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Contents

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TRANSFORMATION OF THE ORGANIZATION OF MULTIMODAL TRANSPORTATION UNDER MARTIAL LAW

Dmytro Bugayko, Volodymyr Reznik, Anton Borysiuk, Danylo Bugayko. "Transformation of the organization of multimodal transportation under martial law". *Multimodal transportations plays a huge role in global economy. A lot of manufactures require different components, located in different remote sectors. In order not to discontinue production processes, multimodal transportation is used. Especially, the war influenced on the whole multimodal transportation system in Ukraine. Ports, harbors and sea ports stopped it's further operation. The main role was fallen on road transportation. A plenty of airports were totally destroyed, the most of main harbor became in occupation, it's further operation is impossible until the full victory of Ukraine. The road transportation became as the save link for supply chains and further economy operating. The one of the main problems in this situation is choosing of the optimal way and best-suited carrier for sequel carriage. The truck corporations continue cooperating with the airline agents, but the basic hubs of them were moved to the neighbor countries, it can appear new questions for optimization the delivery. Such factor as price, quality of the services, distance and time always plays a huge role in supply chains. The main aim of the transport*

company and its staff during multimodal transportation is to provide the delivery of goods, that were ordered by the manufacture just in time providing it's safe and integrity. For optimization of all this factors according to the consignee's preferences the expert evaluation methods are used in given research. There are lot of additional services attracted in such cases, such as: loading, unloading, repacking, changing the kind of packing (boxes, pallets, container repacking and other), in which sub-contractors take part. The union of all this processes mentioned above gives the opportunity to create the whole system of supplying the good from its seller to buyer. Every process is unique depending on the current situation and terms of delivery.

***Keywords**:* transport system, cargo transportation, multimodal transportation, optimization processes, routs planning, delivery scheme modelling.

Дмитро Бугайко, Володимир Резник, Антон Борисюк, Данило Бугайко. «Трансформація організації мультимодальних перевезень в умовах воєнного стану». *Мультимодальні перевезення відіграють величезну роль у світовій економіці. Для багатьох виробництв потрібні різні компоненти, розташовані в різних віддалених секторах. Щоб не зривати виробничі процеси, використовуються мультимодальні перевезення. Особливо війна вплинула на всю систему мультимодальних перевезень в Україні. Порти, гавані та морські порти припинили його подальшу роботу. Основна роль припадала на автомобільний транспорт. Багато аеропортів були повністю знищені, більшість головних гаваней опинились в окупації, їх подальша робота неможлива до повної перемоги України. Автомобільний транспорт став рятівною ланкою для ланцюгів поставок і подальшого функціонування економіки. Однією з головних проблем у цій ситуації є вибір оптимального способу та найбільш підходящого перевізника для подальшого перевезення. Автомобільні корпорації продовжують співпрацювати з авіа агентами, але їх основні хаби перенесли в сусідні країни, можуть виникнути нові питання щодо оптимізації доставки. Такі фактори, як ціна, якість послуг, відстань і час завжди відіграють величезну роль у ланцюгах поставок. Основна мета транспортної компанії та її персоналу при мультимодальних перевезеннях – забезпечити доставку вантажів, замовлених виробником, точно в строк, забезпечивши їх збереження та цілісність. Для оптимізації всіх цих факторів відповідно до переваг вантажоодержувача в даному дослідженні використовуються методи експертної оцінки. У таких випадках залучається багато додаткових послуг, таких як: навантаження, розвантаження, перепакування, зміна виду упаковки (ящики, піддони, перепакування тари та інше), в яких беруть участь субпідрядники. Об'єднання всіх цих вищезгаданих процесів дає можливість створити цілу систему постачання товару від його продавця до покупця. Кожен процес є унікальним залежно від поточної ситуації та умов доставки.*

Ключові слова: транспортна система, вантажне перевезення, мультимодальне перевезення, процеси оптимізації, планування маршрутів, моделювання схеми доставки

Дмитрий Бугайко, Владимир Резник, Антон Борисюк, Даниил Бугайко. "Трансформация организации мультимодальных перевозок в условиях военного положения". *Мультимодальные перевозки играют огромную роль в мировой экономике. Многим производителям требуются разные компоненты, расположенные в разных отдаленных секторах. Чтобы не останавливать производственные процессы, используются мультимодальные перевозки. Особенно война повлияла на всю систему мультимодальных перевозок в Украине. Порты, гавани и морские порты прекратили свою дальнейшую работу. Основная роль легла на автомобильные перевозки. Многие аэропорты были полностью разрушены, большая часть основных гаваней оказалась под оккупацией, дальнейшая их эксплуатация невозможна до полной победы Украины. Автомобильный транспорт стал спасительным звеном для цепочек поставок и дальнейшего функционирования экономики. Одной из основных проблем в этой ситуации является выбор оптимального пути и наиболее подходящего перевозчика для последующей перевозки. Компании-перевозчики продолжают*

сотрудничество с авиа агентами, но основные их хабы перенесены в соседние страны, могут возникнуть новые вопросы по оптимизации доставки. Такой фактор, как цена, качество услуг, расстояние и время всегда играет огромную роль в цепочках поставок. Основной задачей транспортной компании и ее сотрудников при мультимодальных перевозках является обеспечение доставки заказанного производителем товара точно в срок при условии его сохранности и целостности. Для оптимизации всех этих факторов в соответствии с предпочтениями грузополучателя в данном исследовании используются методы экспертной оценки. В таких случаях привлекается множество дополнительных услуг, таких как: погрузка, разгрузка, переупаковка, изменение вида упаковки (ящики, поддоны, переупаковка контейнера и др.), в которых принимают участие субподрядчики. Объединение всех вышеперечисленных процессов дает возможность создать целую систему доставки товара от продавца к покупателю. Каждый процесс уникален в зависимости от текущей ситуации и условий поставки.

Ключевые слова: транспортная система, грузовая перевозка, мультимодальная перевозка, процессы оптимизации, планирование маршрутов, моделирование схемы доставки.

Introduction. Multimodal transportation plays huge role, especially nowadays, multimodal transportations are essential as air flow in our global economy. A lot of manufactures require different components, located in different remote sectors. In order not to discontinue production processes, multimodal transportation is used. Multimodal transportation is the transportation of any goods by two or more modes of transport, organized by one Logistics Company. The carrier has permission to attract for delivery vehicles that belong to other companies. Multimodal transportation - transportation of goods under one contract, but performed by at least two modes of transport; the carrier is responsible for the entire transport, even if this transport is carried out by different modes of transport (for example: railway, sea and road, etc.). The main aim of the transport company and its staff during multimodal transportation is to provide the delivery of goods, that were ordered by the manufacture just in time providing it's safe and integrity [1]. The article is a logical continuation of a number of publications devoted to the development of multimodal transportation development of Ukrainian scientists Y. Kharazishvili [2, 3, 5], D. Bugayko [2 – 6], A.Antonova [5], M. Hryhorak [4], Y. Ierkovska [6], O. Ovdiienko [4], V. Marchuk [5], V Lyashenko [3], Polish scientists Z.Zamiar [5] and scientists of other countries.

The purpose of the article is to provide research is to provide the theoretical foundations and problems of managing multimodal transportation and to develop project recommendations for transformation of the organization of multimodal transportation under martial law. Is also choosing the best carrier for delivery (on the example of Freight Forwarding Organization "Freight Transport Partner"

Presentation of the main results. Classification of strategic restrictions affecting efficiency for transport infrastructure represented Table 1.

Forming new delivery routes, the question of finding new car carriers that will carry out transportation from European airports to Ukraine will arise. They may be carriers with which the company has already cooperated, but they also need to be evaluated for whether they will fit the criteria of the new routes.

Various approaches can be used to solve the problem of choosing a carrier, but one of the simplest, but effective methods is expert evaluation. The methods of expert evaluations are a way of forecasting and evaluating the future results of actions based on the forecasts of experts.

Table 1. Offers strategic restrictions affecting efficiency for transport infrastructure.

A group of restrictions	A types of restrictions	Brief description
1	2	3
1. External	1.1. Innovative resources	Restrictions at the state level, restraining the level of development of the technological base, equipment, the use of resource-saving technologies, which determine the presence of a scientific and technical development department for the development of transport infrastructure
	1.2. Financial resources	The availability of financial resources in the state for investing in transport infrastructure, including the possibility of attracting foreign investment
	1.3. Workforce	The availability of engineering, production, and logistics personnel of the necessary qualifications and appropriate level in the studied region, the possibility of involving personnel in the development of transport infrastructure
	1.4. Environmental resources	The possible negative impact of the use of transport infrastructure on the ecological situation, i.e. to what extent transport, development and expansion of the productivity of its infrastructure correspond to the ecological capabilities of the region in terms of air pollution, ecological load on the biosphere, etc.
	1.5. Political resources	They are determined by the economic policy of the state, the political situation at the time of the management decision, etc.
2. Internal	2.1. Financial resources	The availability of financial resources at enterprises for the formation and development of transport infrastructure, for the implementation of measures for the modernization of the transport fleet, etc.
	2.2. Material resources	Availability of enterprise assets that are a necessary component of the transport system
	2.3. Workforce	The availability of personnel of the appropriate level of qualification who are able to develop management decisions and participate directly in the formation and further use of transport infrastructure
	2.4. Innovative resources	Restrictions restraining the level of development of the technological base of the transport infrastructure, which determine the level of scientific and technical developments regarding the development of a new spectrum of transport and logistics services that consumers need more
	2.5. Information resources	Availability of information communication between all participants of the transportation chain; the possibility of functioning of information systems of different levels on a real-time scale with appropriate accuracy, speed and productivity

Source: Developed by Dmytro Bugayko

When applying the method of expert evaluations, a survey of a special group of experts (5–7 people) is conducted in order to determine certain variables necessary for the evaluation of the researched question. The composition of experts should include people with different types of thinking - figurative and verbal-logical, which contributes to the successful solution of the problem [3]. Quality ratings and their corresponding standard ratings on the scale of desirability represented in Table 2.

Table 2. Quality ratings and their corresponding standard ratings on the scale of desirability

№ з/п	Interval	Quality assessment	Mark on the desirability scale	
			range	average value
1	2	3	4	5
1	3-4	Excellent	More than 0,950	0,975
2	2-3	Very good	0,875-0,950	0,913
3	1-2	Good	0,690-0,875	0,782
4	0-1	Satisfactorily	0,367-0,690	0,530
5	(-1)-0	Bad	0,066-0,367	0,285
6	(-2)-(-1)	Very bad	0,0007-0,066	0,033
7	(-3)-(-2)	Unacceptable	Less than 0,0007	-

Source: Reznik Volodymyr

We will apply the methodology based on the calculation of the integral evaluation to the assessment and selection of optimal carriers.

The essence of the method is to divide the criteria into groups:

1. *Relay* - criteria according to which the evaluation can acquire only two values, either "yes" or "no". An example of such criteria can be the presence of a certificate of conformity, specialized TK, permits for the transportation of dangerous goods, etc.

2. *Quantitative* - assessments according to these criteria are presented in digital form. Examples of such criteria can be the reliability of the carrier (probability of delivery "just in time"), the tariff, the total time of transportation (possibility of deviation from the planned duration of transportation, %), financial stability.

3. *Qualitative* - evaluations according to this group of criteria are of a qualitative nature and can mean "excellent", "very good", etc. As an example, you can choose the following criteria: frequency of service, preservation, qualification of personnel, readiness for negotiations.

We will apply the described methodology to the evaluation of motor transport enterprises with which the FTP Company cooperates and to develop recommendations for choosing the most optimal carriers for further work.

The FTP Company cooperates with various carriers; in addition, the development of new delivery schemes requires the consideration of new potential carriers that can perform transportation according to the relevant criteria. Potential carriers that we will evaluate are the following companies: transport company LEGION, LLC ALL TRANS, PE Elite Trans, PE Solovij-Trans, LLC Don-Forrest KFT, SK Techno, DSV Logistics and Trans Logistics. We will evaluate each of the listed carriers according to the specified criteria in order to single out the companies that most satisfy the criteria for finding the optimal carrier.

The quality control department, transport and forwarding department compiled a list of criteria according to which specialists of the transport department evaluated each carrier. The evaluation results are summarized in the Table

The rank of each criterion reflects how important this criterion is in the calculations. The lowest value of the criterion belongs to the most important criterion, the highest rank to the least important criterion. As we can see, the most important criterion when evaluating carriers is the transportation tariff. Other criteria that are used for assessment are follows: Order processing term, Condition of the car park, Probability of lateness, Personnel qualifications, Freight safety, The quality of the service, Loyalty to deferred payments, Flexibility in decision-making.

Among the given criteria, there is one relay criterion - the company's performance of transportation to Ukraine. According to this criterion, all carriers received a "yes" rating, therefore, they all participate in further

calculations. Among the eight motor transport companies, we will single out two that will most closely meet the specified search criteria. Assessments of transport enterprises according to selected criteria represented in Table 3.

Table 3. Assessments of transport enterprises according to selected criteria (the real carriers FTP cooperates with)

№	Criterion	Carriers								a R
		PE Elite Trans	LLC ALL TRANS	PE Solovij-Trans	LLC Don-Forrest KFT	SK Techno	DSV Logistics	Trans Logistics	LEGION	
1	Transportation tariff, USD/km	6,8	10,2	7,7	8,4	6,9	8,4	9,5	11,2	1
2	Order processing term, hours	9	7	7	8	6	7	5	4	7
3	Condition of the car park	satisf.	very good	good	satisf.	excellent	good	very good	excellent	5
4	Probability of lateness, %	12	4	10	8	12	7	10	3	6
5	Transportation to Ukraine	yes	yes	yes	yes	yes	yes	yes	yes	-
6	Personnel qualifications	good	excellent	very good	good	good	satisf.	satisf.	excellent	3
7	Freight safety, %	90	85	75	80	75	88	80	94	4
8	The quality of the service	excellent	very good	satisf.	good	good	very good	good	excellent	2
9	Loyalty to deferred payments	excellent	good	excellent	very good	satisf.	very good	good	excellent	9
10	Flexibility in decision-making	excellent	satisf.	good	very good	excellent	satisf.	very good	good	8

Source: Developed by authors

The evaluation of transport companies is the calculation of the weight indicator of each criterion. We will make the necessary calculations

$$W_1 = \frac{2 \cdot (9-1+1)}{90} = 0{,}200,$$
$$W_2 = \frac{2 \cdot (9-7+1)}{90} = 0{,}067,$$
$$W_3 = \frac{2 \cdot (9-5+1)}{90} = 0{,}111,$$
$$W_4 = \frac{2 \cdot (9-6+1)}{90} = 0{,}089,$$
$$W_6 = \frac{2 \cdot (9-3+1)}{90} = 0{,}156,$$
$$W_7 = \frac{2 \cdot (9-4+1)}{90} = 0{,}133,$$
$$W_8 = \frac{2 \cdot (9-2+1)}{90} = 0{,}178,$$
$$W_9 = \frac{2 \cdot (9-9+1)}{90} = 0{,}022,$$
$$W_{10} = \frac{2 \cdot (9-8+1)}{90} = 0{,}044.$$

Calculation of assessments according to quantitative criteria represented in Table 4.

Table 4 – Calculation of assessments according to quantitative criteria

№	Criteria	Weight	Extremum	Reference value	PE Elite Trans	LLC ALL TRANS	PE Solovij-Trans	LLC Don-Forrest KFT	SK Techno	DSV Logistics	Trans Logistics	LEGION
1	2	3	4	5	6	7	8	9	10	11	12	13
1	Transportation tariff, USD/km	0,200	min	6,8	1,00	0,67	0,88	0,81	0,99	0,81	0,72	0,61
2	Order processing time, hours	0,067	min	4	0,44	0,57	0,57	0,50	0,67	0,57	0,80	1,00
3	Probability of lateness, %	0,089	min	3	0,25	0,75	0,30	0,38	0,25	0,43	0,30	1,00
4	Freight safety, %	0,133	max	94	0,96	0,90	0,80	0,85	0,80	0,94	0,85	1,00

Source: Developed by Reznik Volodymyr

This is the transportation tariff, order processing time and probability of delay. The last criterion, cargo conservation, should acquire maximum importance. Then, among all the evaluations for each criterion, a reference value was chosen depending on where the extremum is directed. For example, for the transportation tariff, the extremum is minimal. Among the eight estimates for 8 carriers, the first carrier PE Elite Trans has the lowest tariff value and it is equal to 6,8 USD/km. We take this value as a reference value. If the extremum is the maximum, as for example in the cargo economy criterion, then among all the estimates we look for the maximum value - it is equal to 94% and belongs to the company LEGION.

When the reference value is determined, then a quantitative assessment is calculated for each criterion for each carrier according to formulas 1.1 and 1.2. For example, let's calculate the quantitative assessment according to the first criterion for the second carrier LLC ALL TRANS:

All other quantitative assessments are calculated in a similar way. When the quantitative estimates are calculated, it is necessary to take into account the weight factor by multiplying the found quantitative estimates by it. Let's bring to these calculations to the Table 5.

Therefore, the calculation of the quantitative assessment, taking into account the weighting factor, was carried out according to formula. For example, let's calculate this indicator for the "order processing time" criterion for the first carrier: [5]

$$D_{21} = 0{,}067 \cdot 0{,}44 = 0{,}030.$$

All other indicators are calculated in the same way. The last line displays the sum of quantitative assessments. The eighth carrier LEGION has the greatest importance, in which the sum of quantitative assessments is 0,41.

After the quantitative scores are calculated, the qualitative scores are calculated. For this purpose, qualitative assessments are converted to a digital format using Table 5. Each value of the quality rating corresponds to the standard average rating on the scale of desirability.

Table 5. Calculation of assessment according to quantitative criteria, taking into account the weight of criterion

№	Criterion	Weight	PE Elite Trans	LLC ALL TRANS	PE Solovij-Trans	LLC Don-Forrest KFT	SK Techno	DSV Logistics	Trans Logistics	LEGION
1	2	3	6	7	8	9	10	11	12	13
1	Transportation tariff, USD/km	0,200	0,200	0,133	0,177	0,162	0,197	0,162	0,143	0,121
2	Order processing time, hours	0,067	0,030	0,038	0,038	0,033	0,044	0,038	0,053	0,067
3	Probability of lateness, %	0,089	0,022	0,067	0,027	0,033	0,022	0,038	0,027	0,089
4	Freight safety, %	0,133	0,128	0,121	0,106	0,113	0,106	0,125	0,113	0,133
5	The sum of quantitative assessments, taking into account the weight		0,380	0,359	0,348	0,341	0,369	0,363	0,336	0,410

Source: Developed by Bugayko Dmytro and Reznik Volodymyr

The construction of new cargo delivery schemes requires the use of scientific approaches to determine the most optimal option. Currently, we will implement the construction of possible schemes for the delivery of the specified cargo from Hong Kong to the city of Stryi in the Lviv region. The cargo to be delivered is video cards packed in boxes. The number of boxes is 92 units. Cargo volume – 5.58 m3, cargo weight – 1104 kg. The cost of the cargo is 532,000 USD.

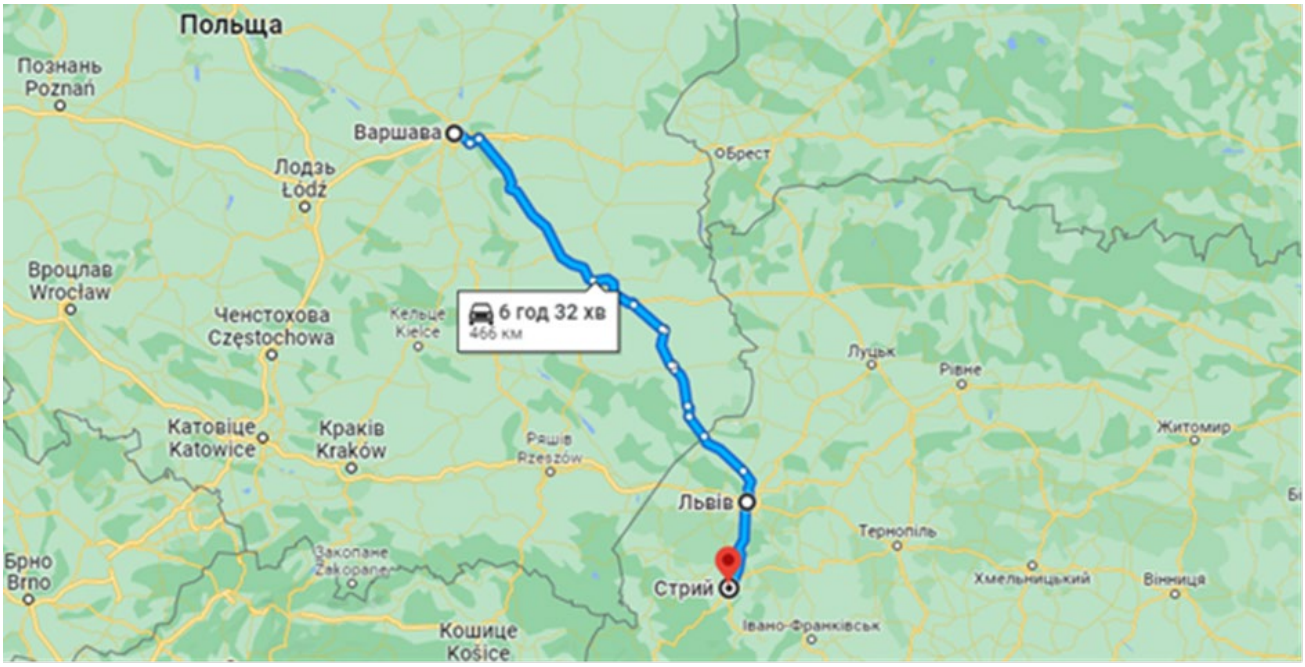

Figure 1. Route from Warsaw to Stryi
Source: Google maps screenshot

From Hong Kong, there is an option of air transport either to Warsaw airport or to Frankfurt airport. The airline that will carry out the transportation is Emirates (IATA code EK). Variability in the formation of delivery schemes will also arise due to the fact that it is possible to receive and transfer cargo to another mode of transport at the destination airports through different agents, with the involvement of different motor carriers.

As we can see, the route from Warsaw to Stryi passes through the Rava Ruska border crossing point.

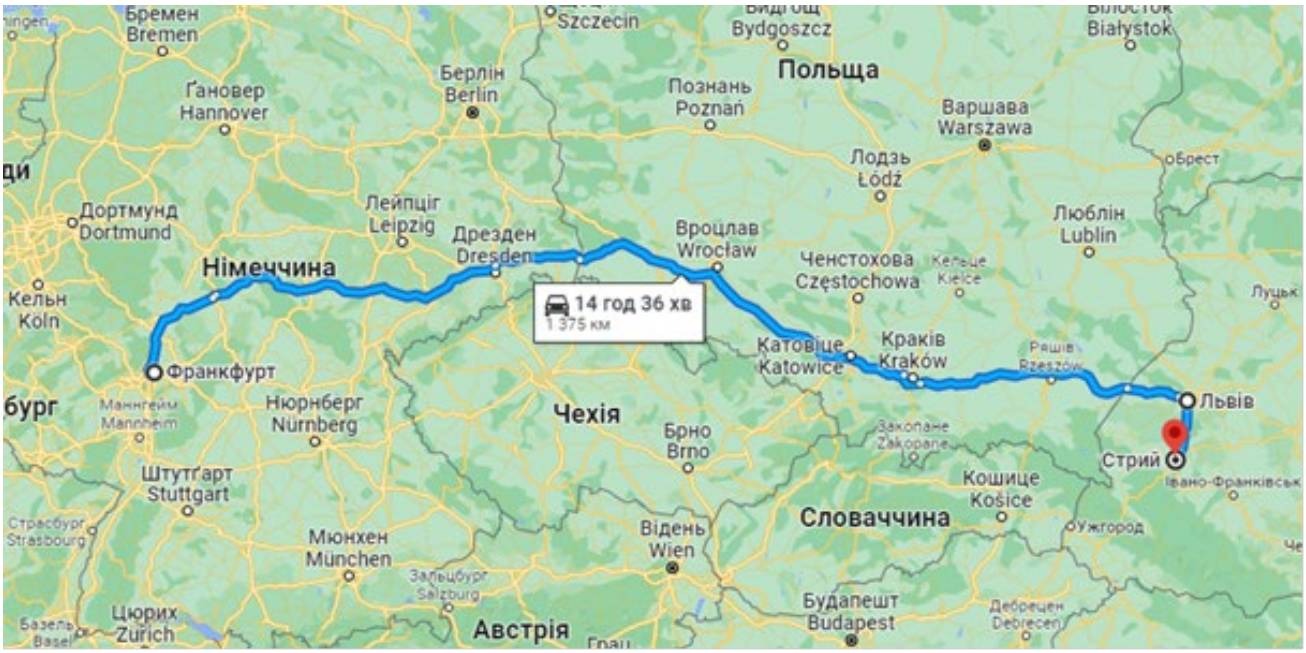

Figure 2. Route from Frankfurt to Stryi

Source: Google Maps screenshot

In this route from Frankfurt, the most optimal point for crossing the border will be Krakovets.

A network graph showing possible delivery schemes is presented in Fig. 3.

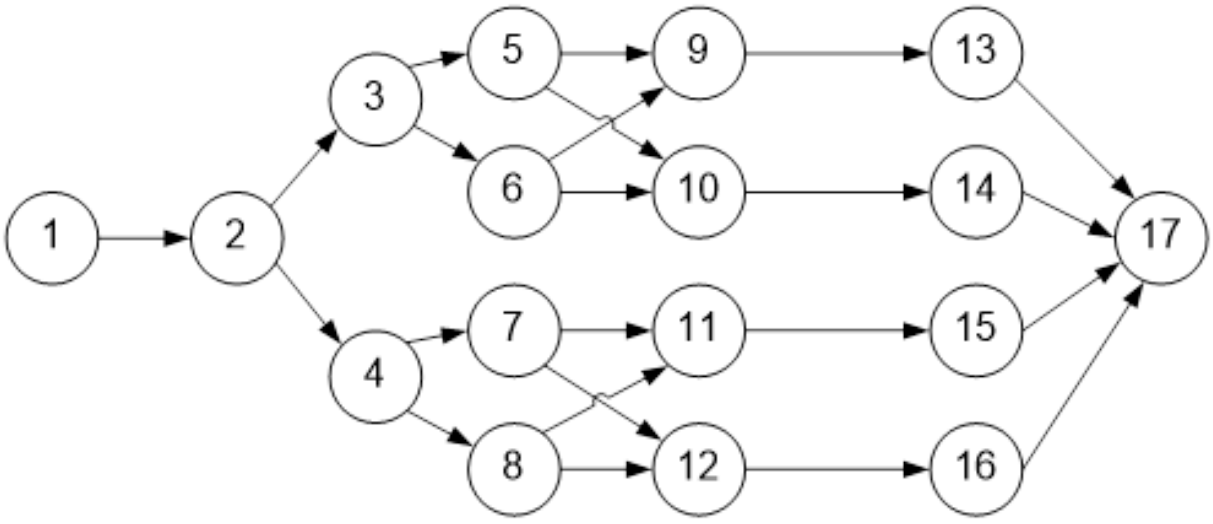

Figure 3 - Network graph of possible delivery schemes

Source: [6]

Works on the delivery of goods by direction Hong Kong to Stryi

The time and cost parameters for each delivery scheme will be defined as the sum of the corresponding values. An additional parameter that takes into account the cost of the cargo, namely the present value it is clear researching the Table 6.

Table 6 - Works on the delivery of goods by direction Hong Kong to Stryi

№ of work		Description of work	Cost, USD	Time, days
1		2	3	4
1	2	Registration of cargo and documents and loading onto the plane	110	1,0
2	3	Delivery by air transport to Warsaw	8534	1,0
2	4	Delivery by air transport to Frankfurt	7507	1,0
3	5	Acceptance of cargo in Warsaw by agent 1	250	1,5
3	6	Acceptance of cargo in Warsaw by agent 2	270	1,0
4	7	Acceptance of cargo in Frankfurt by agent 3	200	1,5
4	8	Acceptance of cargo in Frankfurt by agent 4	245	1,0
5	9	Transfer of the cargo by agent 1 in Warsaw to the carrier LEGION	510	2,5
5	10	Transfer of cargo by agent 1 in Warsaw to the carrier LLC ALL TRANS	510	2,0

Source: Developed by authors

$$C' = (C_{freight} + C_T) \times (1 + \Delta)^n \qquad (1)$$

where C' – assessment of the cost of the cargo and its delivery, taking into account the time factor (integral assessment);

$C_{freight}$ – the purchase price of the cargo;

C_T – transportation costs;

$(1+\Delta)^n$ - multiplier of interest accrual by interest rate Δ by *n* periods.

$$n = T/365 \qquad (2)$$

To calculate the total cost indicator, you need to know the average bank rate parameter. Analysis of the financial market determined that this parameter is equal to 17%.

So, we have calculated the parameters of all possible delivery schemes and the results of the calculations have been summarized in a Table 7.

Table 7 - Results of parameters calculation for various delivery schemes

№ of delivery scheme	Delivery scheme accordingly to network graph	Transportation costs C_T, USD	Delivery time *T*, days	Present value *C'*, USD
1	2	3	4	5
(1)	1-2-3-5-9-13-17	11054	8	544925,96
(2)	1-2-3-5-10-14-17	11124	7,5	544879,00
(3)	1-2-3-6-9-13-17	11059	7,5	544813,79
(4)	1-2-3-6-10-14-17	11129	7	544766,84
(5)	1-2-4-7-11-15-17	*11037*	7,5	544791,72
(6)	1-2-4-7-12-16-17	11077	7,5	544831,85
(7)	1-2-4-8-11-15-17	11092	*6,5*	*544612,59*
(8)	1-2-4-8-12-16-17	11132	7	544769,85

Source: Developed by Reznik Volodymyr

So, the analysis of the calculation results shows that when transporting video cards from Hong Kong to Stryi, the optimal delivery scheme will be:

- according to the "cost" parameter - 5 scheme;

- according to the parameter "time" and "present value" - 7 scheme on the Table 7.

Thus, in the case when all criteria have the same value, it is necessary to use decision-making criteria under conditions of uncertainty. To obtain the comparison results, it is necessary to bring the parameters of Table 1.6 into a relative form by dividing the elements of each column by the minimum value. The results of this transformation are summarized in the Table 1.6. The general appearance of the matrix is shown in Fig.3. Next, the values of the sought criteria for the specified parameters are determined (see Table 8).

Table 8 - Relative parameter values by route Hong Kong – Stryi

№ of delivery scheme	Delivery scheme accordingly to network graph	Relative parameter values		
		T	***C_T***	***C'***
1	2	3	4	5
(1)	1-2-3-5-9-13-17	1,0015	1,2308	1,0006
(2)	1-2-3-5-10-14-17	1,0079	1,1538	1,0005
(3)	1-2-3-6-9-13-17	1,0020	1,1538	1,0004
(4)	1-2-3-6-10-14-17	1,0083	1,0769	1,0003
(5)	1-2-4-7-11-15-17	1,0000	1,1538	1,0003
(6)	1-2-4-7-12-16-17	1,0036	1,1538	1,0004
(7)	1-2-4-8-11-15-17	1,0050	1,0000	1,0000
(8)	1-2-4-8-12-16-17	1,0086	1,0769	1,0003

Source: Developed by Bugayko Dmytro and Reznik Volodymyr

Accordingly to our case the rows (possible actions R_j) of this matrix are possible delivery schemes. The columns (states of nature S_i) are delivery criteria. The elements of the matrix are the result of choosing the *j-th* action and implementing the *i-th* state V_{ji}. [5]

First decision-making criterion that we will apply is Laplace's criterion. The average arithmetic value of losses (M_j) is calculated according to formula bellow for all variants of delivery routes. All states of nature are assumed to be equally probable [6]

$$M_j(R) = \frac{1}{n}\sum_{i=1}^{n} V_{ji} \quad (3)$$

Source where n – the number of states of nature (in our case 3).

Let's calculate the criterion for all delivery schemes:

1 delivery scheme: $M_1 = 1/3 \times (1{,}0015 + 1{,}2308 + 1{,}0006) = 1{,}0776$;
2 delivery scheme: $M_2 = 1/3 \times (1{,}0079 + 1{,}1538 + 1{,}0005) = 1{,}0541$;
3 delivery scheme: $M_3 = 1/3 \times (1{,}0020 + 1{,}1538 + 1{,}0004) = 1{,}0521$;
4 delivery scheme: $M_4 = 1/3 \times (1{,}0083 + 1{,}0769 + 1{,}0003) = 1{,}0285$;
5 delivery scheme: $M_5 = 1/3 \times (1{,}0000 + 1{,}1538 + 1{,}0003) = 1{,}0514$;
6 delivery scheme: $M_6 = 1/3 \times (1{,}0036 + 1{,}1538 + 1{,}0004) = 1{,}0526$;
7 delivery scheme: $M_7 = 1/3 \times (1{,}0050 + 1{,}0000 + 1{,}0000) = 1{,}0017$;
8 delivery scheme: $M_8 = 1/3 \times (1{,}0086 + 1{,}3769 + 1{,}0003) = 1{,}0286$.

Then, among the calculated values, the smallest one is chosen. It will determine the optimal delivery scheme. According to the calculations, the smallest value is 1,0017,

which corresponds to the 7th delivery scheme.

The next criterion that we will apply for decision making is Wald's criterion. It is based on the principle of greatest caution. In the case when the result V_{ji} represents losses, the minimum criterion is used when choosing the optimal strategy. It is necessary to find the largest element in each row at the first stage $\max\{V_{ij}\}$, and then the action R_j (row j) is selected, which will correspond to the smallest element of these largest elements:

$$W = \min_j \max_i \{V_{ij}\} \quad (4)$$

So, we need to determine the largest element in each row:

1 delivery scheme: 1,2308;
2 delivery scheme: 1,1538;
3 delivery scheme: 1,1538;
4 delivery scheme: 1,0769;
5 delivery scheme: 1,1538;
6 delivery scheme: 1,1538;
7 delivery scheme: 1,0050;
8 delivery scheme: 1,0769.

Among the maximum values found, in the last step we determine the smallest one. This is 1,0050 and belongs to 7^{th} scheme.

The third criterion that we will use is Savage's criterion. It is based on the use of a risk matrix, the elements of which are determined by the formula:

$$r_{ij} = V_{ij} - \min_j \{V_{ji}\} \quad (5)$$

That is, r_{ij} - the difference between the best value in column i and the values of V_{ij} at the same i. According to the criterion, it is recommended to choose the strategy in which the value of the risk will take on the smallest value in the most unfavorable situation:

$$W = \min_j \max_i \{r_{ij}\} \quad (6)$$

The results of the calculation of the risk matrix for eight routes are summarized in the Table 9.

Table 9. The risk matrix of Savage's criterion

№ of delivery scheme	Delivery scheme accordingly to network graph	Risk parameter			
		T	***C_T***	***C'***	**max**
(1)	1-2-3-5-9-13-17	0,0015	0,2308	0,0006	0,2308
(2)	1-2-3-5-10-14-17	0,0079	0,1538	0,0005	0,1538
(3)	1-2-3-6-9-13-17	0,0020	0,1538	0,0004	0,1538
(4)	1-2-3-6-10-14-17	0,0083	0,0769	0,0003	0,0769
(5)	1-2-4-7-11-15-17	0,0000	0,1538	0,0003	0,1538
(6)	1-2-4-7-12-16-17	0,0036	0,1538	0,0004	0,1538
(7)	1-2-4-8-11-15-17	0,0050	0,0000	0,0000	0,0050
(8)	1-2-4-8-12-16-17	0,0086	0,0769	0,0003	0,0769

Source: developed by Reznik Volodymyr

In the column with the maximum risk value for each scheme, we will look for the smallest element. This is 0,0050 and it belongs to 7^{th} scheme.

The last criterion that we will consider is Hurwitz criterion. It is based on the following two assumptions: nature can be in the most unfavorable state with probability $(1-\alpha)$ and in the most favorable state with probability α, where α is the confidence coefficient. If the elements of the matrix represent losses, then choose an action that fulfills the following conditions: [7]

$$W = \min_j \left[\alpha \min_i V_{ji} + (1-\alpha) \max_i V_{ji} \right] \quad (7)$$

Source [12]

This criterion establishes a balance between cases of extreme optimism and pessimism by weighting these two ways of behavior with the corresponding weights $(1 - \alpha)$ and α, where $0 \leq \alpha \leq 1$. The value of α is determined depending on the tendency of the decision-maker to be optimistic or pessimistic. If there is no pronounced tendency, $\alpha=0.5$ is most often used. [7]

To determine the desired delivery option according to this criterion, you need to find the sum of the products of the smallest and largest value by the coefficient $\alpha=0.5$. [7]

Let's perform calculations:

1 delivery scheme: 0,5×1,0006+0,5×1,2308=1,1157;
2 delivery scheme: 0,5×1,0005+0,5×1,1538=1,0772;
3 delivery scheme: 0,5×1,0004+0,5×1,1538=1,0771;
4 delivery scheme: 0,5×1,0003+0,5×1,0769=1,0386;
5 delivery scheme: 0,5×1,0003+0,5×1,1538=1,0769;
6 delivery scheme: 0,5×1,0004+0,5×1,1538=1,0771;
7 delivery scheme: 0,5×1,0000+0,5×1,0050=1,0025;
8 delivery scheme: 0,5×1,0003+0,5×1,0769=1,0386. [12]

Among the calculated values, we again choose the smallest element. This is 1,0025 and also belongs to 7th scheme.

Let's summarize all the calculations made according to the four criteria into a Table 10.

Table 10 - Choosing a delivery scheme based on decision-making criteria. [7]

№ of delivery scheme	Laplace's criterion, $M_i(R_j)$	Wald's criterion, max(V_{ij})	Savage's criterion, max(r_{ji})	Hurwitz criterion, $\left[\alpha \min_i V_{ji} + (1-\alpha) \max_i V_{ji}\right]$
(1)	1,0776	1,2308	0,2308	1,1157
(2)	1,0541	1,1538	0,1538	1,0772
(3)	1,0521	1,1538	0,1538	1,0771
(4)	1,0285	1,0769	0,0769	1,0386
(5)	1,0514	1,1538	0,1538	1,0769
(6)	1,0526	1,1538	0,1538	1,0771
(7)	1,0017	1,0050	0,0050	1,0025
(8)	1,0286	1,0769	0,0769	1,0386
Minimum value	***1,0017***	***1,0050***	***0,0050***	***1,0025***

Source: Developed by Bugayko Dmytro

Therefore, taking into account the results of calculations based on various decision-making criteria, it will be advisable to choose the 7th delivery scheme. This scheme involves air transportation to Frankfurt, cooperation with agent 4 there and the use of the LEGION company for road transportation to the destination point (Stryi).

Conclusions. In today's unstable conditions of the functioning of enterprises, it is important in formation a logical chain of building an effective organizational and economic mechanism for the innovative development of the transport industry in the system of multimodal transportation, which is able to ensure the efficiency of management and the competitiveness of the industry.

The innovative activities of transport industry enterprises are aimed at:

- ensuring high quality of transport services;

- timeliness of order fulfillment and transportation;
- ensuring safety of cargo transportation;
- implementation of modern information systems;
- use of energy-saving technologies;
- increasing the environmental friendliness of transport services.

The main reasons that hold back the innovative development of the transport industry in the system of multimodal transportation are:

- the imperfection of the legal basis for carrying out cargo multimodal transportation;
- inconsistency of the rules for the transportation of dangerous goods with the EU norms;
- lack of conditions for the creation and operation of domestic operators of multimodal transportation;
- imperfection of the tariff policy in transport;
- high risks of multimodal operators when organizing such long-distance transportation involving two or more modes of transport;
- technological backwardness of transport and infrastructure, low level of introduction of modern technologies and implementation of innovative policy in the transport industry;
- disproportions between the levels of development of railway infrastructure capacities and the capacities of ports for cargo processing;
- the presence of "bottlenecks" in the infrastructure of transit transportation by railway transport;
- lagging behind in the implementation of new information technologies;
- lack of a compensation mechanism for investments in strategic transport facilities;
- lack of a transparent system of accounting for transport costs and an effective control mechanism for the provision and use of funds intended for the repair, reconstruction and construction of transport infrastructure;
- lack of highly professional and experienced specialists in multimodal transportation, etc.

The creation of new multimodal corridors will allow to overcome the infrastructural imbalance in the territories of large integration associations. In particular, the development of multimodal corridors in the East-West and North-South directions is planned on the territory of the European Union, as well as the creation of four diagonal corridors. Multimodal transportation is especially relevant in the context of realizing the potential of European integration, simplifying trade and logistics procedures, and developing international partnerships. Thus, in the presence of negative macroeconomic trends, today foreign trade operations were carried out with partners from 220 countries of the world, and the largest volumes of exports among services were transport services, which accounted for 54.8% of the total volume of exports.

The state of the pre-war transport market was studied. Until February 2022, the market had a heterogeneous structure of development, because the global regressive processes associated with the global epidemic of the corona virus had a significant impact on it. At the same time, it should be noted that the total volume of transportation increased in 2020 compared to 2019. This was mainly due to road transport. Other types of transport either remained at the same level (water transport, aviation) or decreased (rail). With the beginning of the large-scale invasion, the transport infrastructure of Ukraine was significantly affected, many railway and road routes were destroyed, the sky was completely closed for air transport and seaports were almost completely blocked. The increase in passenger and freight flows in the western direction highlighted the problems of the border infrastructure.

Like many commercial enterprises, logistics companies with the beginning of the war were forced to rebuild their activities, developing new schemes of work in the

conditions of martial law. Thus, the FTP Company, having experienced the destruction of many transportation schemes, had to look for ways to build new routes. Those transportations that were in a mixed connection with the participation of air transport are now planned to be delivered to the airports of Poland or Germany, and from there to Ukraine by road transport.

At the enterprise level, it is necessary to solve the tasks of restructuring one's own business processes or modernizing existing ones to adapt to external circumstances. Thus, due to the cancellation of air transportation and the blockade of sea ports, the FTP company is forced to rebuild its multimodal routes. Delivery by air transport will be carried out to the airports of European countries. Thus, the work simulates various delivery schemes for the route Hong Kong - Stryi, considering the involvement of various delivery airports and the involvement of various agents and carriers.

A scientific approach was applied to form the optimal base of the company's partners, namely companies that carry out road transportation, namely the method of export evaluations for ranking carriers according to certain criteria.

To determine the optimal delivery scheme among the developed options, decision-making methods under conditions of uncertainty, namely the Laplace, Wald, Savage and Hurwitz criteria, were applied..

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