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Methodology for Determining the Optimal Location of Transport Logistics Centres

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Abstract: *The Transport Logistics Centre is a key element of the infrastructure of the transit logistics corridor. Their quantity and efficient functioning largely determine the level of competitiveness of the transit corridor. The paper discusses the key areas of operation of the Transport Logistics Center (TLC), including its modern forms of organisation, classification criteria, and the tasks it aims to address. A multi-criteria expert approach for determining the location of the Transport Logistics Center (TLC) is proposed, based on a system of qualitative and quantitative evaluation indicators and the features of fuzzy set theory. The paper outlines the procedures for determining the agreed-upon activities of experts, as well as the algorithm for analysing and ranking alternative outcomes.*

Keywords: *transport logistics centre; logistics; transit corridor; expert system; indicator system.*

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1. Introduction

Transport logistics centres (TLCs) represent a key element in the transportation of various types of cargo.

A transport logistics centre (in its current context) is a facility where independent operators perform a set of functions aimed at integrating and coordinating logistics flows, as well as increasing their added value.

In this transportation scheme, the role of the Transport Logistics Centre (TLC) is to handle incoming cargo, distribute it in the required direction, form separate batches of cargo, and send them by various types of transport, and optimise time and transportation costs. Thus, the Transport Logistics Centre (TLC) can offer international trade participants a full package of services. After which, it becomes possible to reduce time and financial costs and dramatically increase the quality of the services provided (Doborjginidze, 2019).

There are various types of Transport Logistics Centres (TLC) that carry out different functions and tasks, have distinct specialisations, different types and volumes of services provided, locations, sectoral profiles (affiliation), etc.

To successfully solve the above-mentioned tasks, the Transport Logistics Centre (TLC) shall possess several functions. Namely: transportation, warehousing, logistics, control, financial, information, marketing, and infrastructure functions.

Performing these functions allows logistics centres to reduce costs on cargo transportation, increase the speed of cargo delivery, and optimise the cargo delivery process. Each stage can be decisive and have a certain impact on the economic transaction (Doborjginidze, 2019; Korodyuk & Karkhova, 2018; Drage et al., 2016).

For the successful resolution of logistical tasks in international cargo transportation and the formation of transport networks, with the help of which economically acceptable technologies for cargo transportation and processing will be provided, it is necessary to correctly determine the location of the Transport Logistics Centre (TLC) localisation.

The paper aims to identify the Transport Logistics Centre (TLC) location (regardless of its size or legal structure) based on existing alternative locations, multi-criteria expert assessment, and analysis of the results obtained.

2. Basic Part

Currently, various analytical and expert methods are employed to determine the optimal location of facilities, but they have several shortcomings. For example, the basic shortcomings of analytical methods (e.g., full selection method, heuristic methods, centre of gravity determination method, and mathematical programming method in the direction of total costs, etc.) may be the inability to take into account all possible factors that influence the selection of the location of the transport complex. Expert methods are considered relatively acceptable.

The paper proposes a multi-criteria expert method for determining location, which is based on the use of qualitative and quantitative evaluation indicators and the capabilities of fuzzy set theory (Mchedlishvili, Khutsishvili, & Amilakhvari, 2015).

In general, the purpose of expert analysis methods is to support decision-makers when there is a rather complex problem to be solved, there are certain novelties, the existing information is not complete, it is impossible or very difficult to mathematically formalise the solution process, etc.

There are no standardised rules for preparing and conducting an expert examination. However, it is possible to clearly identify the main stages and determine the corresponding tasks to be solved. Namely:

- Formation of the objectives of expert analysis;
- Formation of an organisational group for the examination;
- Formation of a qualitative and/or quantitative system of indicators by a group of experts;
- Determining a fuzzy assessment questionnaire and scale;
- Processing of the procedure for calculating indicator weights;
- Rules for determining the level of agreement between experts;
- Development of expert evaluation forms;
- Calculating local evaluations (Fuzzy) ;
- Calculating a fuzzy integral estimate;
- Comparison of a fuzzy integral estimate and complex assessment and analysis of results;
- Quantifying possible risks and analysing the results.

It should be noted that assessing the location of the Transport Logistics Centre (TLC) before starting the activity is no less important than a complete, fundamental analysis of the subsequent activity. The goal of this stage should be to rationally substantiate the proposed location of the Transport Logistics Centre (TLC) and make a forecast of its prospects, in order to formulate action recommendations for the decision-maker.

Conducting this analytical assessment based on a single criterion (hereinafter referred to as an indicator) is not valid and reliable; these decisions should be based on multiple indicators, a multi-criteria assessment. That is, the analysis should be conducted based on the combined use of qualitative and quantitative indicators. Such indicators may include assessment indicators related to: Transport issues, territorial location, communication capabilities, security, forms of interaction, environmental problems, costs, land lease and construction, the size of investments and revenues, etc**.** It is possible to change the content and total number of the listed criteria.

A system of qualitative indicators that characterises a certain object or event is a set of interconnected quantities. It should reflect the state and development prospects of a given alternative from every angle. Based on this idea, the paper presents several qualitative indicators of assessment (the first level of the hierarchy) and a unified hierarchical relationship of their sub-indicators (the second level).

For example:

1. Transport capabilities (first level) - sub-indicators: proximity to highways; proximity to transport hubs; multimodal service; proximity to international transport corridors; logistics services market potential - demand volume.

2. Territorial location (first level) - sub-indicators**:** proximity to large settlements; large industrial areas; wholesale trade centres; border crossing; level of market economy development.

3. Communication system (first level) - sub-indicators: internal information technologies; telecommunications technological infrastructure; transport routes of approach; railway routes of approach; utility networks; electricity sources, etc. Other qualitative indicators can be presented similarly.

The expert group develops a fuzzy assessment questionnaire, and each expert independently fills it out. That is, it evaluates the alternative place of the location with the corresponding sub-indicators (characteristics) of the indicators, after which all the assessments are combined into one questionnaire. For example, a hierarchical representation of the first qualitative indicator is shown in the fuzzy assessment questionnaire (Table 2).

For qualitative evaluation, a fuzzy assessment scale is used, where a trapezoidal fuzzy number is assigned to each linguistic evaluation in the range [0,1] (Table 1). These numbers are considered to be fuzzy assessments of the characteristics.

Table 1. Fuzzy Interval Rating Scale

Logical Assessment	**Very Low**	**Low**	**Average**	**High**	**Very High**

Fuzzy Rating	(0;0;0.1;0.3)	(0.1;0.3;0.3;0.5)	(0.3; 0.5; 0.5; 0.7)	(0.5;0.7;0.7;0.9)	(0.7;0.9;1;1)

The use of fuzzy assessments in the expert method creates certain advantages compared to other expert assessment methods. Among them, the possibility of simultaneously using qualitative and quantitative assessment indicators is important (Mchedlishvili, Khutsishvili, & Amilakhvari, 2015; Volokobinsky, Pekarskaya, & Razi, 2016).

The assessment should be carried out by a group of qualified experts. It is practically justified if such a group includes structural components of the Transport Logistics Center (TLC) and qualified employees in the field. (We assume that the experts have almost the same rating and are in agreement, otherwise, we calculate the concordance coefficient.) (Chui & Chan, 1994)

Table 2. Evaluation of the qualitative indicator – "Transportation capabilities"

Indicator Name	Sub-indicators	Fuzzy Rating of the First Indicator				
		(0; 0; 0.1; 0.3)	(0.1;0.3;0,3;0.5)	(0.3;0.3;0.5; 0.7)	(0.5;0.7;0 .7;0.9)	(0.7;0.9;1; 1)
1. Transportation capabilities	Proximity to highways			XXX	XXXX	XXX
	Proximity to transportation hubs			XXXX	XXXX	XX
	Multimodal service			XXXX	XXX	XXX
	Proximity to an international transport corridor			XXXX	XXXX	XXX
Total Fuzzy Rating of the Indicator		X1= (x11; x12; x13; x14)				

In our case, the assessment is done by 10 experts for each sub-indicator (Table 2). (For example, for the first sub-indicator, 3 experts evaluate the alternative as average, 4 experts as good, and 3 as very good). After that, the corresponding fuzzy estimate of the sub-indicator is calculated. We use arithmetic operations on fuzzy numbers.

$$3 * (0.3;0.3;0.5; 0.7) + 4 * (0.5;0.7;0.7;0.9) + 3 * (0.7;0.9;1;1) = (5.0; 6.4; 6.3; 7.3)$$

The estimates for other sub-indicators are calculated similarly, and by summing up the results, we obtain a total fuzzy estimate for each indicator. Since the opinions of all experts shall be taken into account, it becomes necessary to calculate the arithmetic mean of the fuzzy estimates for the indicator. That is, we divide the total fuzzy assessment of the indicator by the number of experts (10) and the number of sub-indicators (4). This way, we receive the total fuzzy estimate of the first indicator.

$$X1= (x11; x12; x13; x14) = (5.0; 6.4; 6.3; 7.3) / 24 = (0.21; 0.27; 0.27; 0.31)$$

The total fuzzy estimates of other qualitative indicators are calculated similarly, Xi= (xi1; xi2; xi3; xi4).

Quantitative indicators can also be used for assessment. However, it is necessary to inform the expert group of the value of each quantitative indicator in the form of a numerical range.

Since quantitative indicators of assessment can have different dimensions, it is advisable to bring them to quantities without dimensions. This is possible by using a certain normalisation rule, which simultaneously allows us to bring the numerical range of the quantitative indicator to a fuzzy number lying in the interval (0,1) (Volokobinsky, Pekarskaya, & Razi, 2016). This action makes it possible to simultaneously evaluate each alternative location using commensurable qualitative and quantitative indicators (Volokobinsky, Pekarskaya, & Razi, 2016).

If $A = (a_1, a_2, a_3, a_4)$ is a quantitative interval indicator of the ith alternative, the best value of which is considered to be the maximum value, then we normalise it as follows: we divide each parameter of the given indicator by the maximum among them, after which this indicator will be equal to:

$$\overline{A} = \left(\frac{a_{i_1}}{a_{max}}, \frac{a_{i_2}}{a_{max}}, \frac{a_{i_3}}{a_{max}}, \frac{a_{i_4}}{a_{max}}\right) \quad (1)$$

where $a_{max} = max\left(a_{i_1}, a_{i_2}, a_{i_3}, a_{i_4}\right)$, $i = 1, 2, ..., N$;

i – Is the number of alternative;

N - Number of alternative locations to consider.

If $A = (a_1, a_2, a_3, a_4)$ is a fuzzy representation of a quantitative indicator for the i-th alternative, the best value of which is considered to be the minimum value, then the minimum among the parameters is divided by all parameters, after which we obtain the corresponding normalised fuzzy rating.

$$\overline{A} = \left(\frac{a_{min}}{a_{i_1}}, \frac{a_{min}}{a_{i_2}}, \frac{a_{min}}{a_{i_3}}, \frac{a_{min}}{a_{i_4}}\right) \quad (2)$$

where $a_{min} = min\left(a_{i_1}, a_{i_2}, a_{i_3}, a_{i_4}\right)$, $i = 1, 2, ..., N$ are formed normalised fuzzy numbers for quantitative indicators. $\left(a^k_{i_1}, a^k_{i_2}, a^k_{i_3}, a^k_{i_4}\right)$ clearly satisfy the inequalities.

$0 \leq \left(a^k_{i_1}, a^k_{i_2}, a^k_{i_3}, a^k_{i_4}\right) \leq 1$,

where k is a number of quantitative indicators.

Calculating weights for evaluation indicators is a rather important and meaningful stage (Zou, Yun, & Sun, 2006). At this time, the expert must decide which indicator is more important (priority) compared to other indicators, which determines the final form of the result, i.e. the integral fuzzy assessment, which is presented in the paper as a weighted sum.

$$X = \sum_{i=1}^{n} \alpha_i X_i. \quad (3)$$

where; $X_1, X_2, \cdots X_n$ are the fuzzy total values of alternative evaluation, and the corresponding weights of the indicators are $\alpha_1, \alpha_2, \cdots \alpha_n$, where $\alpha_i \geq 0$ ori $\in \mathbb{N}$

$$\sum_{i=1}^{n} \alpha_i = 1 . \quad (4)$$

If the values of the indicators are fuzzy numbers like a trapezoid $X_i = \left(x_{i1}, x_{i2}, x_{i3}, x_{i4}\right)$, $i = 1, 2, \cdots n$, then the integral evaluation will take the form:

$$X = (\sum_{i=1}^{n} \alpha_i x_{i1}; \sum_{i=1}^{n} \alpha_i x_{i2}; \sum_{i=1}^{n} \alpha_i x_{i3}; \sum_{i=1}^{n} \alpha_i x_{i4}) \quad (5)$$

Similarly, a fuzzy integral rating of the location of all prospective locations is obtained. To compare fuzzy numbers, it is necessary to bring them to a clear value to simplify the comparison and ranking of alternatives (Carlsson & Fuller, 2002). In this paper, we have used Chang's method, which is easy to use and calculate. If $X = (x_1, x_2, x_3, x_4)$ is an integral fuzzy rating of the alternative, then the formula by Chang is:

$$ch(x) = \frac{x_3^2 + x_3 \bullet x_4 + x_4^2 - x_1^2 - x_1 \bullet x_2 - x_2^2}{6} \quad (6)$$

gives us the corresponding "clear" real number. A larger number indicates a better location. This allows us to select one or more acceptable locations for the Transport Logistics Centre (TLC).

3. Conclusions

The presented method allows us to make a preliminary assessment of locations with different characteristics, using an appropriate system of indicators, and select the best among them. At the initial stage, we will be able to reject ineffective alternatives that are incompatible with strategic goals and plans. This will significantly save both human and material resources. It will be possible to jointly involve representatives of industrial, research, trade, transport, and other logistics organisations included in the Transport Logistics Centre (TLC) in management. It will also be possible to consider the interests of consumers, the state, society, and their participation in the processes.

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