


Article

Logistics Centers in Ukraine: Analysis of the Logistics Center in Lviv

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Abstract: The article analyzes the functioning of existing logistics centers in Ukraine. The logistics real estate segment was developed dynamically in Ukraine in the years before the full-scale invasion of Russia. Most logistics complexes are located in the Kyiv region, sometimes in the cities of Kharkiv, Odesa, Dnipropetrovsk and Lviv. Logistics real estate has suffered significant damage since the start of the war, and some warehouses have been completely destroyed. In order to fulfill a coordinating and integrating role in the implementation of logistics operations in the western region of Ukraine, the authors proposed the creation of a powerful regional logistics center in Lviv. The operation of the center will ensure the provision of a full range of logistics services based on the criterion of minimizing the loss of time and money. The authors proposed an algorithm for determining the optimal location of the logistics center in the region. The regional logistics center has been developed, together with its organizational and functional structure and the relationships between its components.

Keywords: logistics centers; Ukraine; regional LC; warehouse

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1. Introduction

For Ukraine, integration into the European transport system is a highly important strategic task. In the modern conditions of the functioning of the market economy of Ukraine, the issue of the formation of logistics centers becomes especially relevant. For settlements located on trade routes and crossroads, the emergence of logistics centers means large trade revenues, and sometimes real economic growth. Therefore, in serving its own products or providing large warehouse areas with the most modern equipment and parking for vehicles, a logistics center is an international trade entity that attracts international manufacturers, transport companies and 3PL operators. Logistics centers provide a full range of logistics services at the level of world standards in order to increase cargo flows and improve the quality of logistics services.

The aim of the paper is to analyze the current state of development of logistics centers in Ukraine and develop practical recommendations for optimizing the material flows of the region on the basis of logistics by creating a regional logistics center in Lviv.

Inadequate supply of logistics centers in the country has led to inefficient management of logistics flows. This affects the quality and timeliness of the delivery process; the rate of transformation of the material flow; qualitative characteristics of logistics operations; speed of turnover within the country; the degree of benefits that the consumer receives in the form of value-added services; and transportation costs and costs related to the storage of material resources.

An intermodal logistics center is a logistics infrastructure such as industrial and logistics buildings located in a secure environment, where each user provides a range of ancillary services such as container repairs. It allows a high degree of accessibility and transfers cargo from one mode of transport, e.g., ships, to another—including road, rail and

others, generating fewer negative environmental impacts [1,2]. One of the most important tasks in raising the level of efficiency of the sectors of manufacturing enterprises is the continuity of supplying the entities with necessary raw materials, fuels, materials and semifinished products [3–5]. The solution to this problem requires improved support for warehousing, logistics and transport communication infrastructure, as well as the creation of an effective system for managing the circulation of goods and raw materials [6]. This is determined by the level of logistical support for the delivery of products from the warehouses through an optimal system for their movement [7–10]. Road and rail transport services account for the largest share of the total volume of domestic freight transport services: in the case of Poland, they provide 90%, and in the case of Ukraine, more than 60% of the total freight turnover. Freight volumes from warehouses will increase due to small deliveries to points of sale [11,12]. The efficiency of e-commerce businesses relies heavily on efficient logistics services such as cross-docking due to the huge number of small orders involving geographically dispersed customers who have high service expectations, especially in terms of delivery times. It is difficult for logistics operators to increase their capacity in the short term to accommodate the rapidly increasing fulfilment requirements. Logistics companies are using existing resources more efficiently. In this article, we propose delivery synchronization as a new solution in Lviv to further enhance the operation and smooth handling of orders at the LC (logistics center). The LC is one of the key transshipment hubs in the logistics service network [13–15]. Freight transport efficiency is growing rapidly. The sector is also one of the biggest producers of atmospheric emissions. The problem of transport emissions is particularly important for city dwellers due to transport congestion, which is why the concepts of sustainable city logistics and green logistics are emphasized today. Logistics operators should be concerned with reducing the amount of emissions produced [16–18]. For any city, especially Lviv, the emissions produced during the design period of the logistics center are very important.

For example, such scientists as Higgins C., Ferguson M., Kanaroglou P. [19], Kovtun T., Smokova T., Kovtun D. [20] and Wagener N. [21] have studied the theoretical and applied aspects of the functioning of logistics centers.

The implementation and operation of transport and logistics centers in different countries is considered by Mandra V. [22], Mashkantseva S. [23], Mindur M., Turoń, K., Sierpiński, G. [24], Kolesnikov V., Chupryna N., Garkysya V., Kuchkova O. [25], Lukyanova O., Krivtsun D. [26] and others.

The selection of the location of logistics centers is considered in the works of such scientists as Lyfar, V. V. [27], Uyanık C., Tuzkaya G., Oğuztimur S. [28], Muravev D., Hu H., Zhou H., Pamucar D. [29], Battal T. [30] and others.

Lyulchak Z., Danyltsiv O. [31] investigates the state of development of logistics centers, describes their characteristics and outlines the prospects for the development and attractiveness of these objects on the territory of Ukraine. The main obstacles in the creation and development of modern logistics centers are analyzed by Zagorodnia Y. [32].

Kovtun T. and Smokova T. [33] consider the specific features of logistics center creation projects and pay attention to integration risks in projects with a large number of participants. Kucera T. [34–37] draws attention to the following aspect concerning logistical coordination and thus the synchronization of material, information and financial flows, which are monitored by various organizational units and are highly diverse and often contradictory. Logistics is not an end in itself, but is part of every company's strategy, both as a customer-oriented business management concept and a rationalization tool. Warehousing and the related costs play an important role in all aspects of supply chain management.

The ability to provide customized services is a key factor for the success of LC and the entire supply chain, in which the LC is a link. This ability also motivates LCs to automate and implement innovative IT technologies to improve their efficiency and product processing [38–41]. Customer analysis of the demand for fast delivery and variety of small-batch products through human-resource-dependent logistics operations in online marketplaces is sometimes impossible to predict. Logistics robots in fulfilment centers are

expected to undertake more responsibilities due to difficulties in hiring staff and rising labor costs. Amazon operates more than 100,000 robots in its fulfillment centers. Alibaba, UPS and DHL have introduced full automation to improve logistics efficiency [42–48].

The logistics service industry [49–51] is a customer-oriented consumer market, and the ability to identify customer needs and meet them is analyzed, which is important for the competitiveness of companies and the growth of their market share. Therefore, it is very important for service providers [52–54] to identify the factors that influence the quality of service as perceived by customers and, at the same time, when there is a discrepancy between them, for the logistics service provider (LSP) to constantly propose new solutions to improve service quality.

Regional logistics centers are an important element of the logistics system of Ukraine, providing internal and external logistics service needs and playing a coordinating and integrating role in the logistics system and transportation loads. Therefore, special attention was paid to the issue of formation, functioning and development of logistics centers in regions, the activities of which will contribute to the improvement in the organization of transportation and provision of comprehensive service to consumers of warehouses and transport services. The creation of logistics centers on the western border of Ukraine is an important tool for the effective use of the geopolitical potential of the border areas.

Solving this problem requires improving the support of the logistics infrastructure, as well as creating an effective system for managing the flow of goods. Practical aspects of the formation of logistics centers require further research. Since current conditions require new approaches to the formation of logistics centers in Ukraine, the research topic is relevant.

2. Research Methods

The development of logistics centers of Ukraine today is an urgent problem due to the imperfection of national logistics capacities. This has become one of the most important reasons for the decrease in the attractiveness of Ukraine as an international transit country, namely for European markets. The conducted analysis of the functioning of logistics centers in Ukraine indicates their slow development. Most of them are concentrated only in the Kyiv region, sometimes in the cities of Kharkiv, Odesa, Dnipropetrovsk and Lviv. The purpose of this study was to check and possibly specify these data for Ukraine.

Since the beginning of Russia's full-scale war against Ukraine, the logistics infrastructure of Ukraine has suffered significant damage. The greatest losses were suffered by those regions where the fiercest battles took place or are still going on—the Donetsk, Luhansk, Kyiv, Chernihiv, Sumy, Kharkiv, Kherson, Mykolaiv and Zaporizhia regions. In total, today almost 23,000 km of roads and 300 bridges and overpasses have varying degrees of damage and destruction caused by the war, and dozens of railway bridges have been blown up. The damage exceeds USD 100 billion, and it will take at least two years to recover. Due to the war in Ukraine, there are serious problems in the global food supply chain. According to the authors, one of the ways to solve the problem is the formation of a logistics center in the western region of the country, in particular in Lviv, which is currently quite safe. Ukraine's long-term goal is to build a competitive economy within the European Union and attract investments in the country's development for the next few decades.

The advantages of logistics management have been studied and presented by numerous researchers and practitioners. In order to increase their competitive advantage, many companies consider the logistics system as an important tool for their operations. Under these conditions, building long-term relationships between economic regions and customers is a critical success factor in establishing a logistics system. Therefore, the selection of the LC location becomes the most important issue in the implementation of a successful logistics system and economic connections. In the decision-making process, the use of LC location variables is very beneficial. In other words, it is very common to use descriptive variables instead of numerical values when evaluating possible regions in terms of criteria and importance weights.

3. Materials and Results

Although the warehouse real estate market has only just begun to develop in Ukraine, some companies and logistics operators are investing in the construction of large logistics centers. Such complexes are huge areas of warehouses, offices and administrative buildings with developed infrastructure.

The logistics real estate segment developed rapidly in Ukraine in the years preceding the full-scale invasion of Russia. One of the main drivers of the warehouse sector today is the rapid growth of the e-commerce segment. Let us analyze the largest warehouses in Ukraine as of 2021 (Table 1).

Table 1. The largest warehouses in Ukraine, 2021.

No.	Object Name	Location	Area, sq. m
1	Logistic center “RLC-Kvitneve”	Kvitneve, Kyiv region	129,400
2	Warehouse complex “BF Terminal”	Martusivka, Kyiv region	128,336
3	Logistics complex “MLP-CHAYKA”	Chayky, Kyiv region	115,000
4	Logistics complex “AMTEL PROPERTIES”	Bilogorodka, Kyiv region	100,208
5	Logistic center “Kalyinivka”	Kalyinivka, Kyiv region	100,000
6	Logistic center “West Gate Logistic”	Stoyanka, Kyiv region	96,455
7	Warehouse complex “Unilogic Park”	Brovary, Kyiv region	75,000
8	Warehouse complex “Protec Zymna Voda”	Zimna Voda, Lviv region	73,000
9	Warehouse complex “Raben Ukraine”	Velika Dymarka, Kyiv region	70,000
10	Logistics complex “Komodor”	Kalyinivka, Kyiv region	69,000
11	Logistics complex “Odesa Logistics Park”	Dachne, Odesa region	64,600
12	Logistics complex “Makarivskyi”	Kolonshyna, Kyiv region	61,992
13	Logistics complex “EAST GATE LOGISTIC”	Boryspil, Kyiv region	49,716
14	Lviv logistic center PORT	Lviv, Lviv region	46,000
15	Logistic center “RLC-Odesa”	Dachne, Odesa region	36,000

Source: based on TOP-14 largest warehouses in Ukraine [55].

Most of the logistics complexes listed in the table are located in the Kyiv region because this is where the offices of the largest Ukrainian and international companies, industrial facilities and distribution centers are located. Air and rail connections are developed here, and highways of national and international importance pass through it. Logistics complexes are also located in Odesa. This location was previously advantageous due to its proximity to the Odesa trade port, the largest port in Ukraine. However, Ukrainian ports are currently blocked, which negatively affects the operation of the logistics complex. In recent years, large logistics centers have also been built in the Lviv region. Their location is strategically important for companies whose activities are related to EU countries.

Modern warehouse complexes are huge areas where, in addition to the warehouses themselves, there are parking lots, convenient access roads for freight transport, loading and unloading areas and household and office premises. These complexes have everything you need to work with various products of large volumes.

Business requests for such complexes are growing, and subsequently the number of such offers on the warehouse real estate market of Ukraine will increase. As the demand for high-class storage facilities is growing, developers are investing in the development of modern logistics parks. These are objects that fully meet the requirements of modern warehouse logistics [55].

In total, about 200,000 sq. m of warehouses were built in Ukraine in 2020. In first place in terms of volume was Lviv, where more than 100,000 sq. m (49%) were built, 60,000 sq. m of which comprise the logistics complex Protec Zymna Voda (Figure 1).



Figure 1. Geographical structure of warehouses built in Ukraine in 2020. Source: own data.

In 2021, according to Cushman & Wakefield, 130,000 sq. m appeared on the warehouse and logistics real estate market in Kyiv and in the suburbs of the capital (Table 2).

Table 2. Main objects of warehouse and logistics real estate put into operation in Kyiv and its suburbs in 2021.

Name	Location	Developer	GLA, sq. m
Logistics complex	M-04, E40 (Kyiv–Boryspil highway)	ADG	62,000
Logistics and office complex “Makarivskiy” (phase 2)	M-06, E40	ADG	13,600
Logistics complex FM Logistic (phase 4, sections 1–2)	Brovary–Boryspil ring road	FM Logistic	17,600

Source: own data based on logistics real estate 2021 [56].

By the end of 2021, more than 140,000 sq. m in Kyiv and its suburbs were at the development stage and were to be completed in 2022. In addition to Kyiv, in 2021, warehouse and logistics facilities began to be built in Dnipro, Odesa, Lviv and Kharkiv. Given the lack of supply, experts note the low vacancy rate. At the end of the third quarter of 2021, it was 2.3% (Table 3).

Table 3. Rental rates and vacancy of warehouse premises in Ukraine, 2019–2021.

Indicators	Warehouse Location	Years			Percent of Deviation in 2021 from	
		2019	2020	2021	2019	2020
Rental rates, USD	Kyiv	5.05	5.15	5.5	108.9	106.8
	Ukraine	2.9	3.5	3.8	131.0	108.6
Vacancy rate, %	Kyiv	1.7	2.2	2.3	135.3	104.5
	Ukraine	6.3	5.5	6.0	95.2	109.1
Total market volume, million sq. m	Kyiv	1.92	2.0	2.1	109.4	105.0
	Ukraine	3.8	4.1	4.2	110.5	102.4
New offer, sq. m	Kyiv	42,000	76,500	44,500	106.0	58.2
	Ukraine	85,000	208,500	100,000	117.6	48.0

Source: own data based on logistics real estate 2021 [56].

According to the table, it is possible to note a gradual increase in rental rates for warehouse premises. Thus, in Kyiv and the suburbs at the end of 2021, they exceeded in dollar terms the indicators of the end of 2019 by 8.9% and the indicators of 2020 by 6.8%.

In Ukraine as a whole, rental rates for warehouse premises increased in 2021 by 31.0% compared to 2019 and by 8.6% compared to 2020. The vacancy rate in Kyiv increased by 35.3% and 4.5% compared to 2019 and 2020, but it tended to decrease across Ukraine. The total volume of the warehouse market has a tendency to grow, both in Kyiv and in Ukraine as a whole. Every year there are new warehouse spaces offered on the market.

The development of Ukrainian warehouse infrastructure in 2021 largely determined the development of the e-commerce sphere together with the 3PL sphere. Thus, demand from the retail and logistics sectors remained quite high, which stimulated the growth of a number of build-to-suit projects. For example, such companies as “Nova poshta”, “Ukrposhta” and “Rozetka” initiated the construction of new warehouse complexes for their own needs (build-to-suit).

In 2022, in Ukraine, there was a plan to complete the construction and put into operation almost 100,000 sq. m of warehouse space, in particular:

- The first stage of the M06 logistics complex of the Amstar company (32,000 sq. m);
- Industrial park E40 of the Dragon Capital company (21,000 sq. m);
- The second stage of the logistics center RLC II (24,000 sq. m);
- Two small warehouses with an area of about 10,000 sq. m each.

Some of the announced projects are located along the Zhytomyr highway (E40, M06) on the right bank, which indicates the stable popularity of the western direction.

Since the outbreak of the war, logistical real estate has sustained severe harm; some warehouses have even been demolished entirely. The adversary hits warehouses on purpose or uses them to position their occupying camps since they are strategically significant things, which is what caused such severe destruction.

As Fedir Arbuzov, the founder of Watermelon Development, said in his comments to the Interfax-Ukraine agency, Russian troops destroyed more than 440,000 sq. m of logistics real estate in the capital region. The areas where brutal military actions took place were the most affected: the Warsaw direction, Zhytomyr direction and Brovary direction. Since the offer of high-quality logistics real estate (class “A” and “B”) in the capital region reached about 2.1 million sq. m by the end of 2021, it can be noted that more than 20% of the warehouses were damaged by the occupiers [57].

Dmytro Pasenkov, Head of the Department of Warehouse Real Estate at Sushman & Wakwefield in Ukraine, notes that during 2 months of the war in Ukraine, warehouse and logistics buildings worth about USD 1 billion were destroyed [58].

In general, the Kyiv region suffered the following losses [57]:

- The “Foxtrot” warehouse in Gostomel was completely destroyed (almost 30,000 sq. m) as well as a partially destroyed warehouse located nearby (3000 sq. m);
- One of the warehouses of Dragon Capital was badly damaged (9000 sq. m);
- The Bucha terminal (Dragon Capital) was badly affected, with 30,000 sq. m, approximately half, destroyed;
- “Terminal Vorzel” was partially damaged (15,000 sq. m);
- The warehouse of Kuehne + Nagel Ukraine, with an area of approximately 5000 sq. m, was badly damaged and is 90% closed, including office premises in Gorenka;
- The Komodor logistics park (approximately 75,000 sq. m) in Kalynivka was completely destroyed;
- The ATB distribution center in Kopylov (Makariv district) was badly damaged, with a total area ranging from 35,000 sq. m to approximately 10,000 sq. m being destroyed;
- West Gate Logistic, Dragon Capital (parking lot, 100,000 sq. m), was almost completely destroyed (together with the goods of tenants Good Wine, Watsons, Bohnenkamp Ukraine, Ekol Logistics Ukraine and Logistic Plus);
- The “A” class complex, with an area of approximately 20,000 sq. m, of the “Yuta Service” company in Chayky was completely destroyed;

- The Refrigerator Logistic Center (60,000 sq. m, the main tenant of MHP, as well as Fozzy Group) was badly affected;
- The vegetable storage (35,000 sq. m) in Velyka Dymarka is unsuitable for operational activities;
- The logistics center “ATB” (24,000 sq. ms) in Krasylivka, near Brovary, was 80% destroyed.

As mentioned above, on the territory of Ukraine, the placement of warehouse real estate is mostly concentrated around the Kyiv region with a small number of buildings in areas located near the borders and customs. This practice built a chain of movement of goods to the “center”, i.e., the Kyiv region, with subsequent delivery to regional warehouses or to final recipients and consumers, i.e., the movement of goods carried out unnecessary and for extra kilometers after crossing the border or manufacturing. The situation has begun to change in recent years with greater demand for warehouse space in the western and southern regions, and accordingly, the diversification of the warehouse real estate market began to emerge.

Under current conditions, it is promising to further increase the construction of new warehouse complexes, as well as smart logistics centers in the western region, which will be located on the main roads of the border checkpoints. Both those who lost their premises due to the war and those who had warehouses in one city (for example, only in Kyiv) are looking for warehouses in the western region now, and they are diversifying their risks and placing warehouses in several regions [58].

Consider the volume of freight transportation by road transport in the regions of Ukraine in 2021 (Table 4).

Table 4. Freight road transport by region, 2021.

Region	Tonne-Kilometers Road Transport		Volume of Freight Road Transport	
Ukraine	46,429,797.9	100.0	222,572.2	100.0
Vinnitsya	1,211,617.5	2.6	6424.9	2.9
Volyn	2,353,412.5	5.1	5809.5	2.6
Dnipropetrovsk	2,813,662.5	6.1	34,076.6	15.3
Donetsk	594,493.4	1.3	18,786.7	8.4
Zhytomyr	589,729.4	1.3	2106.4	0.9
Zakarpattia	4,321,029.9	9.3	6280.1	2.8
Zaporizhzhya	1,174,584.6	2.5	6928.0	3.1
Ivano-Frankivsk	1,120,044.8	2.4	8311.9	3.7
Kyiv	2,558,818.0	5.5	9680.5	4.3
Kirovohrad	1,035,585.7	2.2	9783.1	4.4
Luhansk	382,468.0	0.8	1732.9	0.8
Lviv	4,434,461.2	9.6	12,672.4	5.7
Mykolayiv	1,203,169.8	2.6	7039.8	3.2
Odesa	2,390,655.0	5.1	11,875.4	5.3
Poltava	1,821,695.5	3.9	8486.3	3.8
Rivne	1,738,676.4	3.7	4893.9	2.2
Sumy	885,499.4	1.9	1990.7	0.9
Ternopil	854,836.3	1.8	4096.1	1.8
Kharkiv	2,668,000.3	5.7	11,607.6	5.2
Kherson	1,094,697.2	2.4	3594.2	1.6
Khmelnyskiy	1,244,270.9	2.7	7304.1	3.3
Cherkasy	2,017,547.3	4.3	7268.4	3.3
Chernivtsi	626,342.6	1.3	1821.0	0.8
Chernihiv	1,073,650.6	2.3	1740.9	0.8
City of Kyiv	6,220,849.1	13.4	28,260.8	12.7

Source: own data based on Ukrstat [59].

As can be seen from Table 4, the largest tonne-kilometers road transport is in Kyiv (13.4%), followed by the Lviv region (9.6%) and Zakarpattia region (9.3%). The volume of

freight road transport is the largest in the Dnipropetrovsk region (15.3% of the total volume of the country), followed by Kyiv (12.7%), the Donetsk region (8.4%) and the Lviv region (5.7%). Therefore, Lviv has significant potential in the transport and storage industry.

In order to fulfill a coordinating and integrating role in the implementation of logistics operations in the western region of Ukraine, we propose the creation of a powerful regional logistics center (LC) in Lviv. The center will function as an accumulation and distribution logistics unit, performing the functions of establishing interaction between modes of transport and organizing material distribution by organizing relationships with consignors, consumers, carriers, forwarders and ensuring timely mutual settlements through banks. The regional logistics center, as an operator of internal cargo flows based on the created information space, will provide effective logistics service for cargo delivery and processing processes and related services in accordance with national standards of transport and forwarding services. The operation of the center will ensure the provision of the entire range of logistics services based on the criterion of minimizing the loss of time and money.

The creation of a regional LC is a complex process that requires a systematic approach, the involvement of qualified specialists, significant investments and taking into account the conditions of a specific region. Therefore, the determination of the location of the LC must be carried out in stages, moving from general decisions to partial ones. The following algorithm is proposed to verify the results of determining the location of an LC in the region (Figure 2). The target value in the model is the optimization of material flows in the region.

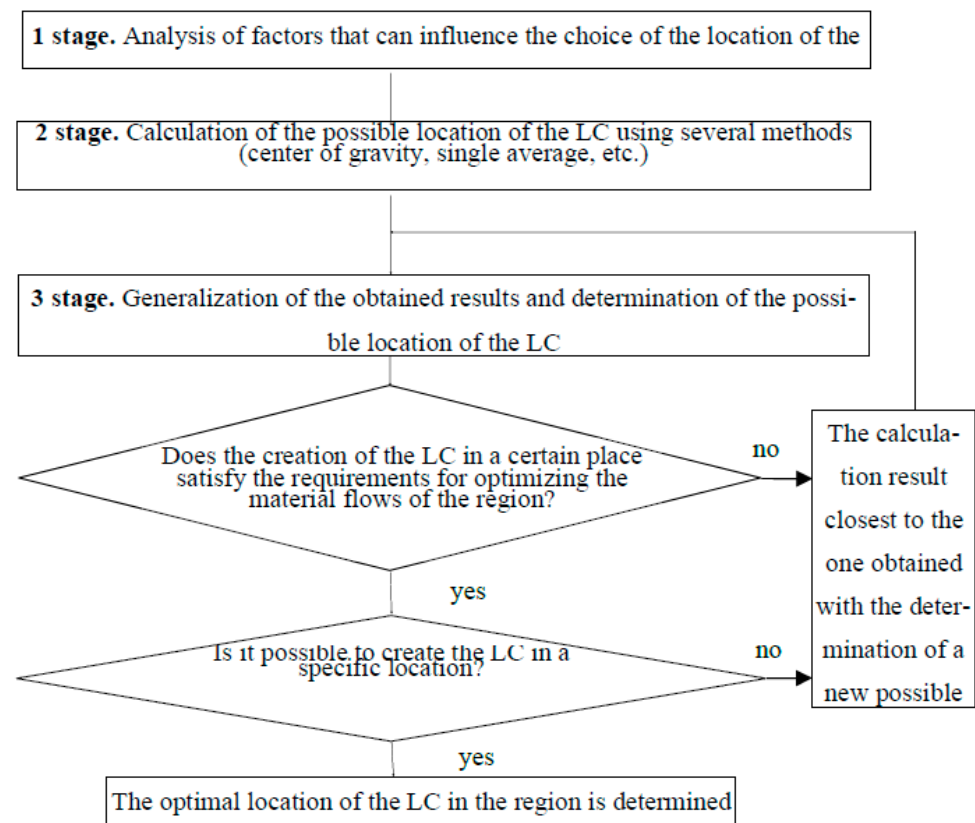


Figure 2. Algorithm for determining the optimal location of the logistics center (LC) in the region. Source: based on optimization of material streams in the region on the foundation of logistic center's creation [60].

A logistics center is a complex system of cargo flows within the same premises or adjacent premises, the main task of which is the timely operational assembly of cargo consisting of different items, which, in turn, are located in different places of one large warehouse, to prepare for their delivery by vehicle to the destination. To ensure such

complex and fast tasks, the use of automation and electronics is necessary, accounting for goods turnover, or in other words, a warehouse management system (WMS), as well as complex racking and transport systems operating in one cycle.

Potential tenants are increasingly using such criteria for choosing a premise.

Innovativeness. More and more objects are being built according to the principle of “green” energy: solar panels are being installed on the roof or on the facade. Mobile applications for facility management are also becoming popular. Now it is possible to let cars into the territory remotely, receive utility payments and turn on the lighting in the warehouse and not spend any effort on it.

Versatility. This consists of the possibility of reconstructing the warehouse for the individual needs of the tenant, for example, added capacity and conversion of premises for production.

Autonomy. This gives the tenant the opportunity to build his “energy system”, where he does not depend on utility energy carriers and energy load. In addition, the resident has his own parking and a separate entrance to the territory.

Complexity. Modern complexes satisfy a much larger volume of needs than just premises for work or shopping. The need to work in high-quality premises with a high level of service and operation services has already been voiced by more than half of tenants. The availability of quality food, showers, changing rooms, places to rest, convenient transportation and even a well-thought-out design of storage facilities can significantly affect the engagement and turnover of staff.

Design. The original design is one of the key components of a modern warehouse real estate project. Good design attracts more attention, increases satisfaction with being in the building and provides a nice area in which to host partners and customers, which ultimately leads to commercial success [56].

For the optimal solution to logistics problems, the logistics center should include the following divisions (Figure 3).

Increasing the efficiency of distribution logistics results in a further reduction in emissions. This will contribute to the global goal of reducing the production of harmful emissions from road transport. The scheduling of vehicles in the LC was proposed as an optimization problem in terms of the parameters: environmental protection, space utilization and logistics operating costs. The low-emission zones in the Lviv LC and their introduction have, in addition to the primary effect, i.e., the creation of low-emission areas, several secondary and tertiary effects. The main denominator among these consequences is that carriers must be outfitted with modern vehicles in order to realize distribution in urban areas with low emission zones. Modern vehicles not only emit less, or produce no direct emissions, but also provide a higher level of safety. This is a passive or active safety component. The introduction of low-emission zones can indirectly result in an improved road accident balance. The introduction of low-emission zones and creation of a new logistics center in Lviv is not the only determinant of the amount of emissions produced. Logistics operators who would be entrusted with the construction of the logistics center would be obliged to use low-emission vehicles for the distribution of goods in Lviv. All of the world’s leading commercial vehicle manufacturers now offer vehicles with alternative drive options. In the light commercial vehicle segment in particular, there is a wide variety of vehicles for specialized needs. The delivery of parcels of various sizes, including mail using a split-load space for the urban distribution of chilled and frozen products, depends on these vehicles in last-mile distribution logistics systems. The majority of vehicles in the light commercial vehicle segment in Western Europe are battery electric vehicles (BEVs) [61]. In the heavy commercial vehicle segment, electric vehicles have been developed, some of which are commercially available in test mode. In the 2030 horizon, most of the leading manufacturers will launch zero-emission electric vehicles.

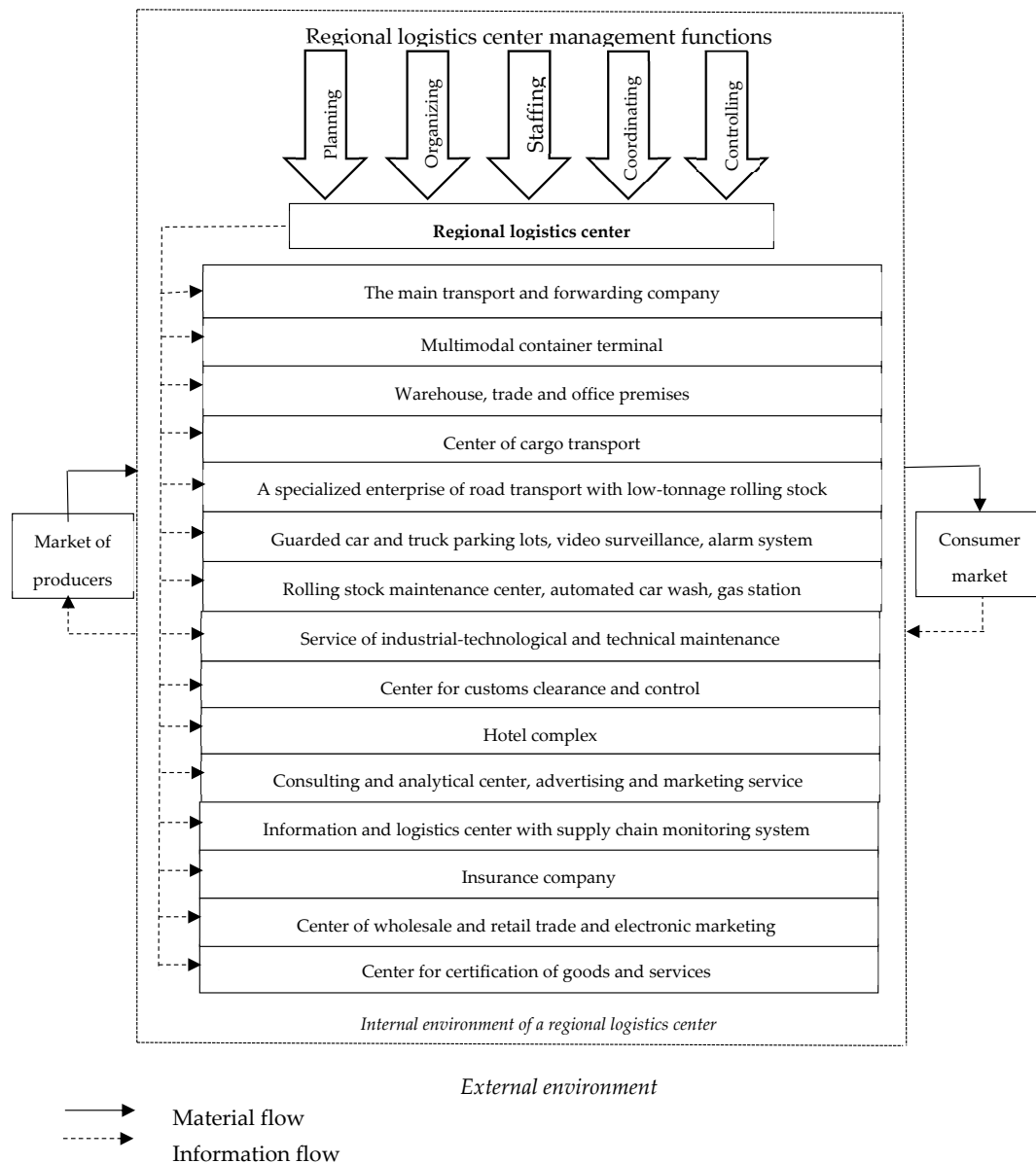


Figure 3. Organizational and functional structure and interrelationship of elements of the regional logistics center. Source: own data.

One segment of the city's green or ecological zones is the low-emissions zone (LEZ), which aims to minimize or significantly reduce air pollution from motor vehicle exhausts and restrict the entry of air-polluting motor vehicles into the urban zone. LEZs are becoming increasingly common globally, and not only in cities, as people are aware of the negative impact of cars on the quality of life and infrastructure. LEZs were introduced in Sweden in 1996 as a first step. Outside Sweden, an LEZ was introduced in the Mont Blanc tunnel between France and Italy in 2002. LEZs were implemented in several cities in Germany, the Netherlands, Northern Italy and London between 2007 and 2008. Since then, the number of LEZs has grown steadily, and they now exist in many EU countries. In Europe, there are more than 260 LEZs in various cities. In Germany, 58 low-emission zones have been introduced since 2018, and this number will continue to grow. The zone requirements have changed several times since then. New emission categories were introduced in 2019, including for EURO 6 trucks. These stricter emission categories will lead to the creation of a ULEZ, or an ultra-low-emission area. France has committed to creating a ULEZ with cleaner mobility and air quality by 2020. All diesel vehicles will be banned from entering

the zones until 2024. Petrol vehicles will be allowed to enter for six more years, i.e., until 2030. The construction of LEZs and ULEZs in Europe will reduce the burden of emissions on the territory and improve the quality of life for the population in the area and Lviv.

The most important element of the LC is the LSP. The regional logistics center can become a source of growth of the main competitive advantages of the region.

Such advantages can be:

- Development of the region's infrastructure;
- Growth of added value in the gross product of the region;
- Growth of the revenue part of local budgets;
- Rationalization of transport flows;
- Intensification of trade;
- Activation of export–import relations and transit;
- Creation of new jobs;
- Significant increase in direct investments in the real sector of the economy, which will ensure dynamic economic development of the region.

The main scientific results of the study are that it has improved the organizational and functional structure of the regional logistics center and shows interrelationship of elements of the internal and external environment of the regional logistics center. An algorithm is proposed for determining the optimal location of the LC in the region, which includes the analysis of factors that can influence the choice of the location of the LC, calculation of the possible location of the LC, generalization of the obtained results and determination of the possible location of the LC. A number of main competitive advantages of the region have been determined, the source of growth of which can be the proposed regional logistics center in Lviv.

4. Discussion

Under modern conditions in Ukraine, there is a large number of negative factors that affect the process of forming logistics centers and slow down their development in general. However, the creation and development of logistics centers in Ukraine is a favorable basis for the European integration of Ukraine, as it inevitably leads to an increase in the volume of foreign economic trade operations, due to the perfection of the system of cargo passage, their registration and processing, which will lead to an increase in the competitiveness of the national economy and will contribute to the attraction of foreign investments.

Taking into account their geographical proximity to Europe, the location of transport corridors and international cargo flows, in addition to increasing the level of logistics infrastructure, will not only allow Ukrainian companies to improve the level of their services, but also positively affect the development of international logistics under conditions of close cooperation between logistics centers and complexes of Ukraine and its neighbors.

Research on the location of logistics centers has been conducted by researchers in China [62–64]. This seems to be due to the size of the country and the growth of the e-commerce market through online intermediaries (Aliexpress, Alibaba). In addition, there are such studies from Kazakhstan [5] and Austria in the recent literature [2]. Ukraine has so far had many regional logistics centers built by logistics operators. The location of an international logistics center in Lviv could contribute not only to the development of Ukraine and in overcoming the crisis after the war, but also the exchange between the country and the European Union.

The location of the LC is a key element in increasing the efficiency of urban freight transport systems and within the implications of supply chain operations. Therefore, the location of the intermodal LC should be analyzed; otherwise, it may cause irreversible consequences in city planning and may create bottlenecks that lead to a rapid increase in the cost of providing transport solutions. All factors influencing the location determination should be planned and well-analyzed. Therefore, local authorities should consider the importance of this topic when making any decision in terms of the strong environmental, social and economic implications before declaring an area as a LC.

5. Conclusions

A study of the functioning of existing logistics centers in Ukraine indicates their slow development. Most of the logistics complexes are located in the Kyiv region, sometimes in the cities of Kharkiv, Odesa, Dnipropetrovsk and Lviv. In total, about 200,000 sq. m of warehouses were built in Ukraine in 2020. In 2021, only 130,000 sq. m appeared on the warehouse and logistics real estate market in Kyiv and in the capital's suburbs. In addition to Kyiv, in 2021, construction of warehouse and logistics facilities began in Dnipro, Odesa, Lviv and Kharkiv.

Since the beginning of the war, logistics real estate has suffered significant damage, with some warehouses being completely destroyed. The fact that warehouses are strategically important objects led to such devastating destruction, as the enemy strikes them purposefully or uses them as locations for their occupation bases. Russian troops destroyed more than 440,000 sq. m (20%) of logistics real estate in the capital region. During 2 months of the war in Ukraine, warehouse and logistics buildings worth USD 1 billion were destroyed.

Inadequate supply of logistics centers in the country has led to inefficient management of logistics flows. This affects the quality and timeliness of the delivery process; the rate of transformation of the material flow; qualitative characteristics of logistics operations; speed of turnover within the country; the degree of benefits that the consumer receives in the form of value-added services; and transportation costs and costs related to the storage of material resources.

Therefore, the development of logistics service systems in the regional socio-economic system can be economically justified at a certain volume of cargo turnover in storage facilities. Thus, the creation of the aforementioned systems depends on cargo streams, or the volume of consumption, which in economic terms is integrated into the corresponding LC facility at the regional level.

Under current conditions, it is promising to further increase the construction of new warehouse complexes, as well as smart logistics centers in the western region, which will be located on the main roads of the border checkpoints. In order to fulfill a coordinating and integrating role in the implementation of logistics operations in the western region of Ukraine, the creation of a powerful regional logistics center in Lviv is proposed. The center will function as an accumulation and distribution logistics unit, performing the functions of establishing interaction between modes of transport and organizing material distribution by organizing relationships with consignors, consumers, carriers and forwarders and ensuring timely mutual settlements through banks. The authors proposed an algorithm for determining the optimal location of the LC in the region. The organizational and functional structure and interrelationship of elements of the regional logistics center have been developed. The creation of a regional logistics center in Lviv will be financially beneficial and competitive on the international market of logistics services in the context of the European integration of Ukraine. The proposed method would provide significantly more objective information for selection of a logistics center location and evaluation in the logistics system. Furthermore, it would allow the region to increase its competitiveness in the market for logistics services in the context of the creation and development of the Lviv–Rzeszow and Ukraine–Europe interregional systems.

LEZs in Lviv and their introduction in the future have, in addition to the primary effect, i.e., the creation of low-emission areas, several environmental effects. However, in order to implement distribution in cities with low-emission zones, including Lviv, it is necessary to equip LSP carriers with modern vehicles. The introduction of LEZs may indirectly result in an improved traffic accident balance and increased safety for residents. In the age of digitalization, logistics operations and all leading car manufacturers have vehicles that, when used, can result in increased efficiency and productivity in distribution, and this is a prerequisite for building smart cities. Increased efficiency and effectiveness in the distribution of goods will result in a further reduction in emissions. This will contribute to the global goal of reducing harmful substances in the atmosphere from transport in Lviv.

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