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DETERMINING THE OPTIMAL SERVICE AREA OF A LOGISTICS CENTER: A QUANTITATIVE APPROACH

Summary. The efficiency of modern logistics is largely determined by the resilience of all components and links within the supply chain. Logistic centers play a critical role in ensuring this stability. The current study presents an approach to optimizing the service area of a logistics center for both urban and suburban regions. Key decisions for suppliers include selecting the mode of delivery – either direct or via a logistics center – and determining their optimal location. Based on expert surveys, delivery cost was identified as the primary decision-making criterion. A mathematical model was developed, incorporating such factors as the size of the service area, delivery density, cargo volume, vehicle capacity, and technical speed. Statistical analysis revealed strong nonlinear correlations between the parameters ($r > 0.85$). Newton's method was employed for optimization. The analysis showed that the most significant factors affecting delivery cost are the service area, cargo volume, and vehicle capacity, while technical speed and delivery point density have less influence. The principal advantage of the proposed approach lies in the development of a simple and intuitive model that can enhance delivery strategies for logistics and transportation companies.

1. INTRODUCTION

Logistics is one of the main branches of the national economy. It gradually develops due to informatization, creating networks, automation, and globalization [1]. In order for logistics to adapt to the trend of economic development, it is necessary to improve its productivity and structure. Therefore, it is critical to deeply study the structure of the logistics system, especially communication in the logistics chain of supplies [2].

In a logistics network, the problem of locating a logistics center relates to choosing one of several logistics distribution centers within several service zones to optimize the entire logistics system under restrictions [3]. Optimization can have varying purposes, for example, optimizing the operational costs of the system or optimizing the shortest transportation path. The corresponding planning of the location of the logistics center improves the effectiveness of transport services for the entire network of the logistics supply chain and increases total profits [4]. If the location of the logistics center is determined to be inadequate, this leads to the problem of accumulation of goods or their delay due to a restriction

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on the capacity of the warehouse (logistics center) and high loading resources [5, 6]. Therefore, building an optimization model for determining the service zone by the logistics center for solving practical problems is one of the current issues in the study of logistics systems.

Existing approaches to determining service zones often overlook the dynamics of demand, the specifics of the service area's transport infrastructure, and the need to integrate various parameters [7, 8]. This leads to an ineffective distribution of resources in the service system, increased costs, and reduced customer service levels, and the matter requires further research. Therefore, the goal of this study is to build a new quantitative model that integrates key factors to determine the optimal service area of the logistics center.

The optimization of service by a logistics center is a multivariate task. To solve it more efficiently, it is necessary to transform the practical problem into a mathematical model. When building a mathematical model, the most important parameters that determine the delivery through the logistics center should be considered. Some of these variables are deterministic, and some are random. The determination of the number of parameters depends on the method used to assess their significance. In this study, we used an expert assessment to include the parameters in the description of the model. For a statistical assessment of the selected parameters, a large number of them must be processed. We developed a hypothesis about the distribution of random values according to certain laws. Regression analysis was used to analyze the experimental data obtained in the study. The constructed models are evaluated with consideration of both linear and nonlinear dependencies on key input parameters. Newton's method is employed to determine the optimal values of the parameters that influence the formation of service areas for logistics centers. As a result, the proposed methodology allows users to implement a systematic approach to optimize the delivery strategies and increase the efficiency of the functioning of supplies circuits due to the optimization of the service zone by the logistics center.

2. ANALYSIS OF LITERARY SOURCES

In recent years, the improvement of indicators of the logistics industry has been discussed among many scientists and practitioners in the industry. Numerous scientists have conducted in-depth studies on the issue of service optimization by logistics centers from different points of view, providing valuable knowledge about how this logistics can increase productivity [9]. The article presents the application of intelligent logistics to enhance the overall efficiency of the logistics sector. However, it does not take into account the specific characteristics of regional development in the transport and logistics sector when servicing orders for individual operators.

Studies that integrate environmental and social aspects when choosing the location of logistics centers show the prospect of improving the logistics of supply [10, 11]. The main methodological approach to choosing the best options is a multi-parameter one. It is most preferred and demonstrates promising achievements in eliminating traditional restrictions, adopting approaches based on data, integrating hybrid methods, managing uncertainty, and clarifying the processes of developing criteria [10]. In this study, evaluation criteria were determined based on selected aspects by a limited group of experts – specifically, industry specialists and leading 3PL company representatives operating within a stable transport and logistics services market. Operational indicators of car operation in service areas are the basis for assessing the level of emission of harmful substances when optimizing the logistics network [11, 12]. These areas of research represent promising methods for determining the location of logistics service centers without taking into account technical restrictions in the operation of cars, their carrying capacity, the capacity of the body, or technical speed.

Recent studies in the field of logistics services have focused on new technologies for artificial intelligence, machine learning, and data processing [13, 14]. Researchers emphasize their importance, favourable factors, and barriers of use, which must be overcome for the successful implementation and full use of developing technologies [13]. The application of artificial intelligence requires substantial resource investments in the transport and logistics support system, while training and adaptation demand both significant time and the involvement of qualified specialists. For the functioning of a persistent logistics system, optimizing the distribution of resources, and improving decision-making, it is

necessary to process a large amount of data [14]. The characteristics of the developing logistics markets in Ukraine and Kazakhstan necessitate prompt decision-making regarding the baseline values of key technological parameters in the transportation process. The more complicated the system, the more information and technical support is necessary when creating intelligent management systems. The introduction of artificial intelligence requires a balanced and effective integration of technologies to satisfy changing industry standards and requirements [15]. It is necessary to apply the technology of artificial intelligence when solving non-standard, multi-level logistics problems. And the assessment of the results requires the creation of individual complex projects.

Big data analytics can largely contribute to the development of delivery logistics [16]. A significant increase in data generation and complexity due to the development of computing power and relational databases has made it possible to open new information through the data collection and processing process. The results of the study [16] show the positive effect of the forecast data analytics on the stability of the logistics system, in particular, on opportunities such as risk management, flexibility, and adaptability. However, the development of sustainability conditions was carried out for specific market conditions (the food sector), which constrained the logistics market by the corresponding demand parameter values. The stability of logistics maintenance takes into account the network structure of the district and the productivity of resources [17]. The use of the values of service indicators with logistics centers allows researchers in [17] to get a flexible model. At the same time, recommendations are formulated for people making decisions on how to organize a persistent service system. The recommendations are directed exclusively at logistics service providers, are general, and do not take the specific features of functional interactions into account.

The authors of the study [18] argue that the resistance of the logistics of the supply of products is significantly increased by informatizing the management process, building a flexible system ready for risks, and taking logistics parameters into account. The allocation of individual parameters of influence on the functioning of the service area requires a detailed assessment of the area, the number of customers, the level of demand, etc., and all these parameters must be represented as dynamic.

The influence of parameters on decision-making on the choice of a logistics center is quite large [19]. These centers do not just plan logistics activities. They affect logistics costs and the level of service. The paper [19] proposes a methodology that combines a description of a complex structure of the solution to the problem, expert opinion, geographical characteristics of the service area, and mathematical modeling to determine the costs and analysis of the location of several logistics' objects. This approach complicates the client's decision-making process in selecting the optimal mode of operational interaction with the logistics center, as there is a quantitative limitation on the service capacity.

Methods that allow the simultaneous consideration of different factors, such as cost, delivery time, infrastructure availability, and technological parameters, are often used in determining the rational service of orders [20, 21]. The authors of the paper [21] show that the first area of the study represents the definition of logistics problems, factors affecting the solution of the choice of the service center, as well as the determination of the significance of factors in megacities, taking into account the opinions of many experts. They also focused on the spatial analysis of parameters for the placement of new logistics centers serving areas. The use of the expert method to select the list of influencing parameters for a logistics center's choice of optimal service area could have provided a quantitative assessment under conditions of limited access to statistical data.

For the visualization, analysis, and optimization of the location of logistics objects, geoinformation systems (GISs) can be used. The development of tools based on GISs made it possible to create a tool for the location of logistics centers in conjunction with multicriterial decision-making [22, 23]. In [22], nine criteria that affect the choice of location of service centers were determined, the spatial data of the criteria were collected, and normalized layers of criteria were created using a GIS. This method imposes significant limitations on the universal applicability of the model and requires substantial adaptation of the criteria to the operational conditions of logistics facilities.

Based on the decision-making structure proposed by the authors in [23], the choice of the location of the logistics center was implemented, depending on the scale of the region, providing technical support for making decisions for the construction of new centers. This study enables the determination of the location for a new service center in a region with stable order volume, without accounting for changes

in the flow structure. The use of modern information systems allows one to more accurately find the location of the services of applications and goods, help drivers in navigation, help organize delivery routes, and calculate the expected arrival time [24]. When using geoinformation systems, it is necessary to take a large number of additional factors into account when choosing the optimal service area. Therefore, it is necessary to distinguish a list of factors of influence and determine the level of their influence, for example, using a quantitative method.

A paper [25] presents a hybrid Multi-Criteria Decision-Making (MCDM) approach, combining AHP and MARCOS methods, to identify the most suitable location for a humanitarian logistics center in Serbia based on a comprehensive set of criteria. However, the model does not account for potential changes in external conditions such as evolving humanitarian needs or long-term geopolitical developments, which could affect the relevance of the selected location. A previous study [26] focused on optimizing industrial process management in postal and logistics centers by aligning operations with transit time quality standards, aiming to enhance overall efficiency and service quality. However, the study does not explicitly address how real-time variability in demand or unexpected disruptions might affect the stability of the proposed optimization framework.

The analysis of the literature reveals a clear gap in existing studies, which are mainly focused on environmental, social, economic, and geographical aspects of choosing the location of logistics centers while ignoring the critical technical characteristics of vehicles, such as the lifting capacity, the capacity of the body, and the technical speed. Further research can focus on the development of quantitative models that integrate these technical restrictions to provide a more realistic determination of optimal service areas and calculation of delivery costs. This would increase the practical applicability of models for logistics companies.

The literature review emphasizes the growing role of artificial intelligence, machine learning, and large data in logistics. The idea is to use these technologies to create intellectual management systems that can process large volumes of data about the service area (e.g., area, number of customers, demand level) as dynamic parameters. This would enable the development of more adaptive and stable models for determining optimal service zones, taking into account changes in time and responding to non-standard situations. The literature indicates the value of expert assessments, especially when access to statistical data is limited.

A promising area is the development of hybrid methodologies that effectively combine qualitative expert assessments with quantitative methods for determining the weight of various factors affecting the choice of optimal service area. This overcomes the problem of a lack of data and increases the validity of the decisions made. The literature review demonstrates the potential of GISs to be used for visualization and to analyze spatial data when choosing the location of logistics centers. Further research can examine deeper GIS integration with the developed quantitative models for determining the optimal service area. This would take into account the spatial characteristics of the service area (e.g., road network density, transport accessibility, customer location) in quantitative calculations and visualize the obtained optimal zones on the map.

In addition, integration with multi-criteria decision-making methods will allow people to take various factors (e.g., cost, operations time, infrastructure availability) into account when determining the optimal zone. The authors note the need for a detailed assessment of the service area and the allocation of specific influence parameters. A pertinent step is a more in-depth elaboration and quantitative assessment of the specified parameters. The development of methods for collecting and processing such detailed data, as well as their inclusion in quantitative models, will increase the accuracy of the determined optimal zones of service.

3. THE PURPOSE AND OBJECTIVES OF THE STUDY

The objective of the study presented in this paper is to develop, verify, and empirically substantiate a comprehensive quantitative model for determining the optimal service zone for a logistics center that operates in limited areas of service, which takes into account key technological and geographical factors (e.g., the size of the service zone, the density of the delivery points, the average daily cargo to the

delivery point, the average loading capacity, technical speed) in order to achieve the minimum delivery cost per unit of products. At the same time, it is necessary to establish quantitative dependencies between these factors and the cost of delivery and to evaluate the sensitivity of the optimal service zone to changes in the main parameters to provide almost significant recommendations to logistics and transport companies to optimize the delivery and placement of logistics centers.

To achieve this purpose, it is necessary to complete the following tasks:

1. Develop a methodology for conducting an expert survey among specialists in the field of logistics and management of supply chains with experience with urban and intercity delivery and optimization of the zones of service of logistics centers. Determine the circle of experts and conduct a survey in order to identify and rank the most significant criteria and factors affecting the choice of optimal service zone and delivery strategies. Analyze the results of an expert survey to justify the choice of key variables that will be included in the mathematical model.
2. Create a multicriterial mathematical model that integrates parameters chosen by experts for quantitative assessment of the cost of delivery per unit of products in conditions of limited areas of service. Verify the developed model by statistical analysis of real and modeled data to confirm its adequacy and the ability to reflect the existing patterns of the distribution of significant variables.
3. Study empirically and determine linear and nonlinear dependencies between experts chosen by experts and the cost of delivery per unit of production using correlation analysis and experimental data. Assess the degree of influence of each of the key factors on the cost of delivery, identify the most significant ones, and determine the nature of their influence (direct or reverse).
4. Using the developed and verified mathematical model, calculate the optimal values of the parameters of the service zone (for example, radius or area) for the logistics center, ensuring that the cost of delivery per unit of products is minimized using the optimization method. Conduct an analysis of the sensitivity of the optimal parameters of the service zone to changes in key factors (e.g., amount of cargo, carrying capacity) and develop practical recommendations for logistics and transport companies to determine the rational zones of service of logistics centers.

4. RESEARCH METHODOLOGY

Based on the aim and tasks, the present study can be divided into three main stages:

Preparatory. Description of the research object (detailing) and the rationale for the choice of model parameters based on expert opinion.

Basic. The mathematical setting of the problem, regression analysis, verification of the adequacy of the obtained models, and the choice of the best option.

Resulting. Determination of the degree of influence of each of the significant parameters in the selected regression and the development of practical recommendations for determining the rational service zone by the logistics center. The structure of the study is presented in Figure 1.

Logistic centers contribute to the concentration and transformation of material flows, changing the parameters of the accepted and issued parties of the cargo (in size, composition, and time of sending).

The purpose of the participation of a logistics center in a service system is not only to accept from transport (e.g., regional) a cargo flow with fixed parameters and process and issue it to another (e.g., intra-district) with other parameters but also to perform this transformation with a minimum cost of delivery per unit of products (Fig. 2).

The interaction of logistics centers (LSs), shippers (Ss), and consignees (Cs), which are located on the border of the city, in the regional district, and the city, respectively, can be described by the set P :

$$P = \{LS; S; C\}. \quad (1)$$

Set of logistics centers, limited by the number K :

$$LS = \{LS_1; LS_2; \dots; LS_K\}. \quad (2)$$

Set of shippers, limited by the number M :

$$S = \begin{bmatrix} S_{11}, S_{12}, \dots, S_{1M} \\ S_{21}, S_{22}, \dots, S_{2M} \\ \dots \\ S_{K1}, S_{K2}, \dots, S_{KM} \end{bmatrix}. \quad (3)$$

Set of consignees, limited by the number N :

$$C = \begin{bmatrix} C_{11}, C_{12}, \dots, C_{1N} \\ C_{21}, C_{22}, \dots, C_{2N} \\ \dots \\ C_{K1}, C_{K2}, \dots, C_{KN} \end{bmatrix}. \quad (4)$$

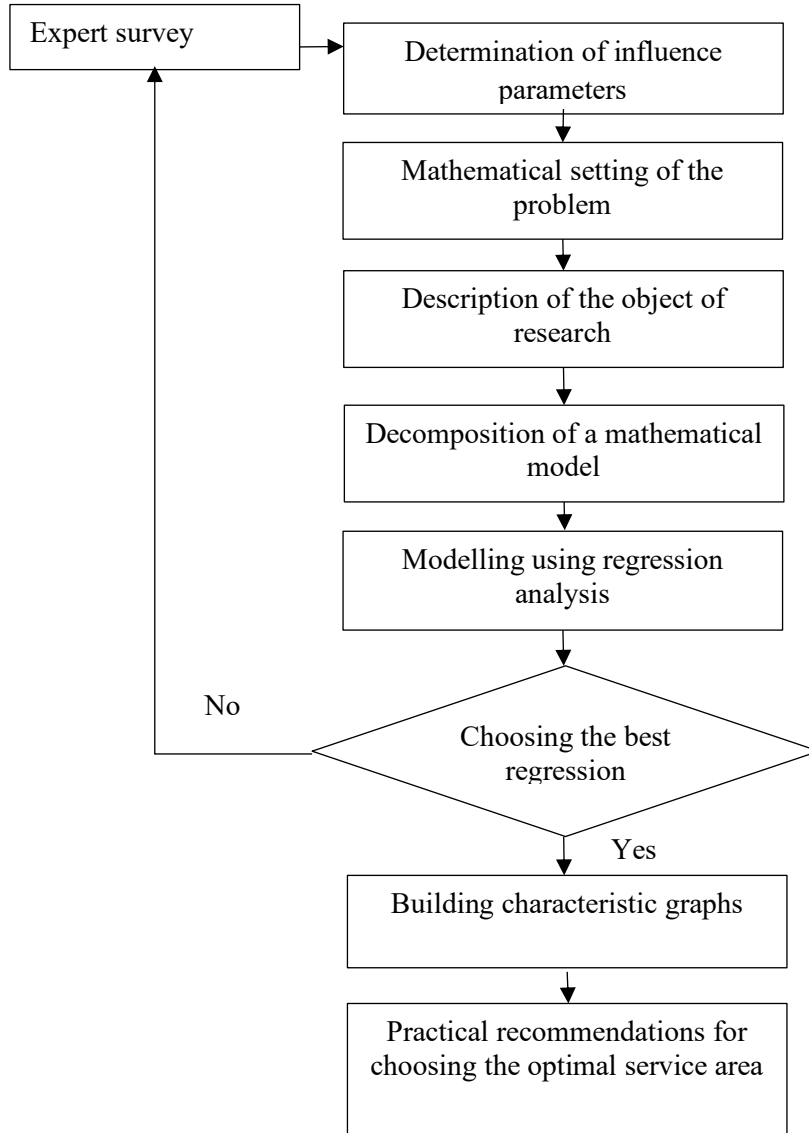


Fig. 1. Structure of the study

According to the structure of the study (Fig. 1), an expert survey was conducted to justify the choice of factors for the future model. It should be noted that for the effective management of supply chains, the opinions of experts in the field of logistics are key [27]. The main participants in the delivery process (shippers (E1–E3), representatives of transport companies (E4–E6), and managers of logistics centers (E7–E8)) are defined as experts. For the choice of experts, the position held (Fig. 3a) and the experience of their work in the field of freight transport (Fig. 3b) are important.

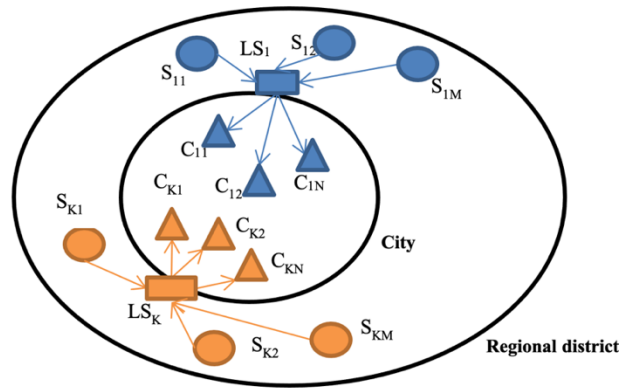


Fig. 2. The interaction scheme of logistics centers, shippers, and consignees, which are located on the border of the city, in the regional district, and the city, respectively

For the expert survey, a 5-point Likert scale was used [28], which is often used to study opinions in logistics [29]. When choosing the significance of the parameter for the future mathematical model, respondents were offered the following interpretation of points: 5 – very important; 4 – important; 3 – rather unimportant than important; 2 – unimportant; 1 – definitely unimportant. The expert survey was conducted by interviews (by phone and in person) from September to October, 2024, in the Kharkov and Almaty regions. An expert assessment of the significance of the parameters for the future model is presented in Table 1.

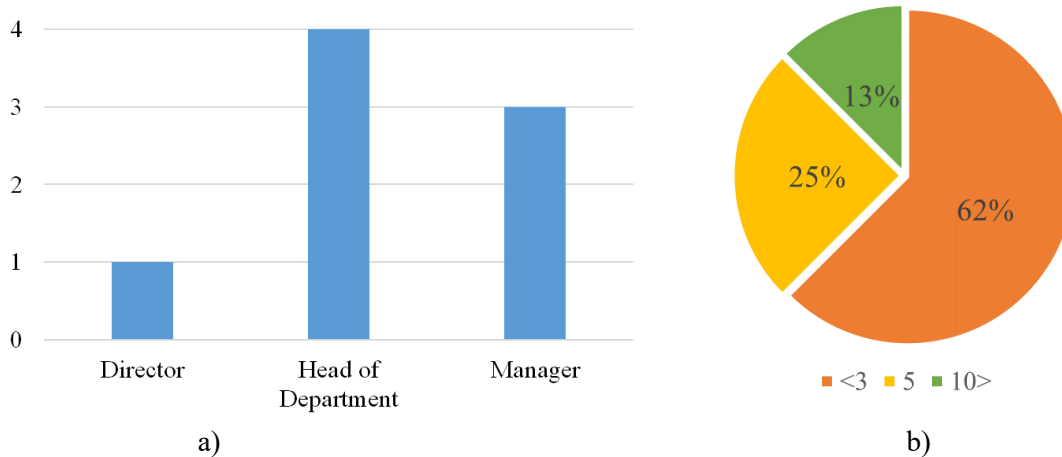


Fig. 3. Distribution of experts by: a) position and b) experience in the field of freight transportation

Based on the results of the calculation of the average value of the expert assessment, significant factors were identified (these are indicated in bold in Table 1). According to the experts, six of the 10 parameters are significant and included in the discussion. For the selection of parameters for future modeling, the average assessment should be 4 points or higher. This is explained by the gradation of the chosen Likert scale, where 4 and 5 points indicate the need to include such parameters in the model, while an average score 3.99 and below represents the doubt of experts regarding the importance of a particular parameter.

Based on expert-defined parameters (i.e., the size of the service zone, the density of the delivery points, the average daily volume of the cargo at the point, the average carrying capacity of the vehicle, the coefficient of use of the carrying capacity, and the technical speed)), a criterion is calculated to determine the optimal service area for a logistics center. The proposed criterion is the delivery cost per unit of products – S_{IT} . This parameter takes into account the cost of delivery from shippers to the logistics center and from this center to consignees.

Table 1

Expert assessment of the significance of parameters

Variable	Expert								Average
	E1	E2	E3	E4	E5	E6	E7	E8	
The size of the service zone	5	4	5	5	5	5	3	4	4.38
Loading downtime	1	2	3	5	3	4	2	1	2.63
The number of loading posts in the logistics center	2	2	1	1	2	3	2	1	1.75
The average daily volume of cargo per point	4	5	5	5	4	5	3	3	4.25
Delivery density	5	3	5	4	5	4	3	5	4.25
The length of the route	2	3	2	4	3	2	4	5	3.13
The coefficient of use of carrying capacity	4	4	5	4	4	4	4	4	4.13
Average vehicle load capacity	5	4	3	3	5	5	5	4	4.25
Travel time	2	3	4	4	4	5	2	3	3.38
Technical speed	5	4	4	5	5	5	2	4	4.13

The mathematical model was formed on the basis of the accounting of the selected parameters of influence: the size of the service zone F , km², delivery density λ , km², average daily volume of the cargo $\bar{g}$, tons, the average carrying capacity of the vehicle q_{1c} , tons, the coefficient of use of the carrying capacity of the vehicle γ , and technical speed V_t , km/h. It is also necessary to take into account the geographical features of the service areas. In the city and in the regional district, the coefficients of the conjugation, determined for the conditions of Ukraine and Kazakhstan, are 2.25 and 0.75, respectively. The model is provided below:

$$\begin{aligned}
 S_{1T} = & \frac{2.25 \cdot \sqrt{\frac{F \cdot (K+1)}{M}} \cdot (a_{ver} + b_{ver} \cdot q_{1c}) + \frac{2.25}{V_t} \cdot \sqrt{\frac{F \cdot (K+1)}{M}} \cdot (a_{fix} + b_{fix} \cdot q_{1c})}{\bar{g}} + \\
 & + \frac{0.75 \cdot \left(\sqrt{\frac{F}{M \cdot (K+1)}} + \frac{N-1}{\sqrt{\lambda}} \right) \cdot (a_{ver} + b_{ver} \cdot q_{1c} \cdot k)}{\bar{g}} + \\
 & + \frac{0.75}{V_t} \cdot \left(\sqrt{\frac{F}{M \cdot (K+1)}} + \frac{N-1}{\sqrt{\lambda}} \right) \cdot (a_{fix} + b_{fix} \cdot q_{1c} \cdot k), \quad (5)
 \end{aligned}$$

where:

a_{ver} and b_{ver} are the assessment coefficients of the relevant costs associated with the operation of vehicles on cargo delivery routes, UAH;

a_{fix} , b_{fix} are the assessment coefficients for the relevant costs associated with the work hours of vehicles during cargo delivery, UAH;

k is the coefficient of relative carrying capacity, which is determined by the ratio of the values of the carrying capacity of vehicles operating on delivery routes from the logistics center to consignees and from shippers to the logistics center.

5. RESULTS AND DISCUSSION

This study was carried out according to the data of transport and logistics companies in Ukraine and Kazakhstan. Based on the opinions of experts from the companies, the values of the following selected parameters of influence were obtained: the average daily volume of the cargo importing was taken in the range from 0.2 to 1.2 tons; the average carrying capacity of the vehicle changed from 1.2 to 14 tons; the coefficient of use of the carrying capacity increased from 0.6 to 1; and technical speed increased

from 15 to 40 km/h. The value of the minimum size of the service zone was 80 km², which corresponds to approximately the minimum area of the cities of Ukraine and Kazakhstan (regional centers). The maximum value of the service zone was accepted by the value of 2500 km², which corresponds to the area of the middle regional district of both Ukraine and Kazakhstan. Delivery density in the area of service is taken along the lower limit of 0.01 km⁻². The upper limit of this factor is 0.05 km⁻². These values were determined by the statistical study of the regions of Ukraine and Kazakhstan. A statistical analysis of these data was carried out, and a verification of the assessment of the law of distribution by the Pierson criterion and the level of trust probability was checked. All hypotheses were confirmed (Table 2).

A plan to conduct an extreme imitation experiment was drawn up. Two levels of variation of parameters selected by experts were chosen – minimal and maximum [30, 31]. It was necessary to conduct 64 series of the experiment. Based on the developed experiment plan, two hypotheses on the linear or nonlinear dependence of the function on the values of the arguments were put forward [30, 32]. To check the hypotheses, a regression analysis was carried out using Excel, in particular, the functions for data analysis – regression. This software allows the user to find the values of such parameters as the coefficients of equations for variables, dispersion, and regression statistics.

The following values of the coefficients for the regression models of a linear and nonlinear species were obtained:

$$S_{1T} = 0.094 \cdot F - 4670.39 \cdot \lambda - 297.92 \cdot g + 28.92 \cdot q_{1c} + 485.95 \cdot \gamma + 2.04 \cdot V_t. \quad (6)$$

$$S_{1T} = \frac{F^{0.037} \cdot q^{0.561}}{\lambda^{0.439} \cdot g^{0.919} \cdot V_t^{0.25}}. \quad (7)$$

Table 2

Statistical assessment of model parameters

Parameter	Sample volume	Range of parameters	Distribution law
Daily volume of the goods imported, tons	96	0.2–1.2	Normal
Carrying capacity of the vehicle, tons	84	1.2–14	Lognormal
Coefficient of the use of carrying capacity	59	0.6–1	Exponential
Technical speed	94	15–40	Normal
Size of the service zone, km ²	88	80–2500	Lognormal
Delivery density, km ⁻²	74	0.01–0.05	Exponential

Based on the R-square values, the nonlinear function showed greater adequacy than the linear function. The values of the coefficients of the nonlinear regression model were checked. All indicators were significant in terms of standard error, *t*-statistics, *p*-value, and lower and upper boundaries.

The developed model is subject to the following conditions of use and limitations: a) the system operates with a limited number of logistics centers, senders, and recipients; b) parameter values are constrained by the service area and the specifics of interactions (queueing is not considered); c) client risks associated with service denial due to capacity overload are not accounted for. The model allows for the incorporation of additional parameters, such as road network density, transport accessibility, and client locations.

Furthermore, the model's generalizability will be enhanced by conducting subsequent validation based on survey results from Polish experts who have experience with or are currently employed in logistics centers within major voivodeships of the country.

The optimal values of all factor features were determined by the numerical method based on the collected statistical data. Newton's method was selected as the numerical method [33, 34]. In Excel, we carried out the command "Service → Solution Search." In the window that appeared, we performed the

following actions. We set the target cell equal to the minimum value. In the search parameters, we indicated the selected Newtonian method and added the restrictions on our model. As a result of the calculations, we obtained the values of delivery per unit of production, depending on the selected parameters of influence (Fig. 4).

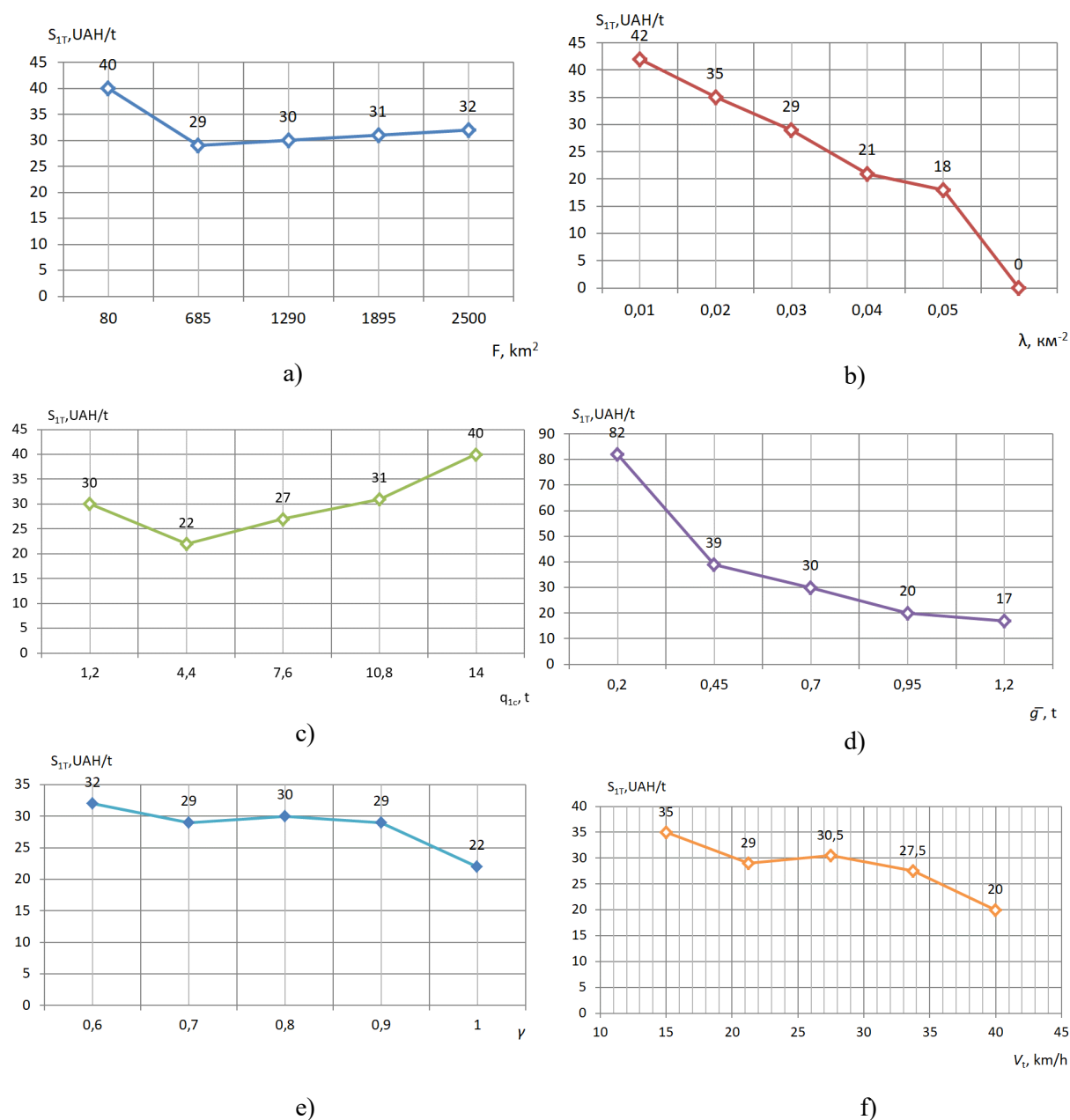


Fig. 4. Characteristic graphs of dependence costs of delivery per unit of products on the selected parameters of influence

The analysis of the characteristic graphics (Fig. 4a) showed that a change in the size of the service zone from 80 to 685 km^2 leads to a decrease in the cost of delivery per unit of products by almost 40%. Then, with an increase in the service zone from 685 to 1895 km^2 , the criterion value decreases by another 10%. However, with an increase in the service zone to 2500 km^2 , the value grows by 6%. Therefore, we can conclude that the size of the service zone and the cost of delivery per unit of products are in parabolic dependence, and any increase in this indicator will lead to an appropriate increase in the criterion.

An increase in the indicator of delivery density leads to a decrease in the cost value per unit of production (Fig. 4b). As the value increases from 0.01 to 0.02 km⁻², there is a decrease in cost of almost 23%. With an increase in this parameter from 0.02 to 0.05 km⁻², the criterion continues to gradually decrease by 5–10%. When vehicle carrying capacity changes from 1.2 to 4.4 tons, the cost of delivery per unit of products decreases by about 20% (Fig. 4c). With an increase from 4.4 to 10.8 tons, the estimation criterion decreases by about 25%. With a further increase in the carrying capacity of the vehicle from 10.8 to 14 tons, an increase in the cost of delivery per unit of production by 13% occurs. When the value of the daily volume of goods imported increases from 0.2 to 0.7 tons, the cost of delivery per unit of production is sharply reduced (Fig. 4d). This is because it is unprofitable to transport very small batches of cargo over long distances. With an increase from 0.7 to 1.2 tons, the cost continues to decrease, but not so sharply: first by 30%, then by another 20% and then another 13%. A change in the vehicle load capacity utilization coefficient by 0.1 within the range from 0.6 to 1 leads to a gradual decrease in the delivery cost per unit of product by 3%. (Fig. 4e). The impact on the cost of delivery per unit of production of the technical speed of cars is such that, when the speed changes from 15 to 22 km/h, the criterion is reduced by almost 10%. With a further increase in speed to 40 km/h, the criterion decreases by another 7% (Fig. 4d).

The size of the service zone, the daily volume of the cargo, and the carrying capacity of the vehicle have the greatest impact on the cost of delivery, while the technical speed and density of points have relatively weak influences.

The following practical recommendations are offered based on the data obtained with the limitations established and the selected priority parameters of the service system:

1. To ensure coordination of delivery schedules for small cargo shipments (0.2-1.2 tons) between the consignor and the consignee.
2. Transport enterprises must focus on using vehicles with carrying capacities of up to 1.5 tons for transportation over short distances.
3. Logistics centers must limit the size of the service zone to 685 km².

6. CONCLUSIONS

This study assessed the task of determining the optimal service area for a logistics center that operates in urban and suburban environments. This requires some consideration of the issue of which territory should cover the logistics center to ensure the most effective and economical delivery of goods. The problem of rationally determining the service area is critical since it directly affects logistics costs, delivery times, customer service, and the overall efficiency of the logistics system. If the service area is too large, this can lead to an increase in transport costs and delivery times; if it is too small, it limits the potential of the logistics center and leads to the incomplete use of its resources.

A methodology including an expert survey was developed to identify and rank the most significant criteria and factors affecting the choice of optimal service zone and delivery strategies. The survey results were analyzed to justify the choice of key variables for the mathematical model integrating the influencing parameters selected by experts (namely, the size of the service zone, the density of delivery points, the average daily volume of cargo importing to the point, the average carrying capacity of the vehicle, the coefficient of use of the carrying capacity and technical speed) for a quantitative assessment of the cost of delivery per unit of products. The geographical features of the service areas (city and regional district) were also taken into account using coefficients.

A statistical data analysis and an empirical study were carried out to establish dependencies between factors and the cost of delivery. A nonlinear dependence of the functional influence of factors on the cost of delivery per unit of products was confirmed. Using the developed model and Newton's method, the optimal values of the service zone parameters for minimizing the cost of delivery per unit of products were calculated. The size of the service zone, the daily volume of the cargo import, and the carrying capacity of the vehicle had the largest impacts on the cost of delivery per unit of products, while the technical speed and density of the delivery points had a weak influence.

The proposed methodology is a systematic approach to optimizing delivery strategies and can be effectively applied by logistics and transport companies. The study fills the gap in existing approaches, integrating the technical characteristics of vehicles (carrying capacity, body capacity, technical speed), which were often ignored in previous models. Based on the obtained data and models, practical recommendations were formulated for participants in the service system (shippers, consignees, transport enterprises, and logistics centers) to ensure the effective delivery of goods and use of vehicles while limiting the size of the service zone.

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