarizing their

[1]Agrebi, M., Abed, M., & Omri, MN Urban distribution centers` Location Selections`s Problem: A survey. 2015 4th IEEE International Conference on Advance Logistics and Transport (ICALT), 246-251.; Onden I., Acar AZ, & Eldemir F. Evaluation of the logistics center locations using multi-criteria spatial approach. Transport, 2016, 33(2), 322-334.https://doi.org/10.3846/16484142.2016.1186113.;Singh RK, Chaudhary N., &

opinions, N. Moroz and Yurgelane-Kaldava[2] offer to choose the best location of the logistics center, consider the following factors:

- location near the city;
- ecological problems;
- financial aspect;
- possible delays in terms of delivery;
- location near important transport hubs;
- the term of delivery to the client;
- location near waste processing plants;
- state issues.

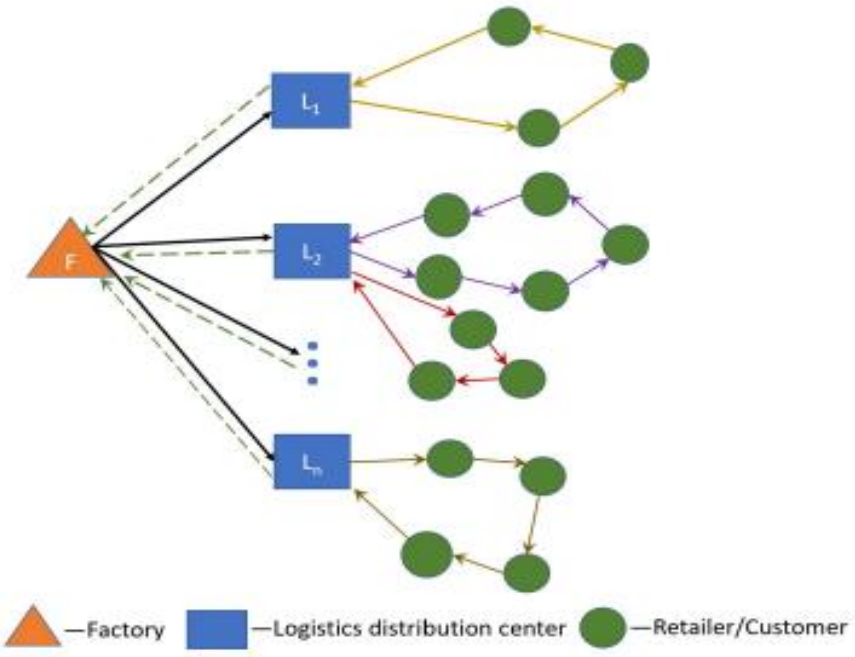

Fig. 2.1 – Schematic diagram of the secondary distribution network

Source: Liu, L.; Lee, LS; Seow, H.-V.; Chen, CY Logistics Center Location-Inventory-Routing Problem Optimization: A Systematic Review Using PRISMA Method. Sustainability 2022, 14, 15853. https://doi.org/10.3390/ su142315853

Saxena N. Selection of warehouse location for a global supply chain: A case study. IIMB Management Review, 2018, 30(4), 343-356.https://doi.org/10.1016/j.iimb.2018.08.009.; Tomic V., Marinkovic D., & Markovic D. The selection of Logistic Centers Location Using MultiCriteria Comparison: Case Study of the Balkan Peninsula. Acta Polytechnica Hungarica, 2018, 11(10), 97-113.

[2]Moroza, Nadina and Jurgelane-Kaldava, Inguna. "Development and Location of Logistics Centers: A Systematic Review of Literature" Economics and Business, 2019, vol.33, no.1, 264-272.

However, the successful geographical placement of infrastructure elements does not yet guarantee business success, but is a necessary condition for it. The problem of the location of logistics centers can and should be considered as a two-level, hierarchical problem. At the first, upper level, a macro-analysis of wider territories – macro-regions should be conducted to determine their overall potential and suitability for placing a logistics center on their territory. At the second, micro level, a microscopic analysis is carried out, which will determine the most appropriate, specific locations of the logistics center in the region previously selected at the first level.

The issue of evaluating and choosing the most suitable geographic area for a logistics center is considered a complex decision-making task, which is well formulated with the help of analytical and mathematical models.And since the mathematical modeling of multiple choice often turns out to be a complex structural problem that does not always lead to an optimal solution, various metaheuristic approaches have appeared to solve these complex models, offering an integrated methodology that effectively searches for the optimal result in relation to the problem of choosing the location of the logistics center.

A comprehensive review of the literature[3] shows that no specific study so far offers any comprehensive approach to logistics center evaluation.

[3]Morteza Yazdani, Prasenjit Chatterjee, Dragan Pamucar, Shankar Chakraborty, Development of an integrated decision making model for location selection of logistics centers in the Spanish autonomous communities, Expert Systems with Applications, Volume 148, 2020, 113208.; Dyczkowska, JA; Reshetnikova, O. Logistics Centers in Ukraine: Analysis of the Logistics Center in Lviv. Energies 2022, 15, 7975.https://doi.org/10.3390/en15217975.; Witkowski K., Mrówczyńska M., Bazan-Krzywoszańska A., Skiba M., Methods for determining potential sites for the location of logistics centers on the basis of multicriteria analysis. LogForum, 2018, 14 (3), 279-292,http://dx.doi.org/10.17270/J.LOG.2018.282.; Alexander TC Onstein, Lóránt A. Tavasszy & Dick A. van Damme Factors determining distribution structure decisions in logistics: a literature review and research agenda, Transport Reviews, 2019, 39:2, 243-260, DOI: 10.1080/01441647.2018.1459929. ;Huang, Y.; Wang, X.; Chen, H. Location Selection for Regional Logistics Center Based on Particle Swarm Optimization. Sustainability 2022, 14, 16409.https://doi.org/10.3390/su142416409.;Rodrigue JP The distribution network of Amazon and the footprint of freight digitalization. J Transp Geogr. 2020 Oct;88:102825. doi: 10.1016/j.jtrangeo.2020.102825. Epub 2020 Aug 12. PMID: 32834678; PMCID: PMC7419283.; Emre Çakmak, İsmail Önden, A. Zafer Acar, Fahrettin Eldemir, Analyzing the location of city logistics centers in Istanbul by integrating Geographic Information Systems with Binary Particle Swarm Optimization algorithm, Case Studies on Transport Policy, 2021, Volume 9, Issue 1, 59 -67.

INthe choice of the location of the geographical location of infrastructure elements is a hierarchical multi-area decision-making process that takes into account: the overall business strategy of the supply chain; the level of culture and costs in it; requirements and needs of consumers and suppliers; local conditions; availability of available places for accommodation (Figure 2.2).

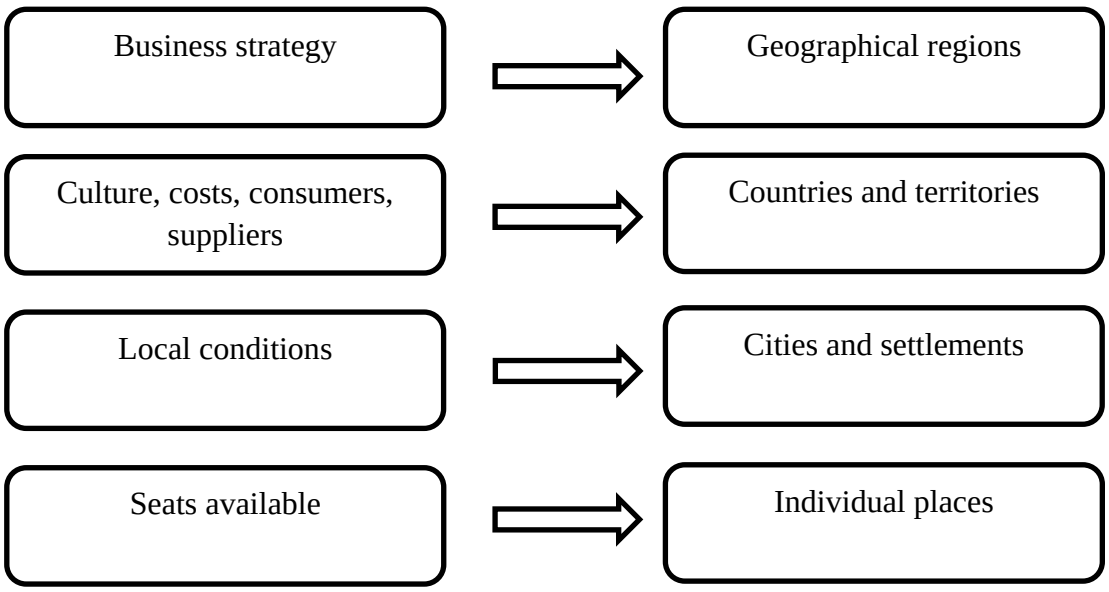

Fig. 2.2 – Hierarchy of decisions made when selecting the location of supply chain elements.

Source: developed by the authors

Therefore, in our opinion, the general principle of choosing the location of elements of the logistics center should include taking into account the following ten factors:

1. Locations of product consumers. Proximity to customers is primarily important for industrial enterprises if the cost of their goods is high or the shelf life is not long, as well as for enterprises in the service sector.

2. Location of suppliers of raw materials. Most manufacturers benefit from locating near suppliers of raw materials and materials, especially if they are heavy, bulky or perishable.

3. Product characteristics.There are three product metrics that influence distribution infrastructure placement decisions: product values, packaging density, and shelf life. High-value products have high storage costs, prompting companies to choose centralized planning. The packing density (number of products per m^3) affects the cost of processing and storing the product. The shelf life prompts companies to choose a non-storage or cross-docking distribution channel scheme.

4. *The amount of logistics costs*. Three main factors of logistics costs can be distinguished: transport costs, inventory costs and storage costs. Placing the logistics center will be appropriate in a place where the total amount of these costs will be smaller.

5. *Level of service*. The five important factors of service level are: supplier's order fulfillment time, product delivery time, reliability of supply, promptness of supply and possibility of return.

6. Culture. It is much easier to develop business in regions with similar institutional conditions (laws, traditions, culture, language, religion, etc.. First of all, this is reflected in the differences between Western and Eastern cultures, Christian, Islamic or Buddhist religions, market and centralized type of economies, etc.

7. *Attitude of authorities*. Central or local authorities can seriously influence the attractiveness of an area by granting preferencesfor certain industries (for example, financial or high-tech) or, on the contrary, hinder through the introduction of additional taxes and fees for the location of environmentally dangerous or harmful types of production (for example, nuclear or chemical). Accordingly, at the stage of supply chain planning, it makes sense to familiarize yourself with the specifics of local legislation and regional investment policy. In addition, it is necessary to take into account local taxes, social and pension payments, control mechanisms of company ownership (for example, through the control of a local partner).

8. *The mentality of the local public*. Populations in different countries have different attitudes to methods of ensuring high labor productivity (for example, high turnover and absenteeism may be common). Also, it is important to determine whether the company will adapt its operations and work organization principles so that they are understandable to local workers, or will implement its own traditions, norms and rules of work performance.

9. *The size and configuration of the site*. The dimensions of the plot should be such that, in addition to the main object, it is possible to place an office, sanitary facilities, security posts and other auxiliary premises. In addition, it is necessary to take into account the space for the operation of vehicles, the absence of which can lead to traffic jams, loss of time and customers.

10. *Transport accessibility of the area*. Here, the transport accessibility of the territory should be taken into account (it is provided with various types of transport, including public transport, the availability of which depends on the availability of facilities both for our own staff and for customers). For example, for the location of a distribution center, preference is given to areas located near major highways. The center of gravity coordinates (X_0; Y_0) are calculated based on the location coordinates (X_i; Y_i) of each supplier and each customer (i), as well as the amount of expected demand from customers and the amount of expected supply from suppliers W_1:

$$X_0 = \frac{\sum X_i \times W_i}{\sum W_i} \tag{2.1}$$

$$Y_0 = \frac{\sum Y_i \times W_i}{\sum W_i}. \tag{2.2}$$

However, under any circumstances or factors, the main principle when choosing the location of supply chain infrastructure elements is based on the method of finding the optimal solution, which is based on finding a compromise between the costs of delivering materials and the costs of distributing cargo flows.

In addition, when making a decision on the construction of a logistics center, it is necessary to answer the following key questions:

– Who will be the residents and tenants of the logistics center and how will they load the sea, railway terminal, airport, customs?

– How to optimally place residents of the logistics center?

– Which enterprises around are united in production chains with residents of the logistics center?

A resident of a logistics center is a business entity that carries out production or service activities from its territory (in accordance with a land or real estate lease agreement, a land or real estate sale agreement). In order to become a resident of the logistics center, it is necessary to submit an application and go through certain selection procedures, after which it is entered in a special register.

When planning a logistics center, it is necessary to analyze alternative options for its location on the basis of socio-economic, political, geographical and transport infrastructure condition criteria.

The location selection criteria allow you to assess the attractiveness of the logistics zone in which the creation of this type of infrastructure is planned (Table 2.1).

Table 2.1 - Criteria for choosing the location of the logistics center

Group	Criteria	Unit
Economical	Gross regional product (GRP) in basic prices of the respective years	UAH
	Index of the physical volume of the gross regional product	% compared to the previous year in comparable prices
	Index of industrial production	% compared to the previous year in comparable prices
	The volume of shipped goods of own production, performed works and services by own forces	UAH
	Production index (manufacturing production)	% compared to the previous year in comparable prices

Continuation of the Table 2.1

Group	Criteria	Unit
Economical	The volume of shipped goods of own production, performed works and services by own forces (production and distribution of electricity, gas, water)	UAH
	Production index (production and distribution of electricity, gas and water)	% compared to the previous year in comparable prices
	The volume of works performed by the type of economic activity "Construction" in the prices of the corresponding years	UAH
	Production index by type of activity "Construction"	% compared to the previous year in comparable prices
	Consumer price index for the period since the beginning of the year	to the corresponding period of the previous year, %
	Retail trade turnover in prices of the corresponding years	UAH
	Retail turnover	% compared to the previous year in comparable prices
	Foreign trade turnover, including: export and import of goods	dollars USA
	Number of small and medium-sized enterprises, including micro-enterprises (at the end of the year)	units
	Investments in fixed capital at the prices of the respective years	UAH
	Index of the physical volume of investments in fixed capital	% compared to the previous year in comparable prices
	Revenues/expenditures and deficit/surplus of the consolidated budget of the region	UAH
Social	The number of economically active population	person
	Average annual number of people employed in the	person
	Average monthly nominal accrued wages in general for the region	UAH
	Average monthly nominal accrued wages in general for the region	% to the previous year
	The level of registered unemployment (at the end	%
	The average registered number of employees of organizations (without external part-time	person
	Age structure of the population	in % by age groups
	Education level index	weight

End of the Table 2.1

Group	Criteria	Unit
Political and legal	The level of political stability	mark
	Efficiency of customs authorities	mark
	Territorial integrity (the number of territories that do not recognize sovereignty or are occupied by	piece
	The completeness of the sovereignty of state power (number of border disputes, military conflicts, political separatism)	piece
Geographical and environmental	Population (annual average)	person
	Population density	people/1km^2
	The area of free territory for construction	Ha
	The share of free territory for development from the total	%
	The state of the climate	mark
State of transport infrastructure	Density of paved public roads	1 km/1000 km^2
	Density of public railway tracks	1 km/10,000 km^2
	Distance to transport corridors	km
	Location relative to airport / seaport / inland waterways	km
	Distance to industrial parks and manufacturers	km
	Condition of highways and railways, pipelines, quality of superstructure, telecommunications infrastructure	mark
	Commercial transportation of goods by types of	tons
	Commercial cargo circulation by types of	t-km
	Structure of export of transport services	%

Source: compiled by the authors

Social criteria will allow to determine the personnel potential in the studied area, since the lack of qualified personnel can cause failures in the development of the logistics center.

Political and legal criteria significantly affect the design of the logistics center, allow you to determine what conditions and support can be created for the implementation of the project and conducting business.

Geographical and ecological criteria that assess the numerical composition of the population, density and the state of ecology of the planned territory also play a significant role in planning.

The criteria of the state of the transport infrastructure make it possible to assess the development of transport services in the studied territory, the possibility of commercial transportation by one or another means of transport.

It is worth noting that the logistics center should be located in such a way that it can provide logistics services to the developed industries of this location and have an infrastructure that corresponds to its functional content. For example, having infrastructure for transshipment of containers, bulk cargo, bulk cargo terminal, grain elevator or infrastructure for tank containers with liquids, etc.

Making a decision about choosing the optimal location of a logistics center is a very difficult economic and mathematical task, because decision-makers have to rationalize the combination of quantitative and qualitative factors, the mass of factors and the trade-offs between them.

Commonly accepted models that allow you to determine the location of the warehouse in the logistics chain, such as the "center of gravity" method, mathematical programming according to the criterion of minimum logistics costs, the linear programming method, Von Thunen's model[4], Weber[5], Greenhat[6] and others, very difficult to apply when designing a logistics center. This is due to the fact that this task is multifactorial, and most of the criteria affecting the choice of location cannot be formalized.

Examples of multi-criteria decision-making methods are the outer sum model (WSM)[7], Analytic Hierarchy Process (AHP)[8], ELECTRE[9] and hybrid

[4]von Thünen, JH Der Isolierte Staat in Beziehung auf Landwirtschaft und Nationalökonomie. Hamburg: Perthes. English translation by Wartenberg, CM (1966) von Thünen's Isolated State. Oxford: Pergamon Press.

[5]Weber, M. (). The theory of social and economic organization (trans. T. Parsons). 1947, New York, NY: Oxford University Press.

[6]Greenhut ML Size of Markets Versus Transport Costs in Industrial Location Surveys and Theory. The Journal of Industrial Economics. Vol. 8, No. 2, 1960, 172-184.

[7]Tscheikner-Gratl F., Egger P., Rauch W., Kleidorfer M. Comparison of Multi-Criteria Decision Support Methods for Integrated Rehabilitation Prioritization. Water 2017, 9, 68. https://doi.org/10.3390/w9020068

[8]Longaray André Andrade, Gois João de Deus Rodrigues, Munhoz Paulo Roberto da Silva Proposal for using AHP Method to Evaluate the Quality of Services Provided by Outsourced Companies, Procedia Computer Science, Volume 55, 2015, 715-724.

[9]Triantaphyllou E. Multi-Criteria Decision Making Methods: A Comparative Study. Kluwer Academic Publishers, Dordrecht. 2000. http://dx.doi.org/10.1007/978-1-4757-3157-6

methods such as AHP-TOPSIS-2N[10], BWM-TOPSIS[11] and building scenarios-MCDA[12].They can be used to select an alternative, rank an alternative in order of preference, rank an alternative, or describe the performance of alternatives[13].

A relatively new MCDM method is the best-worst (BWM) method, which calculates decision factor weights by pairwise comparison of the best (i.e., most important) and worst (i.e., least important) factors[14] (Rezaei 2015).

However, the best method that allows you to make the right decision, in our opinion, is the Analytical Hierarchy (HAI) method[15]. MAI is a systematic procedure of hierarchical presentation of elements that determine the essence of any problem. There are several types of hierarchies:

- dominant - similar to an upside-down tree;
- holarchies - with an inverse relationship;
- modular - from simple to complex.

The MAI method consists in decomposing (decomposing) the problem into increasingly simple component parts and further processing the sequence of statements of the decision-maker using pairwise comparisons. It includes procedures for synthesizing multiple statements, prioritizing criteria, and finding alternative solutions.

It is important that the values obtained in this way are estimates in the ratio scale, but correspond to the so-called "hard" estimates. That is, the main

[10]De Souza LP, Gomes CFS and De Barros AP Implementation of new hybrid AHP–TOPSIS-2N method in sorting and prioritizing of an IT CAPEX project portfolio. International Journal of Information Technology & Decision Making, 2018, 17(04), 977-1005.

[11]Lahri V., Shaw K., Ishizaka A. Sustainable supply chain network design problem: Using the integrated BWM, TOPSIS, possibilistic programming, and ε-constrained methods, Expert Systems with Applications, Volume 168, 2021, 114373.

[12]Cinelli M., Kadziński M., Gonzalez M., Roman Słowiński, How to support the application of multiple criteria decision analysis? Let us start with a comprehensive taxonomy, Omega, Volume 96, 2020, 102261.

[13]Roy B. Multicriteria Methodology Goes Decision Aiding. Kluwer Academic Publishers, Berlin. 1996. URL: http://dx.doi.org/10.1007/978-1-4757-2500-1

[14]Rezaei J. Best-worst multi-criteria decision-making method, Omega, Volume 53, 2015, 49-57.

[15]Tramarico CL, Mizuno D., Salomon VAP, Marins FAS Analytic Hierarchy Process and Supply Chain Management: A Bibliometric Study, Procedia Computer Science, Volume 55, 2015, 441-450.; Pishchulov G., Trautrims A., Chesney T., Gold S., Schwab L. The Voting Analytic Hierarchy Process revisited: A revised method with application to sustainable supplier selection, International Journal of Production Economics, Volume 211, 2019, 166-179.; Madzík P., Falát L. State-of-the-art on analytic hierarchy processes in the last 40 years: Literature review based on Latent Dirichlet Allocation topic modeling. PLoS One. 2022. May 27;17(5): e0268777. doi: 10.1371/journal.pone.0268777. PMID: 35622850; PMCID: PMC914026.

principle of MAI consists in structuring problems in the form of a hierarchy, which is built from the top (goals, T), through intermediate levels (criteria, K), to the lowest level (alternatives, A).

The general view of the hierarchical structure of the logistics center location selection model is presented in Figure 2.3.

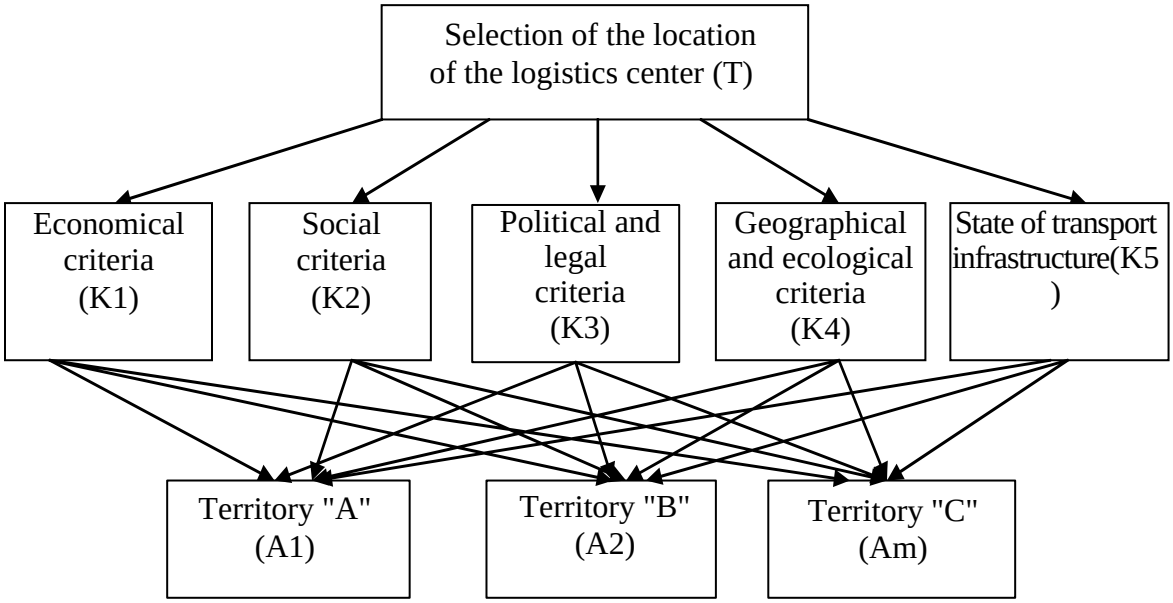

Fig. 2.3 – Hierarchical structure of the logistics center location selection model

Source: compiled by the authors based on Saaty RW The analytic hierarchy process-what it is and how it is used, Mathematical Modelling, 1987, Volume 9, Issues 3-5, 61-176.

The application of this method begins with the formulation of the goal (level 1 of the hierarchy). For example, T - "choice of the optimal location of the logistics center, which increases the efficiency of domestic and international transportation in the Kyiv region."

To make a decision on choosing an alternative, criteria / sub-goals (level 2) are formulated, denoted by K1, K2, ... Kn, and the most important alternative solutions (level 3) to achieve this goal (A1, A2, ... Am).

Stages of the analytical hierarchy method:

1. Evaluation of pairwise comparisons of criteria.

Experts need to prioritize the criteria from the point of view of their significance in relation to the location of the logistics center. Quantification of priorities varies on a scale of intensity/weight (h) from 0 to 9 (for example, 1 – equal importance, 3 – weak preference of one over the other, 5 – significant preference, 7 – significant preference, 9 – unconditional preference, 2, 4 6, 8 – intermediate values).

The result of the assessment of the importance of the criteria is the matrix of pairwise comparisons (V), which is presented in the Table 2.2.

Table 2.2 – General view of the matrix of pairwise comparisons for calculating the importance of criteria

	Criterion 1	**Criterion 2**	**…**	**Criterion j**	**…**	**Criterion n**
Criterion 1	1	v_{12}	…	v_{1j}	…	v_{1n}
Criterion 2	v_{21}	1	…	v_{2j}	…	v_{2n}
…	…	…	…	…	…	…
Criterion i	v_{i1}	v_{i2}	…	1	…	v_{in}
…	…	…	…	…	…	…
Criterion n	v_{n1}	v_{n2}	…	$v_{n.j}$	…	1

The matrix of pairwise comparisons of size n×n is built according to the following rules:

– if the element vi and vj are of equal importance, the number 1 is entered in the corresponding column;

– if the element vi is better than the element vj, the value h is entered, if the opposite is the case, then 1/h.

The total number of pairwise comparisons (q) is calculated using the following formula:

$$q = \frac{n(n-1)}{2} \tag{2.3}$$

2. Evaluation of pairwise comparisons of alternatives for each criterion.

Similarly, to item 1, by comparing the importance of alternatives for each criterion in pairs, a matrix of pairwise comparison of alternatives for each criterion is compiled, i.e. a matrix for criterion K1, a matrix for criterion K2 ... a matrix for criterion Kn.

3. Calculation of the importance of criteria.

An eigenvector is calculated for each i-th criterion*y*, whichis equal to the geometric mean root of the product of the row priorities of the pairwise comparison matrix:

$$y_i = \sqrt[n]{\prod_{j=1}^{n} v_{ij}} \ . \tag{2.4}$$

After that, its own normalized vector is calculated, which shows the contribution of each criterion to the achievement of the goal:

$$y_{in} = \frac{y_i}{\sum_{i=1}^{n} y_i} \ . \tag{2.5}$$

4. Assessment of the importance of alternatives for each criterion.

Similarly, to clause 3, for each i-th alternative, its own vector is determined

$$x_i = \sqrt[m]{\prod_{j=1}^{m} v_{ij}} \text{ and normalized vector } x_{im} = \frac{x_i}{\sum_{i=1}^{m} x_i}$$

*5. Calculation of priorities of alternatives (territories) for optimal placement of the logistics center*is carried out by summing the products of the coefficients of the importance of the criteria by the coefficients of the importance of the alternatives for each individual alternative:

$$f_i = \sum_{i=1}^{n} x_{ijn} \times y_{jn} \tag{2.6}$$

The maximum utility function is the best choice of the alternative (f_{opt}=max f_i).

Therefore, solving the problem of placing a logistics distribution center leads to a positive impact in terms of improving the turnover of stocks, accelerating the turnover of goods and reducing costs. The next stage of forming a logistics center after choosing its location is planning the territory and determining the optimal location of its business units.

2.2 Zoning of the logistics centers

Since the logistics center is a large-scale infrastructural object, first of all it is necessary to decide on the approach to the zoning of its territory. Usually, the areas of the logistics center are:

– public infrastructure (roads, waterways, wharves, railways, electricity supply);

– extension of private/public interaction (terminal, cargo handling complex, public warehouses);

– private superstructure (warehouses, private real estate, service complexes, small industrial facilities)[16].

Toschemes of the logistics center also include:

– customs infrastructure;

– postal/banking/insurance services;

– offices, intermodal terminals, warehouses[17].

In addition, depending on the size of the logistics center and its functions, it may include:

[16]He M., Shen J., Wu X., Luo J. Logistics Space: A Literature Review from the Sustainability Perspective. Sustainability 2018, 10, 2815. https://doi.org/10.3390/su10082815

[17]Logistics Centers Directions For Use. EUROPLATFORMS EEIG. url.https://unece.org/DAM/trans/main/eatl/docs/EN-REV-What_is_a_Freight_VillageFinalcorretto.pdf; Nathan Bounie, Corinne Blanquart. Logistics Centers and Agglomeration Economies: Logistics Clusters or Co-located Logistics Activities? The French Case. World Conference on Transport Research - WCTR 2016, Jul 2016, Shanghai, China. 16.; Dyczkowska, JA; Reshetnikova, O. Logistics Centers in Ukraine: Analysis of the Logistics Center in Lviv. Energies 2022, 15, 7975.https://doi.org/10.3390/en15217975.

– cargo consolidation/deconsolidation centers;

– premises for ensuring security;

– refrigerating warehouses;

– small industrial facilities;

– free trade zones;

– distribution/consolidation centers;

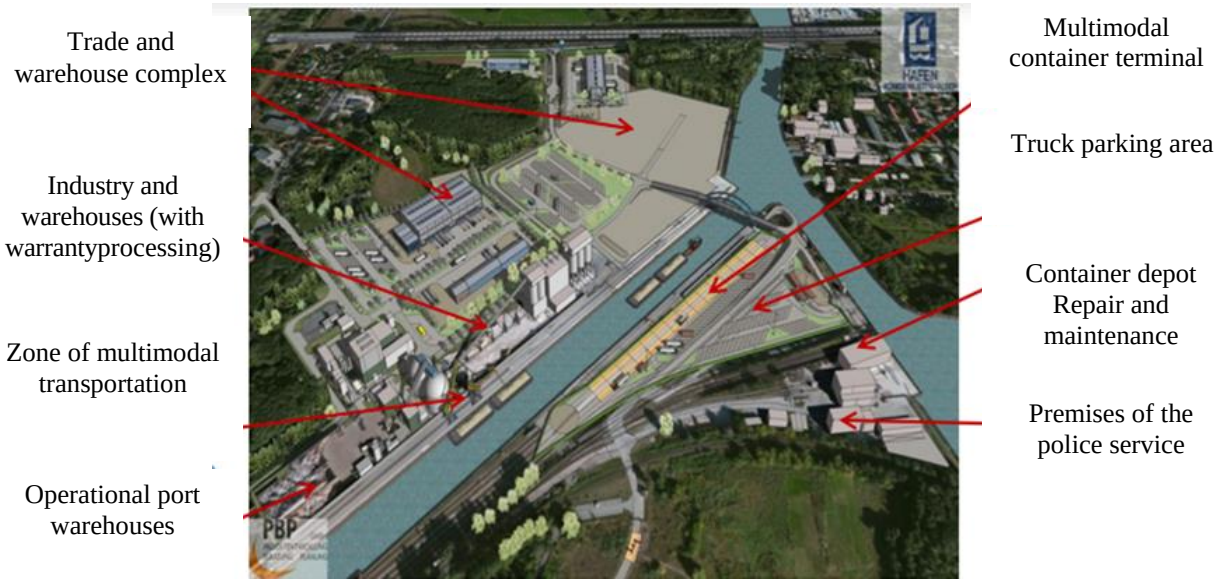

Fig. 2.4 – Zones of the logistics center of Berlin

Source: website of the logistics center

– open storage areas;

– transfer complexes;

– transport parking zones;

– service garages;

– vehicle repair points;

– end-to-end storage systems

– centers of transit combination;

– dangerous goods service centers;

– centers of consulting and research activity.

In view of the above, the division of the logistics territory will be the most appropriateof the center into zones according to the functions it plans to perform (Table 2.3).

Table 2.3 – Zoning of the territory of the logistics center

Logistics center area	Characteristic	Composition of business units
Zone of the multi-/intermodal terminal	The most important zone is where there is a change in modes of transport (usually rail and car), unloading and handling of cargo	Railway station, temporary storage warehouses, multi-/intermodal terminal
Industrial and logistics zone	Warehousing and cargo handling,consolidation, disintegration, commissioning, cross-docking, which provide added value to industrial activity	Industrial and production buildings, technology parks, educational centers, etc
Administrativezone	Occupies a central position accessible to all visitors	Business centers with offices, customs management and control center, security and operation service, insurance companies, transport and forwarding companies, wholesale trading companies and logistics providers, information and consulting companies
Zone of commercial services	Services provided to users and employees of the logistics center	Restaurant/cafe, catering, hotel, conference hall, supermarket, bank, dry cleaning nursery, post office, medicine and others
Service area for transportation	Designed for vehicle maintenance services	Parking, services and repair workshops, gas station

Source: compiled by the authors

Moreover, mutual interaction of the zones is a mandatory condition. Figure 2.5 shows the diagram of relations between the zones of the logistics center.

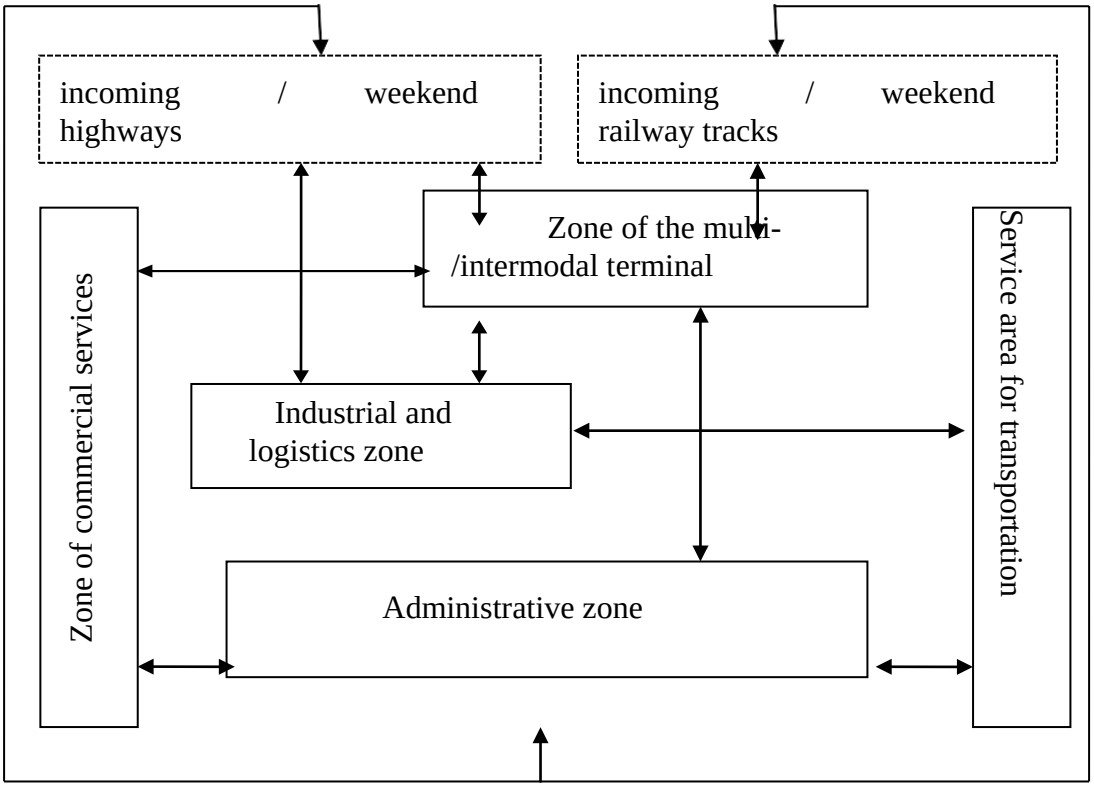

Fig. 2.5 – A typical scheme of interaction between the zones of the logistics center

Source: compiled by the authors

Among them, the industrial-logistics zone deserves special attention, since its optimal zoning contributes to the efficient functioning of the classic production chain: reception of raw materials/components – storage – processing/production – storage of finished products – shipment. In what key role do flavors play.

The quality of warehouse management can be evaluated by key performance indicators (Key Performance Indicators)[18]: the degree of utilization of storage spaces in the warehouse, which is defined as the ratio of the number of occupied spaces to the available spaces, expressed as the difference between

[18]Witold Torbacki, Kinga Kijewska, Identifying Key Performance Indicators to be used in Logistics 4.0 and Industry 4.0 for the needs of sustainable municipal logistics by means of the DEMATEL method, Transportation Research Procedia, Volume 39, 2019, 534-543

available gross and blocked spaces (the WMS system provides for the blocking of part of the warehouse spaces for pallets).

Warehouse capacity utilization is an indicator related to the filling of storage locations, each of which can be described by several parameters, for example, in the WMS system, the "storage location type" indicator, which determines the physical dimensions of the storage location, is essential for evaluating the optimal warehouse capacity.

This indicator is mostly determined at the warehouse design stage, taking into account the information received from suppliers and/or manufacturers, because they determine the necessary standards of the important indicator "type of storage units" on which packed/transported goods are placed. In the table 2.4 gives examples of connections between these two indicators.

Table 2.4 – Examples of the relationship between the type of storage location and the type of storage unit

Type of storage location (W - width; H - height)		**Type of storage unit**	
AL	All types (CrossDoc)		
N1	Normal W < 90 H 120	N01	Pallet W < 90 N 120
N2	Normal W < 90 H 75	N02	Pallet W < 90 N 75
N3	Normal W < 90 H 170	N03	Pallet W < 90 H 175
N4	Normal W < 90 H 245	N04	Pallet W < 90 N 245
W1	Wide W > 90 H 120	W01	Pallet W >90H 120
W2	Wide W > 90 H 75	W02	Pallet W >90 H 75
W3	Wide W > 90 H 170	W03	Pallet W >90H 175
W4	Wide W > 90 H 245	W04	Pallet W >90H 245
S.I	Small W 120 H 45	C01	Free tracks

Source: Optimalna pojemność magazine. URL: EURO LOGISTICS, Październik+listopad 2013, nr 5/2013 (78), 2013. 52-55.

The utilization of the storage capacity is maximum when the storage locations are occupied by 100 percent, so that N01 type pallets are stored in N1 type locations, N02 type pallets are stored in N2, etc. In practice, mostly, there is always a certain number of discrepancies between warehouse locations and

pallet types. If the number of inconsistencies is large enough, then the real capacity of the warehouse is reduced in units of weight and quantity of goods (kilograms, pieces, boxes, sheets, etc., which are used for quantitative control of warehouse activities). This ratio actually reflects the relationship between the performance of the supply chain and the value chain. Due to the fact that WMS systems at the entrance to the warehouse do not have the function of measuring the dimensions or the height of the cargo on the pallet, therefore the control over the filling of the warehouse is carried out statistically using the average value of the weight of the pallet or units of the product.

$$\textit{Warehouse capacity} = \textit{available spaces} \times \textit{average pallet weight}, \quad (2.7)$$

where the average pallet weight is calculated as an arithmetic mean or a weighted arithmetic mean.

However, in recent decades, significant changes have also been taking place in the production sector, caused by the demands of society for the Ghobakhloo rack[19] and cyclical[20] economy. These changes forced the industry to undergo a new transformation, for which Kagermann and co-authors[21] proposed the term Industry 4.0 in 2011, claiming that it describes the fourth industrial revolution. In Industry 4.0, centralized management systems give way to decentralized decision-making[22]. The goal of increasing productivity and, in some cases, increasing the complexity of the business environment and increasing the requirements for them, is to change the processes of logistics and warehousing[23] on the market, helping companies find a delicate compromise

[19]Ghobakhloo M. “Industry 4.0, digitization, and opportunities for sustainability”, Journal of Cleaner Production, 2020, Vol. 252, 119869.

[20]Theeraworawit, M.; Suriyankietkaew, S.; Hallinger, P. Sustainable Supply Chain Management in a Circular Economy: A Bibliometric Review. Sustainability 2022, 14, 9304. https://doi.org/10.3390/su14159304

[21]Kagermann, H., Lukas, W.-D. and Wahlster, W. Industrie 4.0: mit dem Internet der Dinge auf dem Weg zur 4. industriellen Revolution, VDI Nachrichten, 2011, Vol. 1, April, 2.

[22]Kraus K., Kraus N., Manzhura O. Digitalization of business processes of enterprises of the ecosystem of industry 4.0: Virtual-real aspect of economic growth reserves WSEAS Transactions on Business and Economics this link is disabled, 2021, 18, 569-580.

[23]Dev, NK, Shankar, R., Zacharia, ZG and Swami, S. Supply chain resilience for managing the ripple effect in industry 4.0 for green product diffusion, International Journal of Physical Distribution and Logistics Management, 2021, Vol. 51 No. 8, 897-930.

between improved service levels and reasonable operating costs. Logistics centers 4.0 not only digitize their processes, but also use continuous information flows, data analytics and intelligent machine control. They have IT systems that can track millions of items in real-time, as well as storage systems and automated loading and unloading equipment that performs multiple tasks automatically.

On the basis of built-in sensors integrated with other technologies, objects such as machines, products or orders autonomously monitor themselves and are fully vertically integrated into the company's information systems. Accordingly, companies need to adapt their logistics activities and development to new requirements in order to maintain the vital connection between manufacturers and customers that depends on logistics and warehouse operations[24].

The implementation of these technologies is also gaining momentum in logistics centers by line of activity. The sheer volume of movement that occurs in a logistics center makes automation vital to competitiveness. After all, the goal of logistics zones and distribution centers is to: anticipate changes in demand and meet new customer needs as quickly as possible.

It is also worth noting that large logistics centers in Europe and America, as a rule, developed after large industrial centers[25]. Therefore, when designing and zoning a logistics center, it is necessary to take into account the opportunities of the environment: the market of consumers, potential residents and raw material opportunities around the logistics center, which will focus the industry specialization of the industrial and logistics zone of the logistics center. A classic example is an automobile cluster, when an assembly shop with a logistics center is built, and then, as production is localized, factories for manufacturers of car components are built around it.

[24]Winkelhaus, S. and Grosse, EH Logistics 4.0: a systematic review towards a new logistics system, International Journal of Production Research, 2020, Vol. 58 No. 1, 18-43.

[25]Alexander TC Onstein, Ishani Bharadwaj, Lóránt A. Tavasszy, Dick A. van Damme, Abdel el Makhloufi, From XXS to XXL: Towards a typology of distribution center facilities, Journal of Transport Geography, Volume 94, 2021, 103128

As we mentioned earlier, one of the key issues when designing a logistics center is the question of who will be its resident. For this, it is necessary to take into account the peculiarities and needs of residents who will be served by the logistics center.

1. Scale of activities of potential residents.

Medium and large manufacturing companies with large revenues are focused on the local and global market. Therefore, they prefer to place their production on sites of the greenfield type (built from "scratch"), which have a large area, and make high demands on the infrastructural support of the sites. Small and medium-sized enterprises are focused on the local market and most often prefer brownfield sites (on the basis of former industries) or complex sites (with land for construction and real estate for rent/sale).

2. Category of potential residents.

When designing a logistics center, it is necessary to take into account the category of residents served: they can be foreign companies that are going to bring their production to a new market, or local companies that can open a new production or seek to move an existing one outside the city.

3. Specialization of the industrial and logistics zone.

Zoning of the territory of the industrial and logistics zone can be carried out in accordance with the needs of residents of one specialization (for example, woodworking, electric power, etc.) or in accordance with the needs of residents of different industries. In this case, it is necessary to take into account the possibility of placing different productions in relation to ecology (for example, the chemical and food industries cannot be located on the same site). Industrial zones with one specialization can be focused on one anchor resident or on several companies from the same industry.

4. Specialization of residents of the industrial and logistics zone.

Residents served by logistics centers can be divided into two categories according to their specialization: residents engaged in industrial activities and residents belonging to the service sector.

The activities of the former may belong to the following industries: automotive, machine building, metallurgy and metalworking, chemical industry, building materials, woodworking, light industry, food industry, electric power and fuel industry.

The specialization of residents from the service sector can be divided into the following groups: trade, repair and maintenance, logistics, information technology, construction, finance and other services[26].

When choosing the location of the logistics center, it is necessary to determine the need for the provision of transport and logistics services for potential residents and assess the possibility of creating optimal conditions for their implementation.

2.3 Dislocation of residency of the logistics centers

On the territory of the logistics center there are many residents who provide the entire complex of logistics services related to transportation, distribution, warehousing, cargo processing, supply, inventory management and other related services. Many structures are involved in the complex process of planning, construction and operation of the logistics center: governmental, regional, municipal, as well as private investors, developers and logistics operators.

The formation of the logistics center is carried out in accordance with the functions that it and its business units have to perform, and begins with the planning of the residency of the logistics center, which is based on the following parameters:

[26] Hutton TA. Service industries, globalization, and urban restructuring within the Asia-Pacific: new development trajectories and planning responses. Prog Plann. 2003 Jan;61(1):1-74. doi: 10.1016/S0305-9006(03)00013-8. Epub 2003 May 30. PMID: 32287934; PMCID: PMC7127207.

– synergistic effect from the location of residents (for whom some neighbor is a complement);

– optimal internal transportation (residents with rail connections; residents who need an airport; residents who need customs).

This is the approachhas the advantages of combining goals and accumulating resources. It is characterized by the presence of transport capital as a system of social and production relations between residents of the logistics center, which expresses the ability to bring the effect of economic synergy in the conditions of cooperation of the basic factors of the market value of transport infrastructure. Why? Balance factor of the goals of modernization of motor transport infrastructure:

$$Kz = \frac{\sum_{i}^{n} \alpha - \varphi}{\alpha_i} \tag{2.8}$$

where α is the sufficiency index of a separate type of impact.

must necessarily take into account the coefficient of economic sustainability - φ (related to the provision of goals with the appropriate level of resources)

$$\varphi = \frac{\beta\alpha_1 + \beta\alpha_2 + \beta\alpha_3}{\sqrt{\beta\alpha_1 + \beta\alpha_2 + \beta\alpha_3}} \tag{2.9}$$

where βα is the level of providing resources to the goal.

In accordance with the basic principles of the formation of a logistics center as an object of integration of companies in a certain territory, the following can be considered: territorial proximity of its residents, integration of their logistics processes at all levels of management, orientation towards participation in a single logical or trade process, use of a single information space. To determine the optimal location of residents, it is necessary to understand what infrastructure they need to implement their activities near the logistics center.

Residents who deliver large shipments over long distances need rail. These include construction plants, producers of agricultural products, as well as manufacturers of chemical and industrial products. In addition, resident warehouses that are connected to railways should be located in close proximity to the intermodal terminal, in order to reduce costs and time, as well as to unload highways from containers.

Residents who carry out foreign economic activities, that is, export finished products abroad or use foreign components in the production process, need customs clearance services.

Residents who have to transport goods in the shortest possible time over long distances and valuable goods with a high risk of theft need proximity to the airport. They also include residents whose consumers are located in hard-to-reach areas that cannot be supplied by other means of transport. However, residents who carry out regular short-distance transportation or transportation of flammable and explosive cargo do not need access to the airport. Thus, the residents most in need of an airport include manufacturers of food, pharmaceutical and precision engineering products, as well as the post office.

Proximity to the port is necessary for residents who supply bulk bulk (oil and oil products, liquid gas, chemical products) and cargo (iron ore, hard coal, grain). It should also be taken into account that finished industrial products, food, semi-finished products, and general cargo are often transported by water transport.

The possibility of transportation by sea transport is also necessary for residents who deliver their goods abroad, since this type of transport is the basis of international trade. Thus, proximity to the port is most needed by residents of the oil, agricultural, construction, metallurgical, mining and coal industries. Residents who carry out fast delivery of relatively small cargo mostly need proximity only to highways.

As for the proximity of the mutual location of residents, it is necessary to take into account which resident can be an addition to which. For example, some residents require consolidation/deconsolidation and short-term storage of goods, i.e. in cross-docking warehouses. This is especially relevant for manufacturers of perishable products (with a limited shelf life) and for promotional products.

There are also residents who deliver bulk goods in tank containers (cisterns), for example, manufacturers of the chemical and food industry, then the products are bottled and packed in cans, bottles, vials and other containers at the factories, after which they are sent to the store.

Another example is a grain elevator, which can be located near a flour mill. So, after the grain is delivered to the elevator and stored, it is shipped in portions for the production of flour, and then distributed to bakeries in small batches.

Thus, the optimal deployment of residents requires the organization of a minimal transport arm, i.e. the cargo enters one logistics center, is processed, stored and from the logistics center is delivered in small batches to the consumer.

For the convenience of planning, the entire territory of the logistics center should be divided into sectors for residents, and not for each resident separately, as shown in Fig. 2.4. For example, the largest logistics center in Europe, Plataforma Logistica de Zaragoza, is conventionally divided into the following zones: production logistics; air cargo processing area; cargo handling area; commercial objects; social objects; business park; service area; commercial shopping district.

The largest logistics center in Italy, Interporto Bologna, has the following zones: - customs center; intermodal terminal; container terminal; freight yard (at the railway); warehouses of responsible storage; warehouses with a railway ramp; warehouses with a car ramp; business and service center;

restaurants/cafes; Gas station and car wash; area planned for further development.

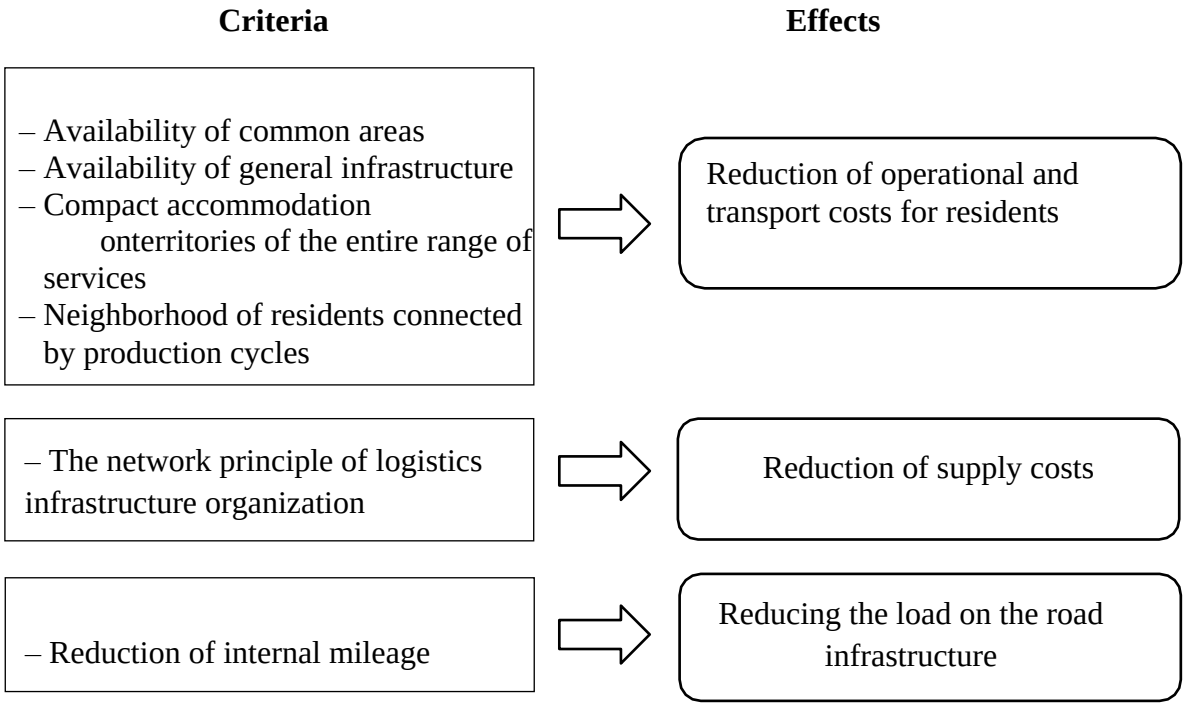

Fig. 2.6 – Multi-criteria model of the logistics center residency dislocation

Source: compiled by the authors

Taking as a basis the parameters we selected (synergistic effect from mutual location and optimal internal transportation), it is possible to identify the criteria that must be oriented when forming a logistics center (Fig. 2.6).

Residency dislocation should facilitate clustering and co-location of companies to facilitate vertical and horizontal cooperation and realization of synergistic relations between them in the field of integrated freight logistics.

The presence of common areas leads to synergies in logistics processes, such as long-distance transportation, storage, packaging and picking.

The availability of common infrastructure contributes to the increase of the internal effect of scale due to the unification of transport networks and the creation of common railway access tracks, savings on loading and unloading equipment, and reduction of the burden on the environment.

Compact placement on the territory of the complex of services combines residents' expenses for customs, public transport, security service, waste disposal service, information services, training and consulting.

CHAPTER 3
ORGANIZATIONAL AND METHODOLOGICAL SOLUTIONS ZFORMATION ANDORGANIZATION OF ACTIVITIES OF LOGISTICS CENTERS

3.1 Development of a reference model of the process of formation of logistics centers

The creation of a logistics center requires the availability of large land resources and large investment investments. Without a detailed and calculated business plan, no investor will invest his money in the project due to the presence of high risks. Despite the fact that currently there are a number of successful examples of the creation of large logistics centers, there is still no single mature established methodology for their formation. It is impossible to blindly follow the experience of logistics infrastructure development of leading countries, without taking into account the differences and specifics of each country separately.

The objective function of the logistic center functioning model has the following form:

$$R(t) = F[N(t), P(t), V(t), H(t)] \quad (3.1)$$

where N(t) − vector of parameters reflecting the incoming flow of orders;

P(t) − a vector of parameters characterizing the structure and equipment of the logistics center;

V(t) − a vector of parameters that reflects the work schedule of the logistics center and the organization of order processing;

H(t) − a vector of parameters characterizing the volume of services offered by the logistics center to its customers.

The input stream vector contains the following parameters:

$$N(t) = [incl(t), Nz(t), Nobmax(t), Nвmax(t)] \quad (3.2)$$

where Nkl(t) − number of clients;

No(t) − number of orders per unit of time;

No. max(t) − maximum order volume;

Nвmax(t) − the maximum order weight.

A vector of parameters characterizing the structure and equipment of the logistics center:

$$P(t)=[Psk(t),Pp(t), Ppers(t), Pmech(t)] \quad (3.3)$$

where Psk(t) − type of storage;

Mr(t) − the number and productivity of loading and unloading points;

Pers(t) − the number and productivity of personnel employed in various departments of the center;

Pmech(t) − the number and productivity of mechanization equipment.

Vector of the structure of the logistics center and order processing organization:

$$V(t)=[Vp(t), Vmech(t), Vpr(t), Vvyzb(t), Vnozb(t)] \quad (3.4)$$

where Vp(t) − working hours of loading and unloading points;

Vmech(t) − operating time of mechanization means;

Vpr(t) − working hours of logistics center employees;

Vvyzb(t) − the path of the cargo from the place of unloading to the place of storage;

Vnozb(t) − the path of the cargo from the place of storage to the place of loading.

A vector of parameters characterizing the volume of services offered by logistics centers to their customers:

$$H(t)=[Hv(t), Ht(t),H(t)] \quad (3.5)$$

where Hv(t)− types of services offered by the logistics center;

Ht(t) − tariffs for logistics center services;

Hobl(t) − necessary equipment for the implementation of the entire range of services.

The project of the logistics center belongs to investment infrastructure projects, which can be implemented taking into account the existing logistics capacities or free land, attractive for the construction and development of this object. The process of formation and organization of logistics centers is based on solving the following issues:

– determination of the coverage area and location of the future logistics center;

– analysis of options for design solutions that will meet all the requirements of the customer;

– definition of warehouse, terminal and transport infrastructure, as well as the corresponding service;

– identification of the main participants of the project, including the management company, and their contribution to its development;

– creation of a chain of added value, which is formed within the framework of a cluster (composition of business structures of a logistics center);

– investment volume planning;

– creation of a simulation model of the logistics center to determine the possibility of its working capacity;

– calculation of the cost of the project and determination of its payback period.

The logistics center project combines financial instruments, as well as strategic, analytical and marketing components. The main tasks of the project:

– show the level of return on investment;

– calculate the investment return period;

– predict changes in internal and external factors affecting the project;

– assess risks;

– to simulate the future cash flow from the project and bring it to the current time (taking into account the discount rate).

Investing in a logistics center is a large capital expenditure with a long payback period, accompanied by high risks, moderate returns, and highly dependent on the country's policies and institutional environment in the country. Therefore, the logistics center project can be supported at all levels of government.

The implementation of the logistics center project requires a professional approach and the use of project management principles, since the effective planning of the logistics center is extremely important both for the developers themselves and for the development of logistics in the country as a whole.

The conceptual basis of the formation of the logistics center is presented in Fig. 3.1.

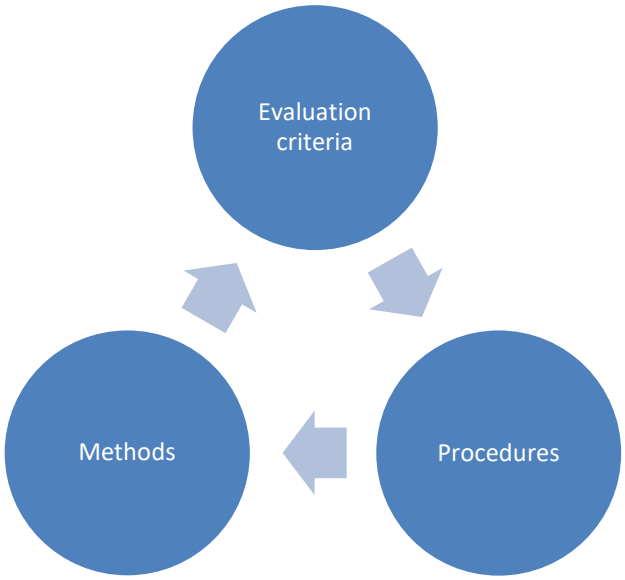

Fig. 3.1 – Conceptual basis for designing logistics centers

Source: compiled by the authors

Currently, potential investors are very careful when choosing a project. When forming a logistics center, the developer faces a big choice – to involve professionals in the field of project management or to deal with the project

independently, involving his employees. Practice shows that the most popular projects are those created by professional companies that have international methods and principles. Experienced project managers perform various management functions at all stages of the project (term, cost, risk, quality and contract management).

Unfortunately, there are still few examples of implementation of investment projects using outsourcing for the implementation of project activities in Ukraine. After all, project management with the help of outsourcing makes it possible to increase the attractiveness of the logistics center for tenants, increase income from the provision of center services, shorten the period of work and ensure the coincidence of the actual results of the business plan project. The logistics center design process consists of three interrelated elements:

1) Planning procedures are a systematic sequence of actions used in various stages of design that lead to the final creation of a logistics center. For example, planning project goals and structure, scheduling works, project financing, communication planning, risk management, contract planning, and more. All procedures must ensure the implementation of the project on time with the minimum cost, taking into account the available resources and the appropriate quality.

2) Planning methods are a set of decision-making support tools for the logistics center project. These include economic-mathematical, heuristic, simulation modeling methods and others.

3) Evaluation criteria of the formation process is a system of evaluation, analysis and comparisons, which includes quantitative and qualitative indicators that allow you to make the right decisions or abandon the wrong ones.

Implementation of a typical project consists of three phases:

- pre-investment;
- investment

- operational.

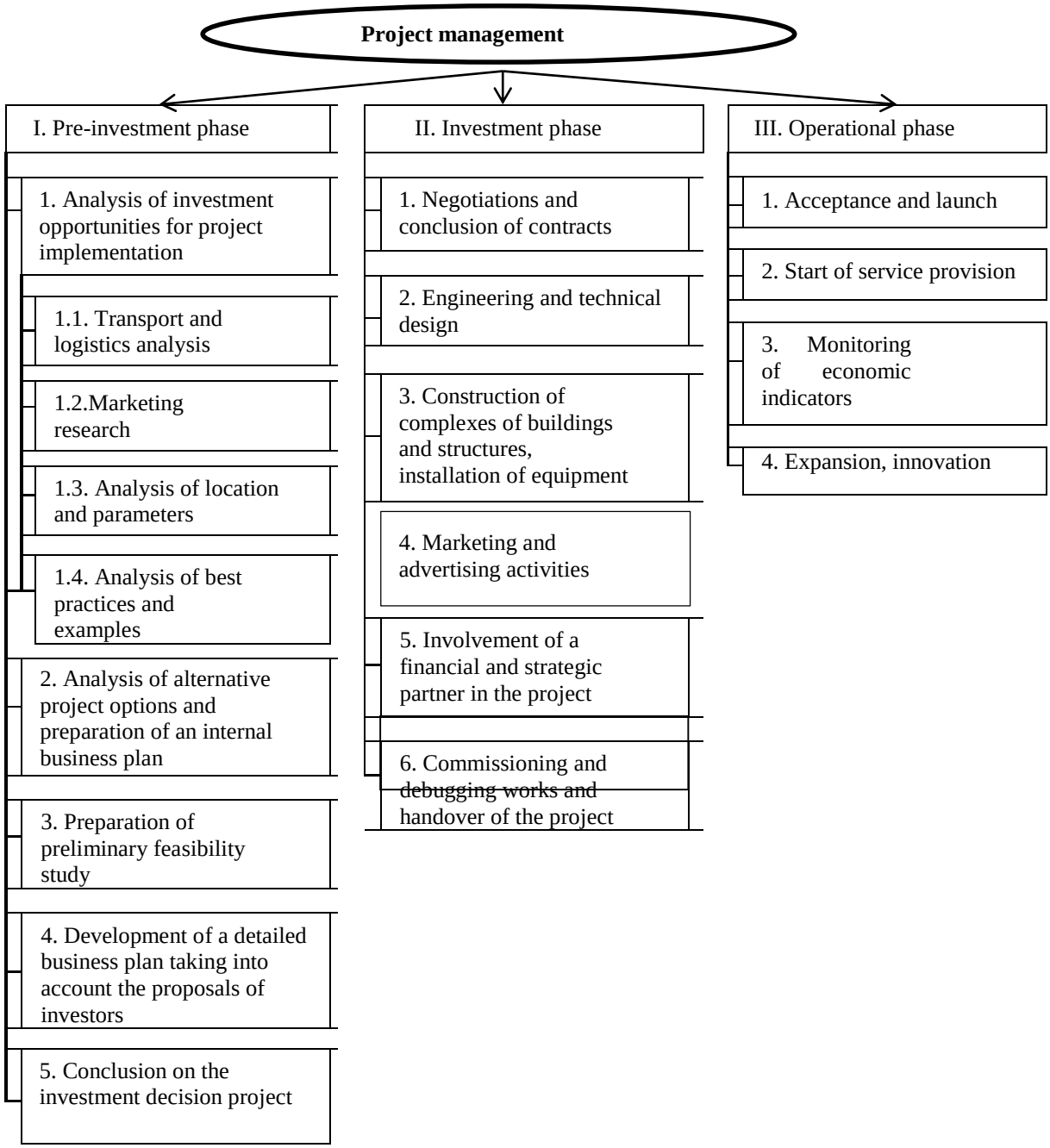

Fig. 3.2 – Scheme of the traditional model of the formation of a logistics center

Source: compiled by the authors

A study of the literature devoted to investment[1]projects of logistics centers allowed us to formulate a general design scheme of logistics centers, which is presented in Figure 3.2.

The ultimate goal of pre-investment is to make a decision on implementation and choose a project scheme. At this stage, the viability of the project is established. Potential investors (owners) must determine for themselves the expediency and economic attractiveness of the proposed measures, for this it is necessary to work out all aspects of the business idea for its viability. This phase includes the following minimum set of procedures:

1. Conducting a marketing analysis consisting of the following tasks:

– determination of the type of logistics center;

– study of demand for the product or service to be presented;

– definition of target segments: a) by type of cargo; b) by type of consumers;

– analysis of competitors and assessment of competitiveness

2. Transport and logistics analysis:

– analysis and forecast of transport flows between points of departure and destination (OD-analysis);

– determination of the types of transport that serve the logistics center;

– logistic justification;

– analysis of the activities of transport and logistics operators.

3. Analysis of the location of the logistics center, determination of its parameters:

[1]Xiongyuan Wang & Jianhua Tan Does logistics service standardization matter for corporate investment?, China Journal of Accounting Studies, 2019, 7:4, 504-523, DOI:10.1080/21697213.2019.1745998;Cichosz, M.,Wallenburg, CMandKnemeyer, AM Digital transformation at logistics service providers: barriers, success factors and leading practices,The International Journal of Logistics Management, 2020, Vol. 31 No. 2, pp. 209-238.https://doi.org/10.1108/IJLM-08-2019-0229.; Juraj Čamaj, Eva Nedeliaková, Adrián Šperka, Lenka Ližbetinová, The Planning of Investment Activities in the Field of Railway Transport with Support of Simulation Tools, Transportation Research Procedia, Volume 53, 2021, 39-49.; Jiehui Jiang, Dezhi Zhang, Qiang Meng, Impact analysis of investment coordination mechanisms in regional low-carbon logistics network design, Transportation Research Part D: Transport and Environment, Volume 92, 2021, 102735.;Gao, X. A Novel Reverse Logistics Network Design Considering Multi-Level Investments for Facility Reconstruction with Environmental Considerations. Sustainability 2019, 11, 2710. https://doi.org/10.3390/su11092710.

– determination of alternative options for the location of the logistics center;

– analysis of transport accessibility of each option;

– choosing the optimal location, needs in the territory, technology and equipment.

4. Detailed analysis of the best foreign practices (benchmarking) and examples, definition of modern trends in the development of logistics centers. Study of operational schemes and business models of examples of foreign projects.

5. Development of a project business plan.

After carrying out the necessary studies, all results should be reflected in documents, these can be separate documents or one complete expanded document that includes all information about the project.

Depending on the scope of the project and the preferences of the initiators, it can be a business concept (a description of a business idea), a business plan (justification of planned investments) or an investment memorandum (a document for attracting investors).

These documents reflect the following information:

– basis for creating a logistics center;

– goals and objectives of the project;

– location and brief description of the logistics center;

– environment (legal, ecological and social aspect);

– types of freight transportation and types of serviced transport;

– types of commercial and auxiliary activities;

– composition of business structures;

– infrastructure description;

– stages of project implementation;

– the need for financing and summary indicators for the project.

With satisfactory performance indicators, as well as acceptable risks, it is possible to proceed to the technical and economic feasibility study (FEA) of the project. The preliminary feasibility study includes a demand-oriented concept, a description of functional requirements, a preliminary version of the master plan, a description of the order of connection to the infrastructure, a description of the capacity indicators and work reserves.

If the feasibility study satisfies the project initiators and they are ready to begin its implementation, then an internal document is adjusted based on the proposed feasibility study, for example, a business plan, which can be supplemented with proposals from potential investors. The business plan of an investment project of a logistics center includes a project assessment ("cost-benefit analysis"), determination of performance indicators (KPI), SWOT analysis, and risk assessment. Thus, the expanded business plan can further serve as an internal document, as well as an external one for attracting financing.

In addition to the described documents, during this phase it is necessary to create additional presentation materials that can be used to attract project financing, for example:

– the concept of territorial development,
– the concept of industrial zone development,
– a map of the location of land plots with an indication of the owners,
– analysis of the most effective development of land plots.

6. Conclusion on the investment decision-making project: consists of the following tasks:

– determination of construction stages;
– determination of the strategy of attracting companies;
– organization of financing;
– project management.

In the second phase (investment), specific actions are taken that require much higher costs and are irreversible. Its ultimate goal is the implementation of

the project and preparation for operation. At this stage, in accordance with the specified conditions of the project and estimates of construction works:

- equipment is ordered;

– industrial facilities are being prepared;

– equipment is supplied and installed;

- start-up and debugging works are performed;

- staff training is organized;

- an advertising campaign, etc. is conducted.

Also, at this stage, the owners usually attract external sources of financing (loans, issuance of additional shares or securities, leasing, attraction of investment funds, attraction of funds from other sources).

The last phase (operational) is characterized by the beginning of the provision of services and the return of external loans in case of their involvement. The operational period also includes monitoring the activities of the logistics center and finding ways for further development.

3.2 Organization of the logistics center on the basis of public-private partnership

The most successful projects of logistics centers are those carried out within the framework of public-private partnership (PPP). The authorized capital belongs to the state authorities and private developers in different share percentages, most often, a large share belongs to the state. The choice of the PPP model and the involvement of state authorities allows overcoming financial, infrastructural and design difficulties. The use of this mutually beneficial cooperation of public and private partnership allows to reduce the risks and costs of the project, attracts additional sources of financing and increases the efficiency of the project implementation.

At the same time, it should be noted that the participants of the partnership pursue different goals, have different motivations and solve their

own tasks through the partnership mechanism. Thus, the state is interested in increasing the volume and improving the quality of logistics services, in strengthening the budget at the appropriate level based on the growth of tax revenues, while business is interested in the development of industrial and social infrastructure, which ensures the creation of favorable conditions for its growth, increasing profitability and stability development Moreover, according to a study conducted in 2018 by the "Center for Transport Strategies" and the company "Deloitte", all participants of the transport market consider the PPP format to be the best option for financing projects, but the respondents did not have a single opinion about the advantages of PPP in comparison with budget financing .

– 58% reduction in risks of excessive spending of budget funds;

– 54% involvement of best practices;

– 50% more transparent mechanism;

– 46% higher quality of built objects and services;

– 46% faster implementation of plans;

– 35% increase in the investment attractiveness of the country.

According to the respondents, the main factors restraining the development of PPPs in the transport infrastructure of Ukraine include:

– 54% weak legal framework;

– 42% insufficient practical state support;

– 35% lack of successful project implementation experience;

– 19% shortage of attractive objects;

– 15% deficit of investors' interest.

Regarding the objects that have the greatest potential for PPP, the participants of the conducted survey believe that they are:

– 85% sea and river ports;

– 65% railway transport;

– 54% highways;

– 27% airports;

– 8% municipal transport[2].

Accordingly, the main goal of PPP in infrastructure is to overcome the infrastructure deficit in the country, especially at the regional level. WITHcreation of proper conditions of interaction between the cluster policy, the European approach of smart specialization of regions and the policy of decentralization will allow to accelerate the development of the economic potential of newly created territorial entities and strengthen their competitive capabilities at various levels, in particular, at the international level.

The new institutional order of the decentralized budget requires the improvement of the financial mechanism for the implementation of state functions, which it provides through the budget system, the essence of which is the state's achievement of public status, that is, the realization of claims to serve public, not private interests, to the status of a public, official and impersonal institution. During the formation of the state, the division of spheres (and types of actions) into public and private is related to economic interests, the division into formal (official) and informal methods of action refers to the system of rules and regulations, and into impersonal and personal (personalized) - to their methods application.

The principle of the strength of the state and its legitimacy are determined by the ability to effectively institutionally delineate and adhere to these limits, especially this applies to the partnership of the state and business through the active use of the funds of a significant number of taxpayers. It is necessary to realize that PPP is not the only type of interaction between the state, banks, the community and the private sector, so it is often confused with other concepts. PPP clearly regulates the sharing of risks between the two sectors and provides financial benefit to the investor, i.e. the private partner, which distinguishes PPP

Public-private partnership in infrastructure. Research "Industry control", 2018URL:https://cfts.org.ua/media/documents/2018/industry-control-2018-ru.pdf

from charity and business social responsibility. PPP is not privatization, at the end of the agreement the property remains with the community for further socialization of its citizens[3].

Modern scientific literature often presents the result of this partnership as a joint venture, which is built on shared knowledge and experience, and which best meets public needs through an appropriate distribution of financial resources, risks, and revenues[4]. Ukrainian scientists present PPP as a form of cooperation for the implementation of socially significant projects[5]. In the Law "On Public-Private Partnership" it is defined as cooperation on a contractual basis between two parties: the state and private entities[6]. If we single out the basic component - finance, then this partnership should be considered as specific innovative mechanisms of project financing and risk distribution among all participants of the agreement. This interpretation of this definition requires the Ukrainian legislation to add the main condition that distinguishes partnership from traditional public and private sector relations - the effective distribution of resources, risks, responsibilities and income. Because, the Ukrainian legislation notes the contractual type of partnership from the two existing types (contractual or concessional), while the institutional nature of the PPP is omitted. However, it is precisely this side of the relationship, which is characterized by the creation of an organizational structure in the financial system for the purpose of joint mutually beneficial investment activity, that requires institutional consolidation[7].

[3]Chukayeva I.K., Bgan A.G. Public-private partnership in the implementation of energy infrastructure projects. Economics and forecasting. 2012. No. 4. P. 47. URL: http://nbuv.gov.ua/UJRN/econprog_2012_4_6

[4] Rall J., Reed J., Farber N. Public-Private Partnerships for Transportation. A Toolkit for Legislators / NCSL Partners Project on PPPs for Transportation, Washington, DC, 2010. 11.:http://www.laneconstruct.com/servlet/servlet.FileDownload?file=015U00000003oMg)

[5] Shulyuk B.S. *Conceptual foundations of the financial mechanism of public-private partnership. Bulletin of ZHTU. 2018. No. 4 (86). 117-122. url*. http://ven.ztu.edu.ua/article/view/154055/15371

[6] On public-private partnership: Law of Ukraine dated July 1, 2010 No. 2404-VI. Art. 11. URL: http://zakon2.rada.gov.ua/laws/show/2404-17

[7] Markeeva O.D., Rozvadovskyi B.L. Actual problems of legal support of public-private partnership in the field of critical infrastructure protection. National Institute of Strategic Studies. 2020. URL: https://niss.gov.ua/sites/default/files/2020-09/derzhavno-pryvatne-partnerstvo.pdf

The imperfection of the institutional order prevents the full use of the organizational mechanisms of PPP development. In particular, the shortcomings of the Law of Ukraine "On Public-Private Partnership" include the "blurring" of the relations it is supposed to regulate. The law does not contain a clear institutional framework of application, suggesting to be guided by non-specific features of PPP and areas of application of PPP (industry of the national economy). At the same time, the most important factor of the PPP as a partnership aimed at the implementation of projects related to public objects and public services that ensure proper socialization of the population as a whole is overlooked. Although in 2015 an addition was made to Art. 4 "Fields of application of state-business partnership" "provision of social services, management of a social institution, institution"[8].

As for the operation of the financial mechanism, its effectiveness fully depends on the effectiveness of the organizational (institutional) side. This Law does not clearly fix the minimum share of private partner participation in the project (in particular, in developed countries the minimum share of private financing is 25%)[9]. The lack of a clear fixation of the financial part of private capital creates conditions for abuse. Even a minimal share of private financing in a joint project allows it to be classified as a PPP, transferring most of the responsibility to the state.

No less important is the lack of a clear definition of practical implementation mechanisms (definition of the stages of implementation of PPP projects, creation of motivation for foreign investors, especially regarding the use of natural resources, which make up a significant part of the idle capital of rural areas, etc.). According to Art. 7 public-private partnership applies to objects that are in state or communal ownership. This makes it impossible to

[8] Law of Ukraine. "On public-private partnership".With changes andadditions made Lawsof Ukraine. 2015. No. 817-VIII. URL: https://ips.ligazakon.net/document/t102404?an=266&ed=2016_05_2

[9]Business in the regions: investment environment "on the ground". European Business Association. 2020. URL: https://eba.com.ua/biznes-u-regionah-investytsijne-seredovyshhe-na-mistsyah/

implement such projects as the construction of objects by a private partner and their subsequent transfer to a state (communal) partner. The role of the State Fund for Regional Development in the financing of PPP projects remains unclearprojects are financed at the expense of the FDRR (in 2021, 294 projects worth 4.2 billion hryvnias will be financed, of which 148 are transitional projects that started in previous years[10]) of two priorities - high-quality restoration of infrastructure in the regions and economic development projects, where there is a great prospect of partnership between the state and private business in the development of territories.

The experience of PPP development in developed countries proves the need for the process of forming a new institutionin order to take into account the fact that among the main types of risks in such a partnership - the financial risk, which is associated with the variability of credit rates, exchange rates and other factors that affect the cost of financing the project, is the most important, and therefore an institutional toolkit for it should be developed mitigation for private capital. This especially applies to newly created communities, where financial risks are complemented by market risks.

To achieve success in expensive infrastructure projects based on PPPs, according to research, the share of state participation in investment should be at least 40-60%[11].In the new economy, clusters of creative industries are an essential component of infrastructure in many countries of the world. According to UN data, the share of the creative economy accounts for 3.4% of world GDP, which is almost 1.6 trillion. dollars The USA has twice the amount of annual income from international tourism. Annual growth rates in different countries

[10]294 regional development projects have been selected for financing in 2021 from the DFRD. Ministry of Development of Communities and Territories of Ukraine, February 19, 2021. URL:https://www.kmu.gov.ua/news/294-proekti-regionalnogo-rozvitku-vidibrani-dlya-finansuvannya-u-2021-roci-koshtom-dfrr

[11]Yukhymenko P.I., Zagurskyi O.M., Grynchuk Yu.S. etc. State-business partnership in the creation of infrastructure in rural areas: theory and practice: monograph / general editor. Dr. Econ. Sciences, professor, academician of the National Academy of Sciences of Ukraine A.S. Danylenko Bila Tserkva: BNAU, 2020. 225.

vary from 4.3% to 17.6%, twice the growth rate of the service sector and four times the growth rate of the industrial production sector[12].

The state's contribution to the PPP can be presented in the form of investments, transfer of assets or other liabilities. The government also provides social, environmental and political support. The public sector monitors the activities of the private sector during the entire project implementation period, and also monitors compliance with the terms of the contracts. The role of the private sector in the partnership is to use its expertise in commercial activities, management, operation and innovation to effectively launch the project. The private sector is responsible for the implementation and operation of the project and assumes a significant part of the project's risks.

The implementation of the PPP begins with the involvement of partners, identification of interested parties and key persons of the project. Further necessary preparation for project implementation is the exchange of business ideas.

Characteristics of the logistics center project within the framework of the PPP:

– has a long-term nature (from 10 to 30 years or more);

– optimal division of risks and responsibilities between the public and private sectors (risks are fixed in the contract with the private partner);

– the authorized capital may belong to state and private partners in different proportions, however, most often, state authorities own the main part;

– uniqueness of the project;

– for the successful implementation of the project and conducting the audit, a steering committee is elected, key stakeholders and partners are determined, project tasks are set, responsibilities are distributed, and a team of project developers is selected;

[12] Recommendations of parliamentary hearings on the topic: "National innovation system: state and legislative support for development." 2018 URL.http://search.ligazakon.ua/l_doc2.nsf/link1/DH6M300A.html

– given the capital-intensive nature of PPP infrastructure projects and the associated risks, private project sponsors often form a separate specialized project company (SPV);

– the cost of the project is estimated according to the concept of Value for Money ("value for money");

– mechanisms of pre-qualification and competitive negotiations are used when choosing a private partner;

– compliance with technical requirements and quality standards of products and services.

In the Table 3.1 shows the general structure of a public-private partnership for logistics centers, which includes potential participants and their possible functions.

Table 3.1 - PPP participants in the design of the logistics center

PPP participants	Functions
Government (ministries and state bodies)	Licensing State guarantees Land ownership Directions of development
Development companies / Residents (financial institutions, developers, managers of enterprises, construction companies)	Real estate development Financing Marketing Ownership of the process
Transport superstructure (port companies, container terminals, telematics platform, service companies, customs)	Open access to transport and service infrastructure
Tenants (forwarders, transport companies, warehouse operators, logistics departments of manufacturing companies, logistics providers)	Rent Transport Warehousing and cargo handling 3PL level services

Source: compiled by the authors

The payback period of the logistics center is on average 8-15 years.The German experience of investment in logistics centers is interesting (Fig. 3.3). The German model of designing logistics centers is characterized by strong state

support both in the planning phase and in the phase of implementation and support of logistics centers.

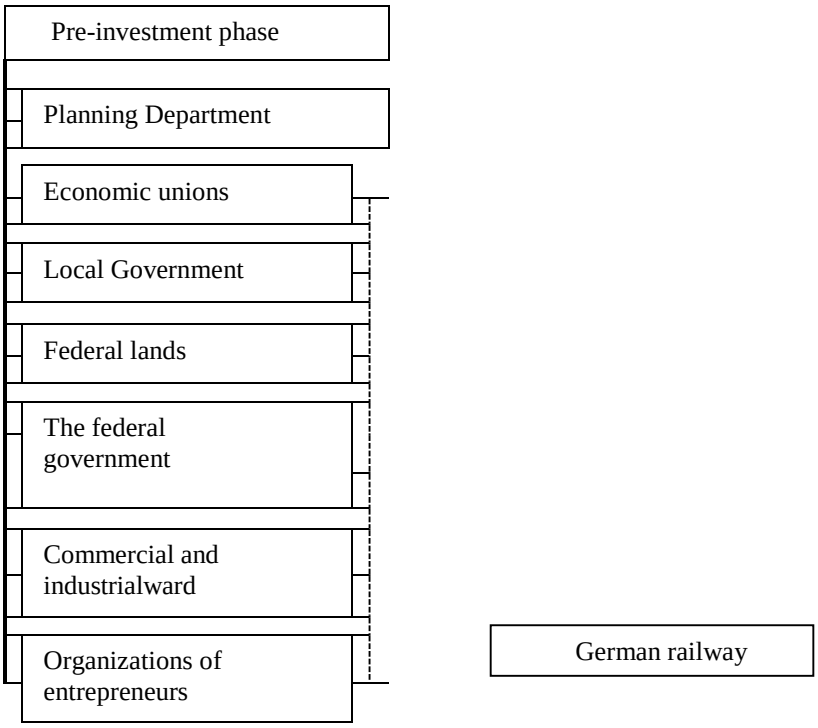

Fig. 3.3 – The German model of investment in logistics centers

Source: Fichert F. Transport policy planning in Germany - An analysis of political programs and investment master plans. Eur. Transp. Res. Rev. 9, 28 (2017). https://doi.org/10.1007/s12544-017-0247-7

The implementation of this model is the most relevant due to the fact that the logistics services market has a tendency to expand into regions. With this, there is an urgent need to increase value-added services. It is worth noting that for the implementation of projects of logistics centers in Ukraine, the concept of "Public-private partnership" is more appropriate, since all levels of public authority are involved in the construction of this type of infrastructure, not only the state one.

Implementation of an investment project using the PPP mechanism differs in complexity and design approach. Therefore, the traditional model can be

adjusted taking into account the design features of the logistics center under PPP conditions (Figure 3.4).

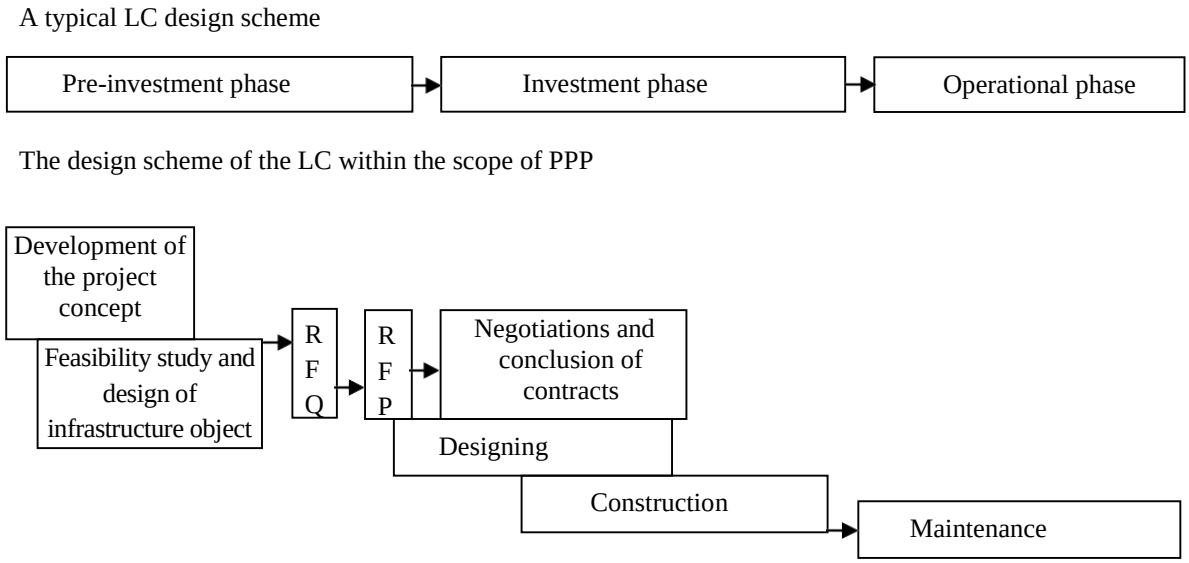

Fig. 3.4 – Comparison of the scheme of formation of a logistics center within PPP and a typical scheme of a traditional model

Source: compiled by the authors

After determining the preliminary concept of the project and calculating the technical and economic indicators, the customer organizes a tender (a request for qualifications (RFQ) and/or a request for proposal (RFP) is issued). As a result, the participants of the project are selected and those responsible for carrying out procedures for the design of the logistics center are determined. Contracts are being negotiated and signed. The choice of one or another form or model of PPP depends on the area in which the project is implemented and its specifics. In fact, each model is not used in its pure form, but mixed models are used.

Due to the fact that the project of a large logistics center has a long implementation period and restrictions on the transfer of state property rights to some objects, as well as high risks, the most acceptable form of PPP for such a

project is a Concession Agreement. However, it is possible to use other models for individual infrastructural elements of the logistics center[13].

Fig. 3.5 – Regional hotspot winners in the logistics heart of Europe – period 2013 - '2019'1)2)

1)'2019' includes warehouses which are announced or started construction in 2018/2019 and will be opened in 2020/2021
2) For Germany Bundesländer; for The Netherlands and Belgium provinces
Source: Buck Consultants International/Bulwiengesa.url. https://bciglobal.com/en/growth-of-mega-distribution-centers-accelerates-in-germany-the-netherlands-and-belgium-efficiency-and-e-commerce-are-main-drivers

Many domestic and foreign investors consider this form of PPP to be insufficiently flexible and attractive, in addition, the state, like a private business, began to approach the investment of funds even more conservatively. Due to the fact that the PPP mechanism in our country is just being formed, it is possible to refer to the experience of foreign countries that implement similar projects based on a new form of interaction between the state and private business. For example, the Life Cycle Contract model[14] successfully

[13]State-business partnership in creating the infrastructure of rural areas: theory and practice: monograph / P.I. Yukhymenko, O.M. Zagurskyi, Yu.S. Grynchuk and others; for the general editor. Dr. Econ. Sciences, professor, academician of the National Academy of Sciences of Ukraine A.S. Danylenko Bila Tserkva: BNAU, 2020. 225 p.

[14]Junaid Tariq, S. Shujaa Safdar Gardezi, Study the delays and conflicts for construction projects and their mutual relationship: A review, Ain Shams Engineering Journal, Volume 14, Issue 1, 2023, 101815.; Altaf M., Alaloul WS, Musarat MA, Bukhari H., Saad S. and Ammad S., BIM Implication of Life Cycle Cost Analysis in Construction Project: A Systematic Review, 2020 Second International Sustainability and Resilience Conference: Technology and Innovation in Building Designs (51154), Sakheer, Bahrain, 2020, 1-7, doi:

implemented in Germany, Belgium, the Netherlands, Portugal and other countries.

Table 3.2 – A possible structure of the financial model of the logistics center

Sections	Content
Basic assumptions	Methodological assumptions (lifetime of the project; duration of the forecast and post-forecast period; type of cash flows; discount rate; growth rate in the post-forecast period).
	Macroeconomics (forecast of deflator indices and inflation: annual inflation, exchange rate₴/$).
	Forecast of capital investments (with VAT) based on the investment schedule; accrued depreciation; VAT refund for fixed assets put into operation.
	Forecast structure of financing (terms and terms of loans, schedules for receiving loans and repayment of debt, schedules for accrual and repayment of interest, outstanding balances for loans and interest).
	Sales forecast; forecast of prices/tariffs for finished products (services).
	Costs of basic materials/resources per unit of output; price forecast of basic resources; forecast of personnel costs; forecast of contingent and fixed costs.
	Forecast of norms of working capital (receivablesbuyers, accounts payable to suppliers, turnover of goods and material values).
	Tax rates (income tax, property tax, VAT, VAT).
Forecast financial reporting	Report on financial results
	Balance sheet.
	Cash flow statement (cash flow from operating, investment and financial activities).
Discountedproject cash flow (FCFF)	Net cash flow, discounted net cash flow.
Key financial indicators coefficients)	Coefficients reflecting investment attractiveness, debt service, debt burden, liquidity, profitability and turnover.
The impact of risk factors on financial forecasts	Increase in cost and terms of construction; unearned revenue; reduction of energy, labor and utility resource savings, savings on repair costs.

Source: compiled by the authors

0.1109/IEEECONF51154.2020.9319970.; Araszkiewicz, Krystyna and Bochenek, Magdalena. "Control of construction projects using the Earned Value Method - case study" Open Engineering, vol. 9, no. 1, 2019, 186-195. https://doi.org/10.1515/eng-2019-0020

Management of the logistics center project within the framework of the PPP may take place differently depending on the PPP model chosen by public education and the distribution of rights and responsibilities of the project participants. The initiator of the project can be a state or municipal government body or, less often, the private sector, which put forward an initiative proposal. However, in both cases, the project must be managed by representatives of the Government. Project planning is carried out by a specialized project team (SPV), which conducts an initial analysis and evaluation of best design practices, provides necessary prior approvals, and evaluates the effectiveness of the project being implemented.

In the Table 3.2 presents the possible structure of the financial model of the logistics center project.

Also, for the successful implementation of the project, the SPV team must anticipate possible risks associated with its implementation. To do this, it is recommended to build a diagram of risks by six categories (politics, macroeconomics, market demand, operations, finance and construction), as well as to determine the method of managing each risk (acceptance, reduction, transfer or rejection). The acceptance method means that the risk is identified and controlled by the project team. The reduction method involves risk management and the development of a plan to reduce it. The transfer method indicates that the risk is transferred to third parties, such as insurance. The rejection method is used when the risk is too high.

At the same time, when considering infectious projects in the field of logistics infrastructure, it should be noted that all of them are always large-scale and costly, therefore their implementation affects various components (economic, socio-cultural, ecological, production, etc.) of the socio-economic system of the territory.

In PPP practice, when investing in the construction of large objects of logistics infrastructure, according to the international classification, the following types of agreements are distinguished:

• DBFO (Design-Build-Finance-Operate – design, construction, financing, management);

• BFO (Build-Finance-Operate – construction-finance management);

• BOT (Build-Operate-Transfer – construction-management-transfer);

• DBF (Design-Build-Finance – design, construction, financing);

• DBF (Design-Build-Finance – design, construction, financing);

• OM (Operation-Maintenance)[15].

However, logistics center construction projects are a special case of investment projects, therefore, during their implementation, special methods of calculating key indicators are used, which form the basis of assessing the socio-economic efficiency of the investment project, namely:

1) the content and structure of the cash flows involved in the project are different, and therefore they are determined separately to measure direct economic, indirect economic and social efficiency;

2) project cash flow discount rates are differentiated to measure the direct, indirect economic and social efficiency of the investment project. These provisions of the proposed methodology are based on the fact that the use of a single discount rate for calculating economic and social efficiency is not only incorrect, but also unlawful;

3) project efficiency is assessed on the basis of the single net present value (NPV) indicator for all types of efficiency or, in the domestic version, the net present income (NPV), which ensures comparability of these indicators for the state and business.

[15]Byungwoo G. Trends and issues of PPP models in transport focused on South Korea and the UK. Public Private Partnerships in Transport: Trends & Theory. 2010. 10.; Schmiedlin RB, Debra PE, Bischoff L. Stone Matrix Asphalt. The Wisconsin experience. Wisconsin road agency, 2002. WISPR–02-02.

The ability to manage the system leads to the problem of choosing actions and inevitably leads to the task of finding the optimal solution from the point of view of management. This type of task is a dynamic programming task built on the so-called principle of optimality: According to it, optimal behavior is characterized by the fact that whatever the initial state and decision at the initial moment, the following decisions should constitute optimal behavior relative to the state obtained as a result of the first decision.

The method of dynamic programming consists in the fact that the optimal control of a complex process (project) is built gradually. At each of the stages, the management of only this stage is optimized, but taking into account the optimality of the entire process (project) as a whole. That is, at each stage, the decision to manage the process (project) is made taking into account its consequences, since management, optimizing the objective function only for this stage, can lead to a suboptimal effect of the entire process (project). Whatever the initial state of the system before the next stage, control decisions are aimed at maximizing the gain at this stage plus the optimal gain at all subsequent stages.

At the same time, it should be noted that the process (project) optimization task is described by the dynamic programming model only when the following conditions are met:

1. The task is interpreted as an n-step management process, in which the overall performance indicator is presented as an algebraic sum of performance indicators at each stage;

2. At each stage, the equilibrium state of the system is determined by a finite quantity*m*state parameters and is controlled by a finite number r of variables, and m and r do not depend on the number of stages n.

3. The choice of management at any stage does not affect the previous stages, and the obtained state at the beginning of this stage is a function of the previous stage and the management decision chosen at it.

Dynamic programming processes can take different forms. We propose an analytical model of the decision-making process, which will be both quite general and computable. This model is conditionally stationary, because it assumes that the investment project of the logistics center is carried out for a short period of time. "Markov decision-making processes" are used to describe system operations, and discrete and dynamic programming methods are used for optimization, in accordance with the general concept of analysis and optimization of multi-step tasks. Markov decision-making problems described in the work of R. Howard[16] is a mathematical programming problem applied to multi-stepof decision-making tasks under conditions of risk. In them, the process of changing the state of any system consists in the fact that at random moments of time t0, t1, t2, ..., tk, the system appears in one or another previously known discrete state successively. Such a random sequence of events is called a Markov chain if, for each step, the probability of transition from one state St to any other Sj does not depend on when and how the system entered the state St. A Markov chain is described using the probability of states, and they form a complete group of events, so their sum is equal to one. Therefore, the investment project for the construction of a logistics center will be a system that at any fixed moment in time can be in one of the numerical states (stage of project implementation), which we will number as Ej = 1, 2, ..., N and assume that at discrete moments time t = 0, 1 system transitions from one state to another. Moreover, the processes of changing states do not occur deterministically, but stochastically and are controlled by the transition matrix

$$P = (\Pi Ei;Ej) \tag{3.6}$$

where: PEi; Ej the probability of the state transition from stage "i" to stage "j" of the investment project of building a logistics center.

[16]Howard RA Dynamic Programming and Markov Processes. The MIT Press, Cambridge, 1960. 136.

Let's introduce the following functions: Xt (Ei) is the probability that the system at the moment of time (t) is in the state Ei = 1,2, ..., N, provided that t = 1,2, ...

Then according to the probability theory:

$$X_{t+1}(E_j) = \sum_{i+1}^{N} P_{E_i;E_j} \times x_t(E_i), E_j = 1,2,...N$$
$$x_0(E_i) = C_i \quad (3.7)$$

Given that the asymptotic behavior of the function is considered in the theory of Markov processes $x_t(E_i)$, with $t \to \infty$ and if all transitional probabilities PEi;Ej are positive, then the defined functions approach the values $x_t(E_i)$, satisfying the "steady-state" equation:

$$X(E_j) = \sum_{i+1}^{N} P_{E_i;E_j} \times x(E_i), E_j = 1,2,...N \quad (3.8)$$

In this model, one of the sets of such matrices can be chosen as a transitional matrix at each step, accordingly, we can choose the matrix P(α) = (PEi; Ej(α)) to determine the policy α. Next, suppose that not only the state changes at each step, but also the costs associated with project development, which are a function of the initial and final state and the decision. In this case, the expression R(α) = (rEi; Ej(α)) is the cost matrix.

The process described above is a Markov decision-making process, therefore the essence of the task solution is reduced to the selection of a sequence of decisions that minimize the mathematical expectation of the costs obtained in the N-step process, given the initial state of the system.

Let $\alpha_1^1; \alpha_2^1; \alpha_3^1$ – alternative options for implementation of the investment project in the 1st period i $h_1^1; h_2^1; h_3^1$ – relevant costs for project implementation according to these options in the first period. Since alternative project implementation options arise at each of the stages, we indicate alternative project implementation options and their costs for the II period $\alpha_1^2; \alpha_2^2; \alpha_3^2$ and h_1^2;

$h_2^2; h_3^2$ in accordance. Then, for the III period, there will be alternative project implementation options and their costs $\alpha_1^3; \alpha_2^3; \alpha_3^3$ and $h_1^3; h_2^3; h_3^3$ in accordance.

The solution to the task of cost minimization is carried out in stages and begins with the search for the minimum number of costs in the III period. Further, such procedures are repeated for II and I periods. The final decision on the development of the project is formed from a sequential choice, starting from the first period of such alternative options, in which the cost indicator is minimal.

Uncertainty and risk factors are assessed by experts as possible additional costs at each stage of development of an investment project and are determined using informal subjective assessment methods. In some cases, the magnitude of the impact of these factors can be determined on an objective basis (for example, based on statistics on the occurrence of adverse events at similar facilities).

Accordingly, the main task is reduced to the construction of an optimal solution at all three stages of choosing the minimum cost indicator, taking into account the uncertainty and risk component. For this, the probability of its occurrence and the amount of profit (minimization of costs, taking into account the component of uncertainty and risk), which can be obtained taking into account this probability, are calculated. The calculation is performed on each decision vector from the initial decision node to the end node of the corresponding result, selecting the branch that leads to the maximum payoff and returning to the previous decision node that is assigned that payoff value.

In our case, the construction of an economic-mathematical model is reduced to the task of managing the development process of an investment project for the construction of a logistics center, the algorithm for solving which consists of the following main stages (Fig. 3.6).

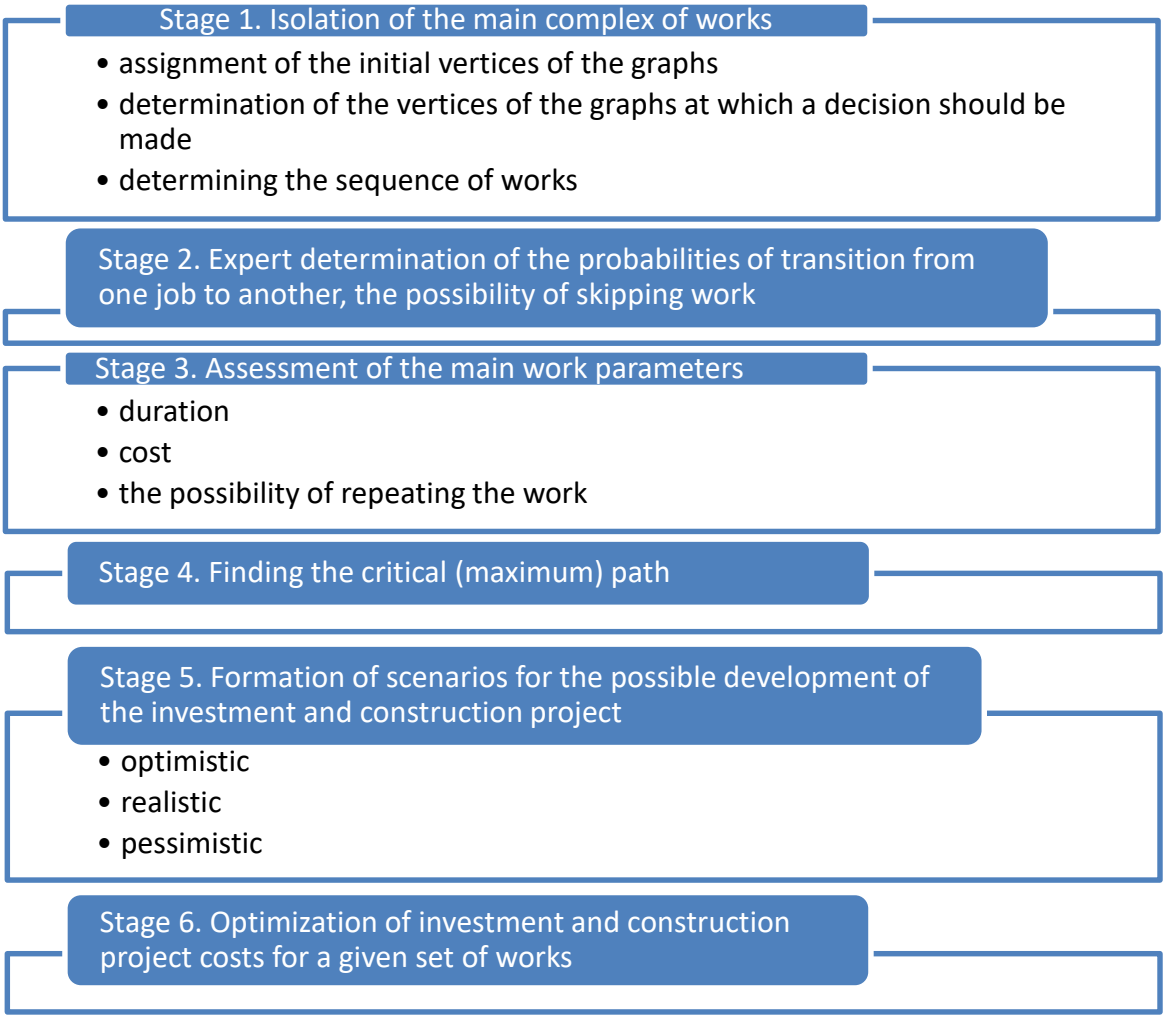

Fig. 3.6 – Algorithm for building an economic-mathematical model for cost optimization of an investment project for the construction of a logistics center

Source: compiled by the authors

Therefore, investment projects in the field of logistics infrastructure are always complex, large-scale and costly. Their implementation affects various components (economic, socio-cultural, environmental, production, etc.) of the socio-economic system of the territory and, accordingly, requires the use of various models of their management both at the design stage and in the implementation process.

The proposed model can prove to be a powerful tool in the operational management of the development process of a logistics center construction

project based on PPP. Based on it, schedules and a calendar plan for its implementation will be built in the future. Thus, interested parties (public or private partner), using the developed model, are able to make quick decisions not only before the start of the investment project, but also during its implementation, as well as receive detailed information about possible permissible losses at decision-making points.

3.3 Comprehensive assessment of logistics center activity

To assess the functioning of the logistics center, it is necessary to conduct a comprehensive study of a set of criteria reflecting various aspects of activity. Such an assessment will allow to assess the efficiency of the LC and choose the optimal management strategy. Indicators can be used both for analysis and comparison and can be expressed both in absolute and relative values. The main requirements for indicators:

– clearly defined and measurable;

– evaluate the internal and external activities of the logistics center;

– evaluate the activity of the logistics center that allows it to make a profit;

– cover different aspects of the same process (eg time and quality);

– to be used by both managers and employees to evaluate work efficiency.

To evaluate the activity of the logistics center, you can use the Balanced Scorecard, which is a business-oriented approach to supply chain management. The Balanced Scorecard indicators are a tool for evaluating productivity, focus on the innovative component and added value, maintain a balance between various criteria. According to the concept of Robert Kaplan and David Norton[17]

[17]Kaplan RS, Norton DP Alignment: Using the Balanced Scorecard to Create Corporate Synergies. Boston, MA: Harvard Business School Press, 2006. 302.

the company's activity should be evaluated according to the following components, which are presented in the Table. 3.3.

Table 3.3 – Components of a balanced scorecard

Prospects	Key objectives
Finances	• use of assets; • optimization of working capital • increasing profitability
Customers and Marketing	• increase in customer satisfaction; • selection of clients that generate the main income.
Business processes	• timely and complete deliveries; • technology optimization; • effective relations with stakeholders.
Personnel	• transfer of powers to employees; • improving their qualifications and ability to adapt, • recognition of staff merits
Surroundings environment/society	• support of local business; • establishing relations with future employees; • leadership in the community.

Source: compiled by the authors based on: Kaplan RS, Norton DP Alignment: Using the Balanced Scorecard to Create Corporate Synergies. Boston, MA: Harvard Business School Press, 2006. 302.

For each section, it is necessary to formulate goals, determine indicators and target values of indicators, as well as initiatives (measures to implement the goal).

The "Finances" section will allow the investor to evaluate the effectiveness of investments in the project, i.e. it reflects the current and planned financial results.

The "Customers and Marketing" section defines the company's position in the market, its competitive advantages and attractiveness to customers.

The Business Processes section describes the business processes (durability, quality, and environment) that play the most significant role in realizing competitive advantage.

The "Personnel" section describes the direction of development of the company's personnel.

The "Environment/Society" section shows the company's place in the market and its opportunities.

Strategic maps can be built on the basis of the formulated indicators. Examples of financial indicators when evaluating a logistics center project can be:

1) Investment attractiveness:

– the project's net discounted income (NPV) is the present value of future income after deducting investments of the current period:

$$NPV = \sum_{i=1}^{N} \frac{NCF_i}{(1+r)^i} - I_{nv} \quad (3.9)$$

where NSF – the net cash income for the i-period,

Inv – initial investment,

r – discount rate.

– the discounted project payback period (DPBP) is the duration of the smallest period after which NPV becomes and remains ≥0, i.e. the investment return period;

– the internal rate of return on equity (IRR on Equity) is the discount rate at which NPV=0.

2) Debt service ratios:

– The interest coverage ratio (ICR) shows the extent to which earnings before interest and taxes (EBIT) cover interest expenses:

$$ICR = \frac{EBIT}{Interest} \quad (3.10)$$

where EBIT – profit before interest and taxes,

Interest – interest payable;

– the debt coverage ratio (DCR) shows how many times the amount of net income exceeds the amount of debt obligations for a certain period:

$$DCR = \frac{CFADS}{Dtbt + Interest\ \ payments} \quad (3.11)$$

where CFADS – the cash flow available for debt service in this calculation period,

Debt + Interest payments –the amount of debt service payments in the settlement period.

– the loan coverage ratio for the entire loan period (LLCR) shows the ratio of the stated value of future cash flows from operating and investing activities for the remaining term of the loan to the outstanding loan balance:

$$LLCR = \frac{NPV}{Outs\tan ding\ \ principal} \quad (3.12)$$

where Outstanding principal is the balance of loan debt at the end of this settlement period.

– cash flow available for debt service (CFADS) shows the amount of cash flow that can be directed to debt service, calculated or before interest payments.

CFADS = OCF + ICF + obtaining debt financing +

+ contributions to the authorized capital, (3.13)

where OCF **–** cash flow from operating activities,

ICF – financial flow from investment activities.

Or after paying or receiving interest:

CFADS loan = OCF + ICF + receipt of debt financing + contributions to authorized capital + interest paid - interest received (3.10)

3) Debt load indicators:

– financial leverage (leverage) shows the ratio of loan capital to equity (Debt/Equity Ratio).

– the level of debt load (Debt/EBITDA) shows the solvency of the organization, calculated as the ratio of total liabilities and profit before deduction of taxes, interest and depreciation.

– indicator of the ratio of debt to CFADS (Debt/CFADS).

4) Liquidity indicators:

–current ratio (Current Ratio) is an indicator that assesses the company's ability to pay off short-term obligations:

$$Currtnt\ Ratio = \frac{Current\ Assets}{Current\ Liabilities} \tag{3.15}$$

where Current Assets are current assets,

Current Liabilities –Current liabilities.

– quick liquidity indicator (Quick Ratio) – an indicator that assesses the company's ability to repay short-term obligations through the sale of liquid assets;

$$Quick\ Ratio = \frac{Current\ Assets - Inventory}{Current\ Liabilities} \tag{3.16}$$

where Inventory is stocks.

Profitability:

– return on assets (ROA) shows the ratio of net profit to the average size of total assets for the period:

$$ROA = \frac{EBIT}{Assets} \tag{3.17}$$

– return on sales (ROS) shows the ratio of EBIT to revenue:

$$ROS = \frac{EBIT}{Sales} \tag{3.18}$$

– return on equity (ROE) shows the ratio of net profit to the average amount of equity for the period^

$$ROE = \frac{Net\ \Pr ofit}{Equity} \tag{3.19}$$

– return on fixed capital (ROCE) shows the ratio of EBIT to fixed capital (equity and long-term liabilities):

$$ROCE = \frac{EBIT}{Equity + Dtbt} \tag{3.20}$$

The normative values of the indicators are shown in Table 3.4.

Table 3.4 - Financial indicators of the balanced system for assessment of logistics center activities and their limits

Indicator	Assessment limits
Net discounted income of the project (NPV)	More than 0
Discounted project payback period (DPBP)	More project implementation period
Internal rate of return on equity (IRR on Equity)	More than the required rate of return
Interest Coverage Ratio (ICR)	Greater than or equal to 1, optimally 3-4
Debt coverage ratio (DCR)	Greater than or equal to 1
Loan coverage ratio for the entire loan period (LLCR)	More than 1.2
Cash flow available for debt service (CFADS)	More than 0
Financial leverage (Debt/Equity)	1-2
Level of debt load	No more than 3
Debt to CFADS ratio	comparable to the level of debt burden
Current ratio	1.5-2
Quick Ratio	More than 1
Return on Assets (ROA)	The higher the better
Return on Sales (ROS)	The higher the better
Return on equity (ROE)	The higher the better (with low financial leverage)
Return on Fixed Capital (ROCE)	interest on loans should be below ROCE

Source: compiled by the authors

However, in addition to financial indicators, a comprehensive assessment of the activity of the logistics center requires the presence of non-financial indicators as well. Examples of non-financial indicators in the sections of the balanced scorecard are presented in Table 3.5.

It should be noted that the selected indicators should be measurable, the data for their calculations should be easily obtained and interpreted, and they should not duplicate each other.

Table 3.5 – Non-financial indicators of the balanced assessment system activities of the logistics center

Indicator	Method of calculation, unit of measurement
SECTION "CLIENTS AND MARKETING"	
The size of the client base	The total number of current company's in warehouse of the logistics center, pcs.
Market share (in terms of value (UAH), natural (pieces) or number of customers)	(Volume of logistics center sales/Volume of market sales)*100.%
The share of small and medium-sized companies from the total number of companies	(Small and medium-sized companies in the logistics center / Total number of company's in warehouse of the logistics center) * 100%
Expected revenue per customer (for each customer lifecycle)	Income from the client - Costs for attracting and keeping the client, UAH.
Brand awareness (in the target market)	(Number of potential customers aware of the brand/Number of potential customers) * 100%
Number of new customers (by service type)	The total number of new customers for the period, pcs
Level of satisfaction with the offered services (NPS index)	Survey of customers about the quality of service on a 10-point scale (0-6 points - critical customers, 7-8 points - neutral, 9-10 points - promoters), the higher the proportion of promoters, the higher the indicator
Number of complaints (by types services)	The number of claims received from customers during the period, pcs.
The average annual growth rate of prices for services	(Prices of the current date – Prices of the base date)/Prices of the base date, %
Timeliness of order fulfillment	(Number of timely completed orders / Number of orders)*100, %
SECTION "BUSINESS PROCESSES"	
Average time to process a customer's order	Number of orders/Number of workers days per month, orders per month
The number of projects completed by the logistics center	Number of publications about completed projects, pcs.
Average project completion time by the logistics center	Number of days/Number of projects, days
Relative deviation of costs from calendar plans of projects	(Deviation from the calendar plan/Basic cost of planned works) * 100%
Production per employee	Cost of service implementation/Average number of employees (per month), hryvnias/person. in the month
Focus factor	(Employee time to complete the task/Total working time) * 100%
Added value of the product/service	Price after processing - Price before processing, hryvnias.
Expenses on marriage	(Loss from defects/Product cost) * 100%

Continuation of the Table 3.5

SECTION "PERSONNEL"	
Number of jobs	The number of workplaces on the current date, pcs.
Equipment utilization ratio	Number of active equipment/Number of available equipment
Prospective number of jobs	The number of workplaces according to the plan, pcs.
Staff turnover of key competencies (for the period)	(Number of dismissed employees/Total staff) * 100%
Implementation of strategic competencies of the logistics center	(Actual number of employees of relevant specialties/Planned need of the logistics center for them)*100, %
Educational level	Evaluation based on the literacy index (2/3 of the weight) and the index of the total share of employees studying (1/3 of the weight)
The speed of closing vacancies	Number of closed vacancies/Number of vacancies that have appeared
Implementation of the employee certification plan	(Number of certified employees / Number of planned for certification)*100, %
Implementation of the qualification and career development plan for employees of the logistics center	(Number of employees who have undergone training/Number of employees scheduled for promotion)*100%
Personnel training costs	Expenses for courses, trainings, promotions qualifications, etc., hryvnias
"ENVIRONMENT"	
The number of implemented proposals regarding improvement of activity	(Number of registered offers/Number of accepted for execution)*100, %
Frequency of published press releases	The number of published press releases during the period
Spending on R&D and market research	The amount of costs for the development of a new product, service, research, etc., UAH.
Implementation of new services	Number of new services, pcs.
Share of automation costs	(Automation costs/Total cost structure) * 100%
The number of completed social projects	Number of implemented social projects, pcs.

Source: compiled by the authors

In addition to the activities of the logistics center, it is necessary to evaluate the efficiency of logistics operations performed by the logistics center in relation to its customers and partners according to the sections of the balanced

scorecard. We include the following groups of indicators: supply indicators, production indicators, finished product distribution indicators, transportation indicators, inventory management indicators (Table 3.6).

Table 3.6 – Indicators of the evaluation of the result of the logistics activity of the logistics center

Indicator	Method of calculation, unit of measurement
Supply indicators:	
Number of suppliers	The number of suppliers of the logistics center, pcs.
Volume of purchases	The total number of delivered goods and material values and components, pcs.
Average order volume	Total volume of sales/Total number of orders, UAH.
The degree of reliability of the supplier	(Number of needs met in a timely manner/ Total number of needs in materials) * 100%
Losses from missing materials	Production stoppage losses/Quantityof missing materials, hryvnias/pc.
Time of receiving a product unit	Total time of receiving goods/Quantity of supplies per month, hour/pc.
Costs of receiving a unit of goods	Total costs for receiving goods/Number of deliveries per month, hryvnias.
The share of supply costs from the total logistics costs	(Delivery Costs/Total Logistics Costs)* 100%
Quality of products supplied	(Number of delivered materials that contained defective elements/Total number of delivered materials) * 100%
Part of the cycle of material support	(Material support cycle time / Contractual order cycle time) * 100%
Production indicators:	
The share of production costs from total logistics costs	(Production costs/Total logistics costs) * 100%
The number of goods and material values in production	The total number of goods and material values and components in production, pcs.
Average production downtime caused by incorrect logistics	The number of minutes (hours) when lines were stopped due to low efficiency of logistics
General productivity of logistics	The number of shipped finished products /Total number of man-hours worked, unit units/person-hour
Coating of finished products	Volume of goods and material values at the current moment/Projected volume of sales by product item, days
Coating of raw materials and materials	Volume of goods and material values at the moment/Volume of production by commodity item, days

Continuation of the table. 3.6

Total fixed costs	Total tax costs operations, UAH
Accuracy of demand planning for finished products	(Actually shipped volumes from each commodity item/Planned shipments from each commodity item since the approval of the initial sales plan) * 100.%
Part of the product manufacturing and assembly cycle	(Product manufacturing and assembly cycle time/Contractual order cycle time)*100%
Volume of work in progress	(Volume of work in progress/Costs for the purchase of materials + Total production costs) * 100%
Production efficiency	(Total regulatory time of production and assembly of all products/Total actual time of production and assembly of all products products) * 100%
Indicators of the distribution of finished products:	
Number of recipients	Number of recipients, pcs.
The share of costs for the distribution of total logistics costs	(Distribution costs/Total logistics costs) * 100%
Quality of shipped products	(Number of shipped products with defects /Total number of orders) * 100%
Timeliness of cargo deliveries	(Number of orders shipped on time/Total number of completed orders) * 100.%
Duration of the production and commercial cycle	(Commercial Cycle Time/Contractual Order Cycle Time) * 100%
Part of the distribution cycle	(Distribution Cycle Time/Contractual Order Cycle Time) * 100%
Implementation of the shipment plan	(Volume shipped from warehouse/Volume of planned shipments)*100, %
Completeness of the volume of supplies	(Number of consecutive customer orders that can be delivered on time in full/Total number of consecutive orders) * 100%
The number of claims for the supply of products	(Number of claims/Total number of orders)*100, %
Transportation indicators:	
Average distance of transportation	Mileage with cargo/Number of trips, km.
Number of vehicles	Number of logistics center's own vehicles, pcs.
Average vehicle cycle time	The average value of the total time of loading products of all trucks (time counting starts from the time of arrival of the vehicle), min.
The timeliness of the vehicle's arrival	(Total number of all vehicles arriving on time/Total no of planned vehicles)*100, %

Continuation of the Table 3.6

The number of vehicles used at full capacity	(Total number of maximum loaded vehicles/Total number vehicles) * 100.%
Costs for transportation of raw materials	Total costs for transportation of raw materials /Total volume of finished products, hryvnias/pcs.
Costs for transportation of final products	Total costs for primary transportation / Total primary volume of finished products, hryvnias/pcs.
The share of transport costs in the total logistics costs	(Transport costs/General logistics costs)* 100%
Average cargo weight	Total weight of shipped finished products / Number of shipped machines of the same type, kg
The speed of cargo shipments	The average number of kilometers traveled during 1 hour of the vehicle being in the outfit, km/h.
Inventory management:	
Number of warehouses	Number of warehouse complexes, pcs.
Number of nomenclature items	Number of nomenclature items, pcs.
The degree of utilization of the maximum capacity of the warehouse	(Total number of placed pallets / Maximum storage capacity in pallet spaces) * 100%
Useful capacity of warehouse equipment	Actual use of motor resource of forklifts/Total amount of available motor resource of forklifts*100%
Productivity of cargo operations	Total number of loaded pallets /Total number of man-hours spent on loading, pallets/man-hour.
Productivity of unloading of raw materials and materials	Total number of unloaded pallets/Total number of man-hours spent on unloading, pallets/man-hour.
Warehouse losses (expiration, damage, combat, warehouse regulation)	Total losses of finished products due to logistics,hryvnias/piece
Potential of direct loading of finished products	Percentage of finished products loaded directly from the palletizer to the truck (out of storage)/Total volume of stored products, %
Product expiration date management	(Finished products with an expired shelf life/Total amount of finished products stored in the warehouse) * 100%
Amount of total working capital	The total value of all stored goods and material values, expressed in full cost price of goods and material values, hryvnias

The end of the Table 3.6

The time of unloading of raw materials and materials	Total time spent on unloading of raw materials and materials, min.
Productivity of forklift drivers during loading and unloading	The total number of pallets moved / The total number of man-hours worked by forklift drivers, pallets / man-hours.
Share of returns of finished products	(Total returned volume of finished products/Total shipped volume of finished products) * 100%
The share of storage costs in the total logisticflow rates	(Storage costs/Total logistics costs) * 100%

Source: compiled by the authors

Also, determining the efficiency of the operation of logistics centers, it is necessary to assess the state of its infrastructure (Table 3.7).

Table 3.7 – Indicators for assessing the state of logistics infrastructure

Indicator	Unit
The total area of the logistics center and each zone separately	Ha
The possibility of expanding the territory of the logistics center and each zone separately	Ha
Area of cross-docking warehouses	thousand square meters
Percentage of filling of available areas	%
The number of railway tracks	piece
Useful length of railway tracks	m.
Container capacity of the terminal	TEU
Current and maximum bandwidth	TEU/year
Composition of the fleet (number of container carriers, etc.)	piece
Number of change declarations processed by customs	piece/change
A number of trailers are available for placement in the parking area	piece
Distance to the largest cities	km
Distance to the airport, railway station, port	km
Distance from industrial and residential areas	km
Estimated transit time on the way from the nearest big city	hours
Capacity utilization of logistics facilities	%

Source: compiled by the authors

We propose to evaluate the indicators of the organizational and management activity of logistics centers (Table 3.8), which are non-formalized indicators, using the method of expert evaluations. The values of the indicators

are determined by scoring points (on a scale from 0 to 10) by experts in accordance with the verification of the availability of documentation, monitoring data of the technical condition of buildings and equipment, inspection of buildings and territory, verification of claims, accidents and deadlines for their elimination.

Table 3.8 – Indicators of evaluation of organizational and management activities of logistics centers

Indicator	Coefficient importance	Calculation method
Work to ensure the required level of equipment performance	0.20	Scored on a scale from 1 to 5 in accordance with the rules and regulations. 5points - excellent quality of service work (full compliance); 4 points – good quality (compliance with basic parameters); 3 points – satisfactory quality (conformity only in the most important parameters); 2 points – acceptable quality (non-compliance with one of the main parameters) 1 point – unsatisfactory quality (complete discrepancy).
Maintenance of the territory	0.20	
Provision of services	0.20	
Financial and economic activity	0.10	
Training of management company employees	0.10	
Quality of management	0.10	
Logistics center development activities	0.10	

Source: compiled by the authors

For each indicator, the coefficient of significance is determined (in Table 3.8, calculated according to a survey of representatives of management companies of logistics centers[18]) and the average score is calculated taking into account the significance factor (the sum of experts' points, divided by the number of assessments, multiplied by the significance factor).

[18] Logistics in Ukraine https://logistics-ukraine.com/category/rubrication/storage-warehouses/

The score is set according to the average total score for each indicator: up to 4 points – unsatisfactory, 5 points – satisfactory, between 6 and 7 points – average, 8 points – good, 9 points – very good and 10 – excellent.

Ranking is done using the Fishburne rule:

$$r_i = \frac{2(N - i + 1)}{(N - 1)N} \tag{3.21}$$

Thus, the analysis of the activities of the logistics center involves the complex, systematic use of indicators for all four groups, in order to comprehensively and objectively investigate the economic, logistical, and organizational-management activities of the logistics center.

CONCLUSIONS

The work presents a systematic approach to issues of formation, operation and development of logistics centers in accordance with modern requirements for logistics infrastructure and expanding the range of logistics services.

In the course of the dissertation research, the following scientific and practical results and conclusions were obtained:

1. Modern logistics centers play an important role in the implementation of international and domestic transportation by functions and volume of services that provide added value, consolidate the activities of warehouses, terminals and distribution centers. For the development of the country's transport and logistics system, it is necessary to improve the customs clearance of goods, develop international and intermodal transportation, create a modern logistics infrastructure and increase the efficiency of logistics business processes.

2. Based on the analysis of foreign and domestic literature, classification features are formulated that fit the modern understanding of the logistics center. Classification of logistics centers according to the developed characteristics: according to the scale of the territory, according to the types of transport involved, according to the type of ownership, according to the size of the occupied territory and performed functions, according to the type of cargo processed, in relation to the port, according to the nature of the specialization of the terminals in the logistics centers, allows you to organize the terminology and fully cover the variety of their types.

3. A key issue regarding the organization of a logistics center is determining its location. The paper proposes an analytical hierarchy method for location selection. In order to organize the interaction of business units of the logistics center, the work presents a multi-criteria model of residency dislocation, which allows to achieve a reduction in the operational and

transportation costs of residents, and a reduction in supply costs.

4. Logistics center project management can be divided into three main phases: the pre-investment phase, which is the analysis of opportunities and the development of a business plan, the investment phase, during which negotiations and commissioning work are carried out, and the operational phase, which is responsible for the launch of the project and further expansion.

5. The most successful projects of logistics centers are projects implemented within the framework of PPPs, the participants of which can be ministries and state bodies, developers and residents, transport infrastructure and various tenants. The logistics center design scheme under PPP is different from the typical one and consists of the following stages: concept development, feasibility study and design, release of request for qualification and/or request for proposal, contracting, design, construction and maintenance. The proposed reference model of the process of formation of logistics centers within the framework of PPP with financial substantiation of project results enables the project stakeholder to make effective decisions regarding the formation of a logistics center.

6. Based on the analysis of the structuring and functioning of the logistics center, the indicators for evaluating the activity of logistics centers were systematized, the ways of choosing the composition of indicators were substantiated, which makes it possible to increase the effectiveness of the analysis of strategic and tactical processes of managing the logistics center and ensure its systematic development. To evaluate the operation of logistics centers, you can use a balanced system of indicators, which can be divided into four sections: finance, customers, business processes, training and development. It is recommended to use no more than forty indicators, most of which are financial. In addition to SSP, it is also possible to evaluate indicators of logistics activities (supply, production, distribution, transportation and inventory management) and to evaluate location criteria (organizational and infrastructural).

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