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INFORMATION TECHNOLOGY OF FORMING OPTION FOR LOGISTICS DISTRIBUTION CHANNEL CONFIGURATION RESISTANT TO EMERGENCIES

The problem and the main stages of choosing a rational configuration of a four-level logistics network that is resistant to the impact of emergencies for strategic planning are considered. The problem under consideration belongs to the class of multicriteria optimization problems. Criteria related to the financial costs of building and operating a logistics distribution channel, as well as criteria related to the level of quality of customer service, are contradictory. To solve the problem of stability of the logistics system configuration to emergencies, such as failure of intermediate warehouses, failure of transport arteries, etc., a strategic management information system was developed by integrating existing software components at the level of enterprise software applications. The integration of the system was based on a service-oriented architecture, as all its components are heterogeneous in nature. This approach allows you to reuse existing program code. To determine a sustainable configuration option, two criteria are used, which are considered equivalent: the level of costs for the maintenance of the logistics channel and the level of service quality in the event of different emergencies. Since the probability of emergencies is unknown, the minimax criterion is used to minimize the risk when choosing a rational configuration of the logistics network. For this purpose, losses from emergencies are calculated according to all criteria, and there is a variant of the logistics network configuration that will be the least risky. That is, we will not be able to get a worse result than the one we rely on. The results of the study are presented in the form of a configuration variant of the logistics distribution system, which can be used in the future to determine business options.

Keywords: strategic management, logistic system configuration option, service level, emergency situation, minimax criterion, service-oriented architecture.

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ІНФОРМАЦІЙНА ТЕХНОЛОГІЯ ФОРМУВАННЯ ВАРІАНТУ КОНФІГУРАЦІЇ ЛОГІСТИЧНОГО КАНАЛУ ДИСТРИБУЦІЇ СТІЙКОГО ДО НАДЗВИЧАЙНИХ СИТУАЦІЙ

Розглянена задача та основні етапи вибору раціональної конфігурації чотирьохрівневої логістичної мережі, що стійка до впливу надзвичайних ситуацій, для стратегічного планування. Задача, що розглядається, належить до класу задач багатокритеріальної оптимізації. Критерії, що пов'язані з фінансовими витратами на будівництво та функціонування логістичного каналу дистрибуції, а також критерії, пов'язані з рівнем якості обслуговування споживачів, є суперечливими. Для вирішення проблеми стійкості конфігурації логістичної системи до надзвичайних ситуацій, таких як: вихід з ладу проміжних складів, відмова транспортних артерій тощо, розроблено інформаційну систему стратегічного управління за допомогою інтеграції існуючих програмних компонентів на рівні корпоративних програмних додатків. Інтеграція системи базувалася на основі сервіс-орієнтованої архітектури, так як усі її компоненти є різномірними за своєю природою. Такий підхід дозволяє перевикористати існуючий програмний код. Для визначення стійкого варіанту конфігурації використовуються два критерії, які вважаються рівноцінними: рівень витрат на утримання логістичного каналу та рівень якості обслуговування при настанні різних варіантів надзвичайних ситуацій. Так як імовірність настання надзвичайних ситуацій невідома, мінімаксний критерій використовується для мінімізації ризику при виборі раціональної конфігурації логістичної мережі. Для цього вираховуються збитки від надзвичайних ситуацій по всім критеріям, та знаходиться варіант конфігурації логістичної мережі, який буде найменш ризиковим. Тобто, ми не зможемо отримати гірший результат, ніж той, на який ми опираємося. Результати дослідження представлені у вигляді варіанту конфігурації логістичної системи дистрибуції, яка може бути використана в подальшому для визначення варіантів ведення бізнесу.

Ключові слова: стратегічний менеджмент, варіант конфігурації логістичної мережі, рівень сервісу, надзвичайна ситуація, мінімаксний критерій, сервіс-орієнтована архітектура.

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ИНФОРМАЦИОННАЯ ТЕХНОЛОГИЯ ФОРМИРОВАНИЯ ВАРИАНТА КОНФИГУРАЦИИ ЛОГИСТИЧЕСКОГО КАНАЛА ДИСТРИБУЦИИ УСТОЙЧИВОГО К ЧРЕЗВЫЧАЙНЫМ СИТУАЦИЯМ

Рассмотрена задача и основные этапы выбора рациональной конфигурации четырехуровневой логистической сети, устойчивой к воздействию чрезвычайных ситуаций, для стратегического планирования. Рассматриваемая задача относится к классу задач многокритериальной оптимизации. Критерии, связанные с финансовыми затратами на строительство и функционирование логистического канала дистрибуции, а также критерии, связанные с уровнем качества обслуживания потребителей, противоречивы. Для решения проблемы устойчивости конфигурации логистической системы к чрезвычайным ситуациям, таким как выход из строя промежуточных составов, отказ транспортных артерий и т.п., разработана информационная система стратегического управления посредством интеграции существующих программных компонентов на уровне корпоративных программных приложений. Интеграция системы базировалась на основе сервиса ориентированной архитектуры, так как все ее компоненты разнородны по своей природе. Такой подход позволяет использовать существующий программный код. Для определения устойчивого варианта конфигурации используются два критерия, которые считаются равноценными: уровень затрат на содержание логистического канала и качество обслуживания при наступлении различных вариантов чрезвычайных ситуаций. Так как вероятность наступления чрезвычайных ситуаций не известна, минимаксный критерий используется для минимизации риска при выборе рациональной конфигурации логистической сети. Для этого рассчитываются убытки от чрезвычайных ситуаций по всем критериям, и находится вариант конфигурации логистической сети, который будет менее рискованным. То есть мы не сможем получить худший результат, чем тот, на который мы опираемся. Результаты исследования представлены в виде варианта конфигурации логистической системы дистрибуции, которая может использоваться в дальнейшем для определения вариантов ведения бизнеса.

Ключевые слова: стратегический менеджмент, вариант конфигурации логистической сети, уровень сервиса, чрезвычайная ситуация, минимаксный критерий, сервис-ориентированная архитектура.

Introduction. Logistic system configuration is a connections such as roads through which logistics flows spatial structure of nodes such as warehouses, and move. The central production company is interested in

optimizing logistics performance to reduce transportation and storage costs. The study considers a four-level logistics network, which consists of warehouses of production, national, regional and local levels. In strategic planning, it is necessary to determine which configuration of the logistics network will be optimal for the business, so that costs are as low as possible and the level of service is as high as possible.

To minimize transportation costs, an information system has been developed [1]. The optimal location of regional warehouses and volumes of deliveries are found with the help of this information system. As a result, the decision-making expert obtains logistics network configuration options based on the entered parameters. The obtained configuration options are equivalent, but have different degrees of resistance to emergencies, for example: problems with transport, closure of warehouses, shortage of products, blockage of transport arteries, etc. The stability of the logistics network configuration is a very important characteristic for strategic management, so the expert when choosing a configuration option should be aware of the degree of its stability, so that in an emergency the logistics company suffers less damage than it could.

The aim of the work is to develop a software module for the existing information system to form a matrix of variants of losses from emergencies, which is the basis for choosing the criteria of multicriteria synthesis: maximin, maximax criteria, Hurwitz criteria and Laplace criteria. The decision-maker can choose a criterion depending on the degree of uncertainty about the probability of emergencies. The developed module helps experts to assess the degree of stability of logistics network configuration options when choosing a logistics network configuration option for strategic planning, which in the long run will help to reduce costs, losses and increase the level of service.

Literature review. The issue of optimizing various indicators in logistics, such as cost and level of service, has been and remains extremely relevant. Powers [2] described the importance of computer modeling in logistics and decision-making in logistics. He wrote that three types of solver technologies heuristics, optimization, and simulation are used most often when dealing with a problem being solved in logistics.

The direction of optimization in logistics was covered by Michael R. Bartolacci et al. [3], who described the process of finding optimal supply chains for a three-tier logistics network in terms of transportation costs from vendors, through distribution centers (DC) and to consumers, having for initial data DC capacities, costs per CWT shipped from vendors to DCs, costs per CWT shipped from DCs to customers and customer demands. In this work, the logistics network has only three levels, which are sometimes not enough for some logistics companies.

Recent works in the field of logistics simulation include the work of Jesus Silva et al. [4], who developed a computer simulation of the logistics distribution system and conducted experiments by changing the input

parameters of the model and obtained different levels of logistic systems performance. To model the logistics network Thibaut Demare et al. [5] utilized agent-based model and dynamic graphs to obtain a model that helps the decision making of land planning. Agent modeling can also be used to determine service levels of logistics network configuration options, as was described in Ihor Godlevskiy [6].

Multiple Criteria Decision Making (MSDM) methodology for solving problems is also often used in logistics, as it is important to find a solution that will provide an acceptable level of various criteria, such as the cost of transportation and the level of service. For example, Jacek Zak [7] demonstrated how MSDM can be utilized to obtain solutions in mass transit systems for transit system development scenarios and for crew size optimization.

Methods. The problem under consideration is related to strategic management, so it is important to consider the problem of resilience of the existing configuration options of the logistics channel to emergencies, such as: failure of intermediate warehouses, shortage of products, problems with transport arteries, etc.

Criteria related to the financial costs of building and operating a logistics channel, as well as criteria related to the quality level of consumer service, are contradictory.

First, variable vectors were selected:

- 1) S – determines the structure of the logistics channel.
- 2) P – determines the parameters of the system.
- 3) Π – determines the parameters that are set at the beginning and are immutable [8].

Next, the models of structural-parametric synthesis were defined in general terms. The first group of criteria was determined by the vector

$$\bar{F} = \{\bar{F}_i\} = \{f_i(S, P, \Pi), i \in I\}, \quad (1)$$

where I is the set of criteria of the first group [8].

The second group of criteria was defined as

$$\bar{\Phi} = \{\bar{\Phi}_j\} = \{\varphi_j(S, P, \Pi), j \in J\}, \quad (2)$$

where J is the set of criteria of the second group. The range of allowable variation of the variables vectors S and P of criteria (1), (2) was determined by the following restrictions

$$q_g(S, P, \Pi) \leq b_g, g \in G, \quad (3)$$

where G is the set of constraints, $\{b_g\}$ is the vector of parameters, which can be determined by constraints on both the structure and the parameters of the system [8].

Since criteria (1), (2) may have a different dimension, it was brought to isomorphic form using following functions

$$\omega_i^f(f_i(S, P, \Pi)) = \frac{f_i(S, P, \Pi) - f_i^{\text{НГ}}}{f_i^{\text{НК}} - f_i^{\text{НГ}}}, i \in I, \quad (4)$$

$$\omega_j^\varphi(\varphi_j(S, P, \Pi)) = \frac{\varphi_j(S, P, \Pi) - \varphi_j^{\text{НГ}}}{\varphi_j^{\text{НК}} - \varphi_j^{\text{НГ}}}, j \in J, \quad (5)$$

where f_i^{HK}, f_i^{HF} are the best and worst values of the i -th criterion of the first group and $\varphi_j^{HK}, \varphi_j^{HF}$ are the best and worst values of the j -th criterion of the second group [8].

The next step was to determine the weighting factors of these criteria to create complex criteria. For this purpose, the methodology of collective expert assessment was used [1] and complex criteria were presented in the following form

$$F(S, P, \Pi) = \sum_{i \in I} \rho_i^f \omega_i^f(S, P, \Pi), \quad (6)$$

$$\Phi(S, P, \Pi) = \sum_{j \in J} \rho_j^\varphi \omega_j^\varphi(S, P, \Pi). \quad (7)$$

where

$$\rho_i^f \geq 0, i \in I; \sum_{i \in I} \rho_i^f = 1; \quad (8)$$

$$\rho_j^\varphi \geq 0, j \in J; \sum_{j \in J} \rho_j^\varphi = 1, \quad (9)$$

where $\{\rho_i^f\}, \{\rho_j^\varphi\}$ – is the vector of weighting factors of the criteria of the first and second groups [8].

Based on the variation of the variables vector S for each structure of the parameters vector P , a set of configuration options for the logistics channel was formed. From these options, a set of effective solutions \bar{B} (Pareto set) was selected.

Set of effective solutions \bar{B} – was narrowed by setting the vectors of upper and lower limits for weighting factors of importance criteria F and Φ , $\mu_B = (\mu_B^F, \mu_B^\Phi)$ and $\mu_H = (\mu_H^F, \mu_H^\Phi)$, which met the following requirements

$$\mu_B^F, \mu_B^\Phi, \mu_H^F, \mu_H^\Phi \geq 0,$$

$$\mu_B^F + \mu_B^\Phi = 1,$$

$$\mu_H^F + \mu_H^\Phi = 1.$$

As a result, a set was formed $B \subseteq \bar{B}$. We assume that it consists of N configuration options for the logistics channel, the method of obtaining which is described in [9].

$$B = \{B_1, B_2, B_3, \dots, B_N\} \quad (6)$$

Next a set of emergency situations (ES) was formed $A = \{A_1, A_2, A_3, \dots, A_M\}$ [8].

Assume that the likelihood of ES is known, and each causes a predetermined loss in terms of criteria F and Φ , where i – version logistics channel and j – version ES (table 1).

Table 1 – Negative payoffs from the emergencies occurrence

	A_1	A_2	A_3	...	A_M
B_1	U_{11}	U_{12}	U_{13}	...	U_{1M}
B_2	U_{21}	U_{22}	U_{23}	...	U_{2M}
...
B_N	U_{N1}	U_{N2}	U_{N3}	...	U_{NM}

The following criteria can be used when choosing a rational strategy [10].

1. The probability of each emergency is unknown. – Minimax criterion

$$U^* = \min_{i=1, N} \max_{j=1, M} U_{ij}$$

This strategy eliminates risk. In this case, the decision maker can not have a worse result than the one he focuses on. Therefore, it is considered that this criterion is one of the fundamental ones.

- Criterion of extreme optimism

$$U^* = \min_{i=1, N} \max_{j=1, M} U_{ij}$$

In this case, a decision maker sees his position from a gambler's point of view who bets for the best option.

- Hurwitz criterion

$$U^* = \min_{i=1, N} \bar{U}_i(\alpha),$$

where`

$$\bar{U}_i(\alpha) = \alpha \bar{m}_i + (1 - \alpha) \bar{M}_i,$$

$$\bar{m}_i = \min_{j=1, M} U_{ij},$$

$$\bar{M}_i = \max_{j=1, M} U_{ij}, 0 \leq \alpha \leq 1$$

For this criterion, the evaluation function is between the views of extreme optimism and extreme pessimism.

2. The probability of each emergency is the same. In this case, the Laplace criterion is used, which has the following form

$$U^* = \min_{i=1, N} \left\{ \frac{1}{M} \sum_{j=1}^M U_{ij} \right\}$$

3. The probability of each emergency is known and these probabilities are equal to $\bar{P}_1, \bar{P}_2, \dots, \bar{P}_M$. Then

$$U^* = \min_{i=1, N} \left\{ \sum_{j=1}^M \bar{P}_j U_{ij} \right\}$$

The minimax criterion was used for rational strategy choosing, which provides the greatest caution in the choice for the situation where the probability of occurrence of each emergency is unknown.

Further the matrix $U = \{U_{ij}\}$ (table 1) was formed on the basis of a complex criterion W , which is determined by convolution of criteria F and Φ

$$W = \rho^F F + \rho^\varphi \Phi; \rho^F, \rho^\varphi \geq 0, \rho^F + \rho^\varphi = 1, \quad (10)$$

where ρ^F, ρ^φ – weight coefficients of complex criteria of the first and second groups [8].

Sets B and $A \times B$ meet the following values of the criteria of the first and second groups

$$B = \{B_i, i = \overline{1, N}\} \Rightarrow \{\overline{W}_i, i = \overline{1, N}\}, \quad (10)$$

$$(B \times A) = \{B_i, i = \overline{1, N}\} \times \{A_j, j = \overline{1, M}\} \Rightarrow \{\overline{W}_{ij}, i = \overline{1, N}, j = \overline{1, M}\}.$$

As a result, the elements of the matrix U are

$$U_{ij} = (\overline{W}_i - \overline{W}_{ij}), \quad i = \overline{1, N}; \quad j = \overline{1, M} \quad [8].$$

Information technology. Consequently an information system was created to find a rational variant of the logistics network configuration. For this purpose, the previously implemented services of finding the optimal variant of the logistics network configuration and finding the service level were integrated. The integration was carried out at the level of enterprise software applications (Enterprise Application Integration – EAI), which means reusing not only the internal data of the applications being integrated, but also their program code. Technology based on service-oriented architectures (SOA) was used as the integration technology [11]. Fig. 1 depicts the interaction of integrated components.

Results. A total of 4 configurations with different constraints of regional warehouse number were analyzed using 3 types of emergencies: closing of a regional

warehouse that serves logistic channel, changing the shortest way from national to the regional warehouse due to road repair, closing national warehouse. The results of the changes in configurations are shown as the list of warehouses of the regional level.

Configuration 1 has the constraint of national warehouses number equals 5 which are: Zhytomyr, Kyiv, Dnipro, Odesa, Mykolaiv (table 2). Emergency 1 is closing the regional warehouse in Dnipro city. When emergency 1 happened logistic system configuration changed and a regional warehouse in Lutsk city would be opened. Emergency 2 is the situation when the road Odesa – Mykolaiv (132 km long) is closed due to road repair and the detour is 479 km long. When emergency 2 occurs, it is cheaper to open a warehouse in Lutsk city than transport products from Odesa to Mykolaiv by detour. Emergency 3 is a temporary or permanent closing of a national level warehouse in Odesa. If situation 3 happened, a regional warehouse in Kharkiv city would be opened.

Configuration 2 has the constraint of national warehouses number equals 6 which are: Zhytomyr, Kyiv, Dnipro, Odesa, Mykolaiv, Lutsk (table 3). When emergency 1 happened regional warehouse in Kharkiv city would be opened replacing one in Dnipro. When emergency 2 happened regional warehouses in Kharkiv and Lviv cities would be opened. If situation 3 happened, a regional warehouses in Lviv and Kharkiv cities would be opened instead of Mykolaiv and Kyiv warehouses.

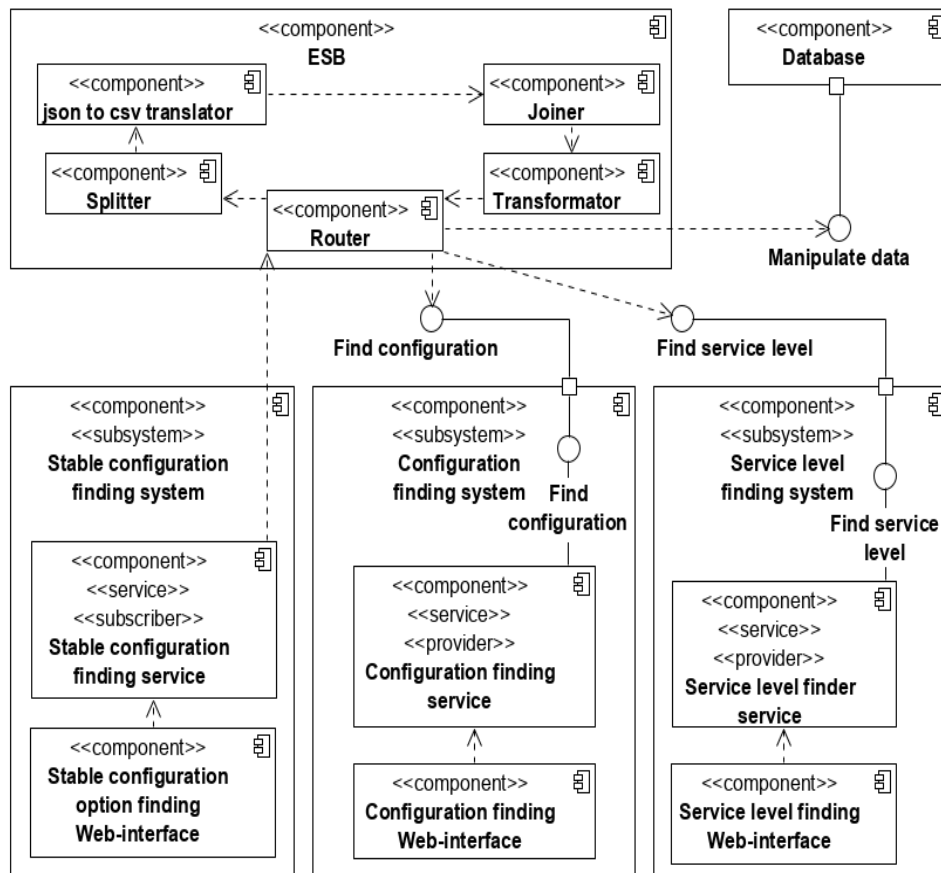


Fig. 1. Components diagram

Table 2 – Regional warehouses for configuration 1 in different emergencies

Configuration 1			
Emergency absence	Emergency		
	1	2	3
Zhytomyr	Zhytomyr	Zhytomyr	Zhytomyr
Kyiv	Kyiv	Kyiv	Kyiv
Dnipro	Lutsk	Dnipro	Lutsk
Odesa	Odesa	Odesa	Odesa
Mykolaiv	Mykolaiv	Lutsk	Kharkiv

Table 3 – Regional warehouses for configuration 1 in different emergencies

Configuration 2			
Emergency absence	Emergency		
	1	2	3
Zhytomyr	Zhytomyr	Zhytomyr	Zhytomyr
Lutsk	Lutsk	Lutsk	Lutsk
Kyiv	Kyiv	Kyiv	Kharkiv
Dnipro	Kharkiv	Lviv	Dnipro
Odesa	Odesa	Odesa	Odesa
Mykolaiv	Mykolaiv	Kharkiv	Lviv

Tables 4–6 show regional warehouses that were selected for emergencies 1–3 in comparison with the initial configuration.

Table 4 – Regional warehouses for configuration 1 in different emergencies

Configuration 3			
Emergency absence	Emergency		
	1	2	3
Zhytomyr	Zhytomyr	Zhytomyr	Zhytomyr
Lutsk	Lutsk	Lutsk	Lutsk
Kyiv	Kyiv	Kyiv	Kyiv
Dnipro	Kharkiv	Dnipro	Dnipro
Odesa	Odesa	Odesa	Odesa
Lviv	Lviv	Lviv	Lviv
Mykolaiv	Mykolaiv	Mykolaiv	Kharkiv

Table 5 – Regional warehouses for configuration 1 in different emergencies

Configuration 4			
Emergency absence	Emergency		
	1	2	3
Zhytomyr	Zhytomyr	Zhytomyr	Zhytomyr
Lutsk	Lutsk	Lutsk	Lutsk
Kyiv	Kyiv	Kyiv	Kyiv
Dnipro	Odesa	Dnipro	Dnipro
Odesa	Lviv	Odesa	Odesa
Lviv	Kharkiv	Lviv	Lviv
Kharkiv	Mykolaiv	Kharkiv	Kharkiv
Mykolaiv		Mykolaiv	Mykolaiv

As a result of changing logistic system configuration due to emergencies, products are transported over longer distances than in initial configurations. This leads to increasing in the cost of goods transportation.

Table 6 represents the value of the negative payoffs from the emergency occurrence.

Table 6 – Negative payoffs from the emergencies occurrence

	Emergency 1	Emergency 2	Emergency 3
Configuraion 1	0.0120	0.0120	0.8115
Configuraion 2	0.0646	0.0646	0.5693
Configuraion 3	0.0744	0.0625	0.3027
Configuraion 4	0.4908	0.5161	0.3191

As fundamental minimax criterion was used to eliminate the risk of choosing the worst alternative than foreshadowed one, configuration 3 was selected as the most rationable configuration. When using other criteria, the result may differ from that obtained.

Further use of the obtained results is associated with determining the option of doing business using the method of hierarchies analysis based on SWOT analysis [12].

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