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Valerii Samsonkin, Viktor Myronenko, Iuliia Bulgakova,
Rosalia Shcherbyna, Oksana Yurchenko, Oleksandr Pohorilyi

CHAPTER 1

MULTIMODAL LOGISTICS SOLUTIONS IN THE CONDITIONS OF INCIDENTAL SITUATIONS AND THREATS TO TRANSPORT SAFETY

ABSTRACT

It is considered which multimodal logistics solutions in emergency situations and threats to transport safety have shown their effectiveness during the war in Ukraine, as well as promising transport and logistics solutions that allow integrating Ukraine into the European transport space at a new level of transport competitiveness and defense capability. Logistic solutions are proposed from the local level for logistical and logistical support during the evacuation of internally displaced persons to the transcontinental level, namely a multimodal logistics system for the transportation of passengers and goods with the participation of new high-speed railways of European track width. At the same time, both complex mathematical models of humanitarian logistics tasks used in emergency situations and simple calculation methods for use in extreme conditions are considered.

The priority of transportation safety is taken into account, therefore, a digital information organizational and educational system for managing the safety of railway traffic at an enterprise is proposed, which can be scaled up to the size of large transport systems, which will provide the highest level of traffic safety due to high-quality training of enterprise personnel, and highlights the practical experience of implementing such an information organizational-training system.

KEYWORDS

Transport events, humanitarian logistics, mathematical models of transport processes, logistics operations, humanitarian supply chains, population evacuation, intermodal transportation, traffic safety management information system.

The consequences of the war imposed by russia are horrendous, including for the transport infrastructure and transportation of passengers and goods. In addition, it showed that logistics in a war is no less important than weapons.

Unlike previous wars that our people experienced, this one, from the very beginning on February 24, 2022, finds maximum documentation and reflection in the information field. And even what has not yet been announced will eventually become available information.

Here is a piece of military news on one of the many Ukrainian websites [1], which keeps a tragic "chronicle" of the war from its very beginning to the present: ... 19:36. As a result of the shelling of the city of Liubotin, Kharkiv region, seven houses in the private sector immediately caught fire. A man died..., two more people were hospitalized ... 19:15. **russian troops are intensively shelling the Severodonetsk agglomeration: more than 20 buildings are damaged**, there is a dead several floors collapsed in one of the high-rise buildings, and a dozen of them were damaged in a day [2]. It is known about one dead in Severodonetsk and one in Rubizhne. Also in these cities, another 10 people were injured from shelling... a total of 26 people were rescued and evacuated... 18:25. **During the siege of Mariupol, about 5 thousand people died in the city – the mayor ...** 90 % (2340 units) of all residential multi-storey buildings were destroyed in the city in 27 days [3].

Another website [4] reports that in Mykolaiv, as a result of enemy rocket fire, two people were killed, seven were injured, housing infrastructure was damaged, fires broke out in residential buildings, and hits on the territory of the hospital were recorded.

It hurts to read such news. But, we must do this in order to learn from them lessons for the future, until our northeastern crazy killer neighbor is finally calmed down.

The above news and information is summarized in the form of a table below in **Table 1.1** as an example.

Table 1.1 An example of the interpretation of wartime news

How many destroyed/damaged houses			How many people		
apartment buildings	**private**	**other**	**died**	**injured/hurt**	**rescued/evacuated/needed to be evacuated**
0	7	0	1	2	?
14	8	5	2	10	26
2340	?	?	5000	?	?
2	2	1	0	7	?
...	...	...	...	...	...
80	4	2	Probable were in the house*		

*Note: * Assumption, for information analysis purposes*

The information in **Table 1.1** is far from complete, as evidenced by the question marks "?" in cages (this is news for only one hour of the day, taken at random from the initial stage of the war). In the above example, the last row of the table, in the absence of information, contains assumptions about how many people could probably be in the house at the time of its destruction/damage by an enemy attack (average 80 people in an apartment building, 4 in a private house, 2 in other houses).

From this example, in the results of our analysis, it follows that the consequences for people who have become victims of an enemy strike on residential areas can be as follows, with the probabilities indicated in **Table 1.2** and **Fig. 1.1** below.

Table 1.2 Probabilistic estimates of the consequences of hostilities

Death	Injury	Rescue	Uncertainty	Sum of probabilities
0.0160	0.0404	0.2085	0.7351	1.0000

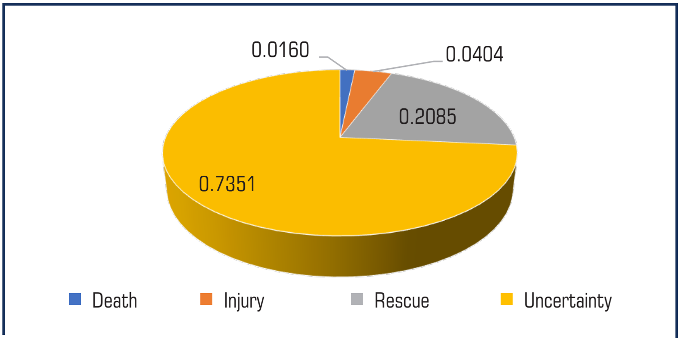


Fig. 1.1 An example of a probabilistic evaluation of the consequences of an impact on residential areas

Obviously, with more information, the results of the analysis will be more accurate, but this should be the task of individual studies. Such studies will provide a basis for building mathematical models for predicting transport and material flows, depending on the factors and scale of emergencies and the threats that caused them. Such mathematical models will make it possible to better adapt transport and logistics systems to them in order to reduce the negative consequences of such situations, damage, casualties and suffering of people.

In particular, the processing by methods of mathematical statistics of even open news information about the consequences of hostilities, including the flows of refugees and evacuees, will make it possible to create basic mathematical models for forecasting flows. Subsequent ad hoc studies of more information will help refine these traffic forecast models and use them for practical purposes, namely as inputs to humanitarian logistics transport systems in order to optimize these systems. Some optimization models of this kind are considered below.

1.1 MATHEMATICAL MODELS OF OPTIMIZATION OF TRANSPORT SYSTEMS AND TECHNOLOGIES OF HUMANITARIAN LOGISTICS

There cannot be at least two emergency situations (ES) with the same consequences. Each time, new emergencies pose new challenges in the field of humanitarian logistics, which can be defined as the "*process of planning, implementing and controlling the efficient, cost-effective flow and storage of goods and materials, as well as relevant information from point of origin to point* *of consumption, in order to alleviate the suffering of affected people*" [5]. However, common features can also be found in the practical experience of responding to various emergencies in order to generalize this experience and translate it into mathematical models that will help make the right management decisions. Let's try to illustrate this approach on the example of several publications on mathematical modeling of the processes of humanitarian logistics and transport services in emergency situations.

The publication [5] by a group of authors from India is devoted to the analysis of criteria for making managerial decisions in humanitarian logistics based on optimization mathematical models.

Humanitarian logistics differs from logistics operations in commercial supply chains due to a large number of features: uncertainty in the choice of route; change in the capacity of infrastructure facilities; change in demand; safety concerns; previously unused routes; other issues such as broken communications systems, limited availability of resources, and the need for efficient and timely delivery.

Fig. 1.2 shows a diagram showing two types of traffic flows:

– upper arrow, from left to right, from relief distribution centers, shelters, etc. to the disasters sites – relief distribution;

– bottom arrow, from right to left, from the disasters sites to relief distribution centers, shelters, etc. – casualty transportation/evacuation.

Fig. 1.2 Priority humanitarian logistics operations in an emergency and related traffic flows

Classifying the parameters of mathematical modeling, the authors of [5] initially consider the traffic flow "casuality transportation/evacuation" and note that most often the following are considered as objective functions of optimization problems:

– transport costs as maintenance costs, the cost of vehicle (or other vehicle) downtime and costs depending on the distance of the trip;

– loading and unloading time as the time of loading and unloading resources into the vehicle;

– distance – selection of the shortest path;

– travel time – minimum travel time;

– evacuation time – minimum evacuation time;

– quantity – unsatisfied demand and level of demand satisfaction, total number of lives saved, number of emergency units needed.

Considering the "relief distribution" transport flow, the authors of [5] define it as the flow of resources from warehouses or medical centers to affected areas. This distribution provides assistance in the form of food, medicine, shelter and other related resources to help the wounded.

Because of the uncertainty in the post-disaster environment, the maximum distribution of aid can be achieved through effective planning. Some of the uncertainties in post-disaster conditions are changes in demand, damage to transport links, damage to facilities, and scarcity of resources.

Better distribution of aid is essential to achieving demand satisfaction, reducing unmet demand, minimizing fatalities and maximizing life savings.

Most distribution models are single-purpose and deterministic (that is, they do not take into account the factors of stochasticity, randomness of processes).

The objective functions used to optimize distribution operations can be as follows: the cost of relief distribution; timing of relief distribution; speed of reaction; allocation of resources; cases with the dead; satisfaction of demand; unsatisfied demand; the total number of lives saved; the number of victims waiting for help.

The work [6] considers mathematical models of intermodal/multimodal technologies for the delivery of humanitarian aid with the participation of maritime transport (**Table 1.3**).

Table 1.3 Analysis of mathematical models of intermodal/multimodal technologies for the delivery of humanitarian aid with the participation of maritime transport

Methodology	Performance indicators	Multi-modal	Shipping	Based on maritime transport	Is a real case used?
Linear programming	Cost/Unmet demand				
Linear programming	Price	X			
Stochastic programming	Price	X			X
Linear/Integer programming	Unsatisfied demand	X			X
Mixed integer numerical programming	Cost/Unmet demand				
Integer programming	Cost/Response time				
Conceptual comparison	Price	X	X	X	X
Stochastic programming	Unsatisfied demand		X		X
Simulation	Cost/Response time	X	X	X	X
Integer programming	Response time	X	X	X	X

It is noted (mark X) that most of the models consider multimodal technologies for the delivery of humanitarian aid.

The review of humanitarian logistics studies [7] considers mathematical models of humanitarian supply chains.

The social structure of humanitarian supply chains (HSC), shown in the diagram below (**Fig. 1.3**), is considered.

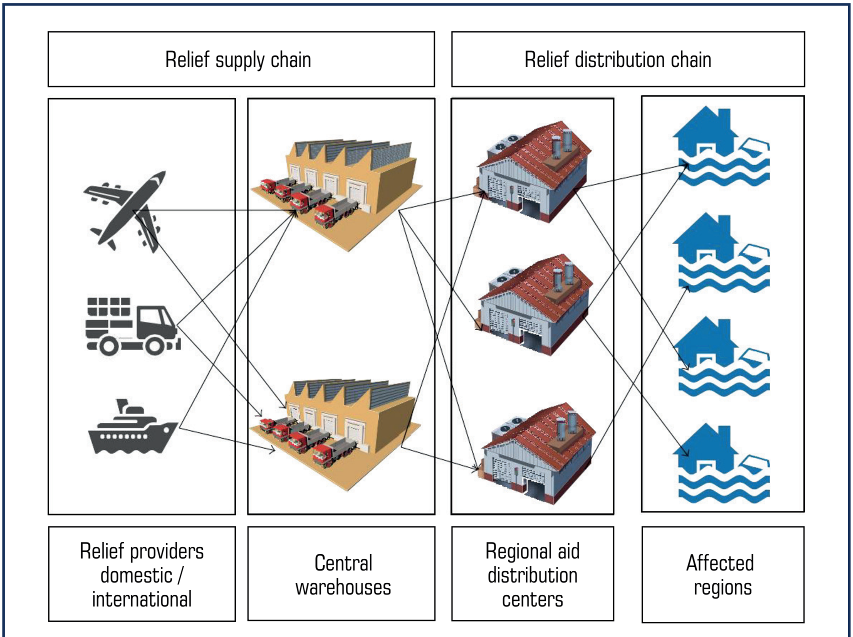


Fig. 1.3 Conceptual framework and components of the humanitarian supply chain (HSC)

A detailed analysis of the mathematical models of different authors used to optimize the transport processes of humanitarian logistics is given. In particular, below in **Table 1.4** presents descriptions of mathematical models of various problems. The content of these tables (in the columns Objective function, Constraint/solution and Problem type) deserves careful study. It shows how diverse the tasks of humanitarian logistics are and, accordingly, how differently the target optimization functions are formulated, under what restrictions decisions have to be made.

As can be seen from **Table 1.4**, in the considered models of the location of an object in the humanitarian supply chain, the only thing that is common to all HSC tasks is that the objective functions of optimization tasks are always the maximum or minimum of something. Something else follows each time from the goal that needs to be achieved in this particular emergency (cover the maximum territory, help the maximum number of people, use the least amount of transport, reduce logistics costs, etc.).

Moreover, something always interferes with the achievement of this goal (or goals) in real life – either an insufficient number of warehouses, too much demand for goods, humanitarian aid items, or an insufficient number of them, or a limited working time of drivers. What interferes in real life, in a mathematical model should be described by mathematical formulas, equations, inequalities – limitations of models that reflect reality.

Table 1.4 Site location models in the humanitarian supply chain (HSC)

Authors	Objective function	Constraint/solution	Task type
Balcik and Beamon	Maximize (demand coverage by distribution centers)	Budget constraints, inventory levels in distribution centers	Maximum coverage model
Bozorgi-Amiri et al.	Minimize (costs of pre-disaster preparation, procurement, transportation, maintenance, shortages)	Distribution center capacity, commodity flow, supply and demand	Seat partition model
Horner and Downs	Minimize (the cost of distributing relief goods)	Demand limitation, number of distribution centers	Intermediate distribution object model
Dekle et al.	Minimize (means for each area with given distance)	Determine object location for each area	Cover layout model
Hong et al.	Minimize (total logistics cost)	Distance between train and object, number of objects, demand	Object location model
Chang et al.	Minimize (transport cost, facility installation cost, life-saving equipment distance cost)	The number of objects and their capacity, the priority of allocation, storage, shortage, penalties for surplus	Seat partition model
McCall	Minimize (nautical miles of casualty, disadvantage)	Facility capacity, number of disaster preparation kits, unsatisfied demand	Object location model
Rawls and Turnquist	Minimize (costs of opening a facility, unsatisfied demand, transportation)	Location and decision on the level of stocks at each site	Seat partition model
Zhang et al.	Minimize (cost of total time to dispatch emergency resources)	Equilibrium of supply and demand for a primary catastrophe, equilibrium of supply and demand of a potential secondary catastrophe, available resources for a secondary catastrophe	Seat partition model
Akgün et al.	Minimize (risk of unsatisfied demand)	Response time, distance between object and disaster site	Object location model
Barzinpour and Esmaeili	Maximize (cumulative population coverage); Minimize (total spending)	Supply and demand, transport capacity, warehouse capacity	Seat partition model
Abounacer et al.	Minimize (distance from distribution center to demand point, number of facilities, dissatisfied demand)	Daily working hours, supply and demand, vehicle capacity	Location-transport model
Rawls and Turnquist	Minimize (costs of acquiring a product, deciding on stocks, transportation, shortages, maintenance)	Demand, number of objects, inventory level	Dynamic allocation model
Murali et al	Maximize (number of people on medication)	Supply and demand, distance, facility capacity	Maximum coverage model
Lin et al.	Minimize (shortage penalty, delivery delay, shipping cost, unfair service cost)	Number of warehouses, vehicles, travel time, number of delivery items	Object location model

In conclusion, let's note that we consider the materials presented here to be useful in solving the problems of humanitarian logistics associated with the deployment of certain objects in a certain territory affected by an emergency, such as central warehouses, regional centers for the distribution of humanitarian aid, storage facilities, warehouses, points of medical assistance, taking into account the available opportunities for transport services. Also, pay attention to the fact that in humanitarian logistics today multimodal/intermodal transport technologies have already found their rightful place, which is reflected in the corresponding mathematical models (**Table 1.3**).

Conclusions. The general analysis carried out allows to conclude that a sufficient mathematical apparatus has been developed for optimizing processes and making managerial decisions in the field of humanitarian logistics. However, the experience of the war showed that events can develop instantly, leaving no room for complex mathematical models. Both during evacuation and during the provision of assistance and material support to the victims, the time for making a decision can take not even hours, but minutes.

Therefore, along with the corresponding mathematical models and software products, simpler methods for justifying decisions, both technological and managerial, should be developed, and people who could apply these techniques even under extreme conditions should be trained.

1.1.1 EVACUATION – UKRAINIAN REALITIES AND WAR EXPERIENCE

From the above example (**Fig. 1.1**, **Tables 1.1, 1.2**) and the experience of the war, it is known that attacks on cities, as well as their threat, create huge waves of migration of people seeking salvation, which can be in the nature of a stampede, or can be more planned, organized evacuation. In our example, it can be seen that the potential evacuation flow is many times greater than the number of dead and wounded, and the same is known from the experience of other armed conflicts, wars and other emergencies.

The current legislation of Ukraine, which guides the work of the State Emergency Service (SES), provides for a certain procedure for organizing evacuation. In particular, that "... the population is subject to mandatory evacuation in the event of a threat of an accident with the release of radioactive and hazardous chemicals, catastrophic flooding of the area and earthquakes, massive forest and peat fires, landslides, other geological and hydrogeological phenomena and processes, emergency situations. at arsenals, bases (warehouses) of weapons, missiles, ammunition and rocket fuel components, other explosive and fire hazardous objects of the Armed Forces, armed conflicts (from areas of possible hostilities to safe areas)" [8].

Partial evacuation of the population is carried out on the basis of a decision of the local state administration or an official with the authority to make such a decision. To conduct a general evacuation of the population, the available vehicles of the corresponding administrative territory are involved, and in the event of an immediate threat to the life or health of the population, additional vehicles of business entities and citizens [8].

The first days of the war, a massive attack on Kyiv and other cities, shelling and battles that were already taking place in their suburbs, led to a mass escape from the war zones and the evacuation of the population. The evacuation took place in the following main ways:

– private vehicles (those who had such an opportunity), mainly in a western direction;

– evacuation bus flights (they were organized by both authorities and volunteers, private carriers, tour operators);

– by rail from Kyiv and other cities, by evacuation trains of local, distant and international traffic (since roads, bridges were overloaded, destroyed or blocked, and air traffic was stopped).

For an organized evacuation in Kyiv and other cities, prefabricated evacuation points were announced in advance, from which traffic should be carried out.

During this critical period, when everything was hanging by a thread, the situation in the transport and logistics sector, including the forced flight and evacuation of the population, managed to be maintained only thanks to self-organization, already traditional for modern Ukrainian society, mutual assistance of people, mass volunteer movement and heroic efforts of Ukrainian transportation companies.

It is impossible not to mention the huge contribution of Ukrainian railways to the salvation of thousands of people. For 8 days since the beginning of the aggression, Ukrzaliznytsia has taken more than 1 million citizens out of hot spots. Further, during the most acute period of the first months of the war, the volume of evacuation traffic only increased. So, on March 12, Ukrzaliznytsia sent at least 43 trains from Kyiv to western Ukraine. Also 8 trains from Odesa, 12 from Poltava, 18 from Vinnytsia, 5 from Zaporizhzhia. It will be possible to leave Kramatorsk, Kharkiv, Kryvyi Rih, Odesa, Zhytomyr.

Additional evacuation flights were scheduled during the day, taking into account the actual passenger traffic. All evacuation flights from east to west were free. From Lviv and other cities in the west of the country, many went further, abroad.

Helped organize international humanitarian logistics and other countries. Free rail travel for Ukrainians was introduced in 11 European countries. To take advantage of the offer, it was enough to show your passport.

In Belgium, Ukrainians were transported without paying a fare to any point on SNCB, high-speed TGV and Thalys, Eurostar trains. For Ukrainians, there was an offer of free travel throughout Hungary on MAV-START trains, on all routes in Georgia, on Deutche Bahn flights from Poland to Germany. The Netherlands provided Ukrainians with a daily ticket valid for 24 hours to board any train. Ukrainians were transported to Poland in the 2nd class across the country in TLK and IC PKP Intercity trains. In Finland, for Ukrainians, the offer is valid from the railway carrier VR, in France – on SNFC trains.

In Slovakia, citizens of Ukraine could use the services of the ZSSK railway company and the bus carrier Slovak Lines. In the Czech Republic, Ukrainians were provided with free travel on Leo Express transport (trains and buses) and CD. The latter also carries out humanitarian flights from the borders of Ukraine with Poland and Slovakia to the territory of the Czech Republic. Free travel in the municipal transport of Vienna was introduced by Austria [10].

Conclusions. Let's note that the last of the quoted paragraphs refers to the provision of intermodal (that is, mixed, bus and rail) transportation services, and in the case of Slovak carriers and the Czech operator Leo Express, multimodal transportation, the most convenient for passengers, although more complex for the operator of such transportation, which provides them.

In addition, here and above, the experience of evacuating the population outside Ukraine was considered, where governments, non-governmental organizations and citizens of other countries were involved. But a significant part of the evacuees moved to safer places within the country, they became internally displaced persons (IDPs). This ("internal") evacuation has its own characteristics.

1.2 LOGISTICS OF EVACUATION AND PROVISION OF INTERNALLY DISPLACED PERSONS

The evacuation of internally displaced persons (IDPs) in a belligerent country occurs simultaneously with hostilities and is no less important than the latter. People who are forced to evacuate under such circumstances are the most vulnerable because they were most often in or in close proximity to a war zone or other emergency.

These people are critically short of time to get to a safer place; it happens that they do not know where to find such a place or they are mistaken in their decision. There are frequent cases when people from the center of Kyiv on the first day of the war fled to Bucha or Irpin, because they believed that it was safer there, but ended up in the hell of war, and were forced to flee further.

Due to the lack or lack of time to make decisions and meetings, such people are often the least materially and financially secure, many of them escaped only in the clothes that they had, having managed to take only documents, or even without them, because everything was left in ruins or house occupied by the enemy. Therefore, the evacuation of potential IDPs should take place as quickly as possible and to the nearest safe place of temporary residence (for example, an IDP camp), which, in turn, should be located as **close as possible to trains or other sources from which logistical, medical and other provision of IDPs in safe places of temporary residence** (**Fig. 1.3** – central warehouses, regional centers for the distribution of humanitarian aid, storage facilities, warehouses, medical aid points), taking into account the available transport services. This approach fully coincides with the requirements of the current legislation of Ukraine [8], which establishes that: "The evacuation is ensured by:

– creation of evacuation authorities at the regional and local levels, as well as evacuation authorities at economic facilities;

– development of an evacuation plan for the population;

– determination of safe areas suitable for accommodating the evacuated population and material and cultural values;

– organization of notification of heads of economic entities and the population about the beginning of the evacuation;

– organization of evacuation management;

– life support of the evacuated population in places of its safe accommodation;

– participation in command and staff exercises and on-site training;

– training the population in actions during the evacuation" [8].

In addition, the legislation [8] defines the evacuation authorities: "The evacuation authorities include evacuation commissions, evacuation collection points, intermediate evacuation points, evacuation reception points… Prefabricated evacuation points are designed to collect and register the evacuated population and organize their removal (exit) to safe areas and are located near railway stations, sea and river ports, marinas, evacuation routes, as well as on existing city squares, in open safe places or safe premises".

However, in this way, the legislation creates only the preconditions for the evacuation, but its organization requires the solution of a number of practical, including calculated, problems of transport and logistics support. The current regulatory documents on the organization of evacuation do not contain guidelines or recommendations for such calculations.

Therefore, below let's propose a methodology and give examples of calculations that will help fill this gap. These calculations can be done quickly, even with a calculator, if it is not possible to apply the mathematical models discussed above.

1.2.1 CALCULATION OF EVACUATION TRANSPORT NEEDS (EXAMPLE)

Let's take a look at a specific example.

An example of calculations. Initial data and calculation formulas:

Population subject to evacuation – A_E, persons.

Evacuation is carried out by groups of 20 people in one vehicle (minibus, number of passengers seats n_A=20). Currently for evacuation from the emergency zone – T_E, hour.

Vehicle turnaround time (bus round trip) – $R_V = 2\left(L_E/V_E + n_A/60\right)$, hour (where L_E is the evacuation distance, km; V_E is the average vehicle speed during evacuation, km/h), rounded to the nearest whole number. The number of complete turnaround (turnaround trips) of the vehicle during – $n_R = T_E/R_V$ the need for vehicles units. The need for drivers $N_V = \left(A_E/n_A T_E\right)\cdot R_V$, persons (where t_D is the duration of the driver's working day, hours). Fuel requirement $2L_E\cdot\left(A_E/n_A\right)\cdot\left(24/T_E\right)\cdot\left(H_S/100\right)$, l (where H_S is the basic linear norm for the vehicle mileage, l/100 km).

Calculation results. (Calculations are made for the number of people evacuated A_E=1000 people. The time for embarkation and disembarkation of one passenger with luggage is assumed to be 1 minute).

The results of calculations for different durations of evacuation are shown in **Fig. 1.4**.

As can be seen from **Fig. 1.4**, the duration and distance of the evacuation is a determining factor for the size of the required fleet of vehicles. The shorter this duration (more urgent evacuation) and the greater the distance (to the final point of evacuation), the more vehicles are required (if the number of people and evacuated material and cultural values is unchanged). The number of seats in the vehicle affects the number of seats needed in reverse – the more seats for passengers, the less vehicles are required (ceteris paribus).

In the case when it is difficult to use the formula by which **Table 1.5** offers a simple mnemonic technique using four digits and two arithmetic operations (**Fig. 1.5**).

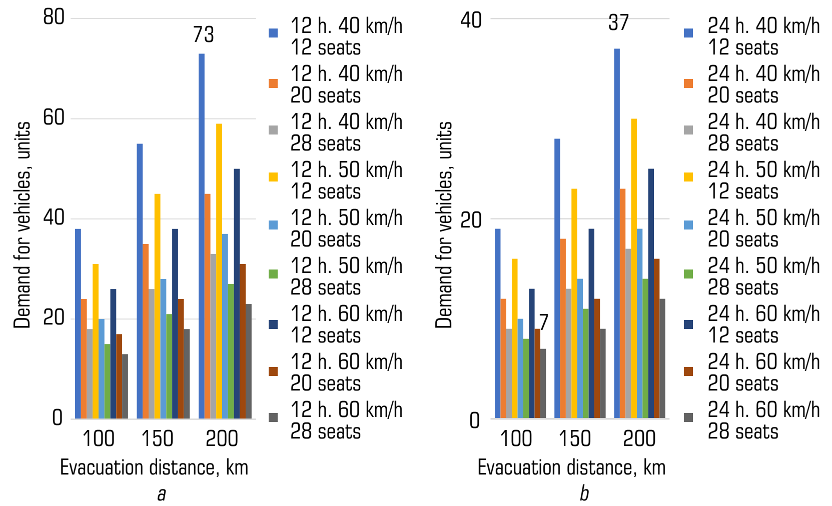


Fig. 1.4 The need for vehicles for evacuation depending on the duration, speed and passenger capacity of vehicles: *a* – duration of evacuation is 12 hours; *b* – duration of the evacuation is 24 hours (twice the time to evacuate, the number of evacuees is the same)

Table 1.5 Demand for vehicles $N_V = 2\left(L_E/V_E + n_A/60\right)\cdot\left(A_E/n_A T_E\right)$, units

T_E, h	V_E, km/h	n_A, seats	L_E, km		
			100	**150**	**200**
12	40	12	38	55	73
12	40	20	24	35	45
12	40	28	18	26	33
12	50	12	31	45	59
12	50	20	20	28	37
12	50	28	15	21	27
12	60	12	26	38	50
12	60	20	17	24	31
12	60	28	13	18	23
24	40	12	19	28	37
24	40	20	12	18	23
24	40	28	9	13	17
24	50	12	16	23	30
24	50	20	10	14	19
24	50	28	8	11	14
24	60	12	13	19	25
24	60	20	9	12	16
24	60	28	7	9	12

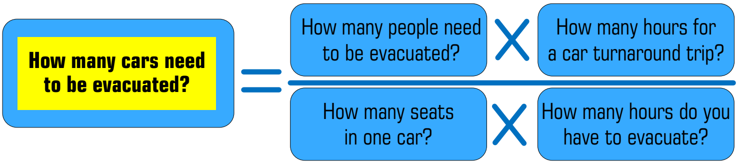


Fig. 1.5 Calculation of the required number of vehicles for evacuation

The results of calculations according to **Table 1.6** are shown in **Fig. 1.6**.

Table 1.6 Need for drivers* $a_D = T_E N_V / t_D$, persons

T_E, h	t_D, h	N_V, vehicles							
		5	15	25	35	45	55	65	75
12	6	10	30	50	70	90	110	130	150
12	8	8	23	38	53	68	83	98	113
12	12	5	15	25	35	45	55	65	75
24	6	20	60	100	140	180	220	260	300
24	8	15	45	75	105	135	165	195	225
24	12	10	30	50	70	90	110	130	150

*Note: * where t_D – the duration of the driver's working day, hour*

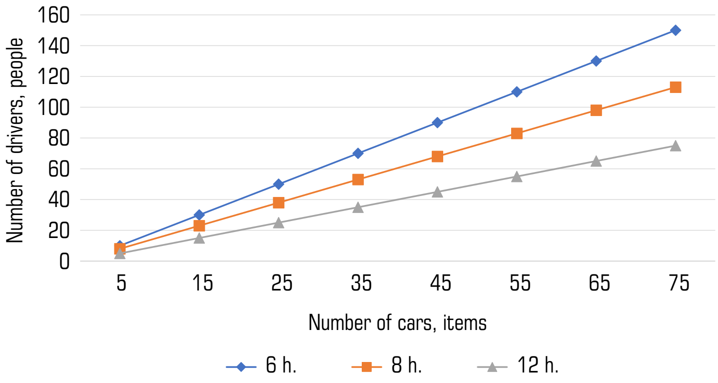


Fig. 1.6 The need for drivers of vehicles with different working hours of drivers

As can be seen from the results of the calculation, the greater the need for drivers, the longer the duration of the evacuation and the greater the required fleet of vehicles. The need for drivers decreases with the increase in the duration of their working hours and vice versa. This need can be determined without the formula, according to which the **Table 1.6** is calculated (**Fig. 1.7**).

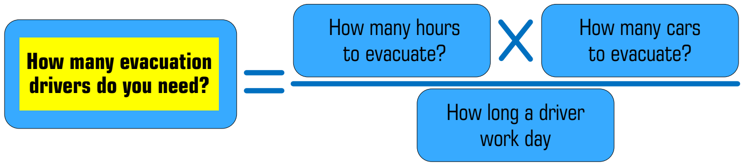


Fig. 1.7 Calculation of the need for the required number of drivers for a vehicle

Once there are answers to the most pressing questions: how many vehicles and drivers are needed to evacuate, it is possible to determine the need for fuel (**Table 1.7**).

The basic linear norm for the mileage of a vehicle is set in accordance with the Norm of fuel and lubricants consumption in road transport [11]. It is possible to calculate this need without the formula (**Fig. 1.8**), according to which **Table 1.7** (the result will be 4.2 % more than the formula).

Table 1.7 Fuel requirement $2L_E \cdot (A_E/n_A) \cdot (24/T_E) \cdot (H_S/100)$, l (where H_S is the basic linear norm for vehicle mileage, l/100 km; A_E=1000 people)

T_E, h	n_A, seats	L_E, km		
		100	**150**	**200**
12	12	5433.3	8150.0	10866.7
12	20	3260.0	4890.0	6520.0
12	28	2328.6	3492.9	4657.1
24	12	2716.7	4075.0	5433.3
24	20	1630.0	2445.0	3260.0
24	28	1164.3	1746.4	2328.6

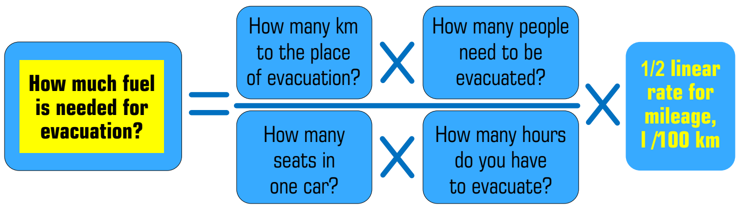
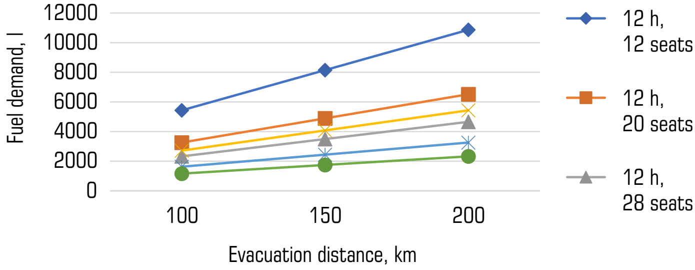


Fig. 1.8 Calculation of the need for the required amount of fuel for a vehicle for evacuation

The results of calculations according to **Table 1.7** are shown in **Fig. 1.9**.



⬡ **Fig. 1.9** Fuel requirement depending on the distance, duration of the evacuation and the number of seats in the vehicle

As calculations show, when using vehicles of smaller passenger capacity and reducing the duration of evacuation (ceteris paribus), the need for fuel increases significantly. That is, urgent evacuation is always more expensive. But if it is not carried out, the consequences can be even more severe.

1.2.2 LOGISTIC AND MATERIAL PROVISION OF LIVING CONDITIONS FOR EVACUATED INTERNALLY DISPLACED PERSONS

From the experience of this war, there are cases when people fled from the front-line Kharkiv, around which fighting was already going on, to supposedly safe Lviv, and there they found death during rocket fire. There are no safe places in this war. And at the same time, it is clear and verified that at least relative safety can give the maximum dispersal of people from places that can be hit by the enemy (and these are practically all settlements). Such relatively safe places (outside populated areas) may be intermediate evacuations and evacuation reception points, the organization of which is provided for by the current legislation.

Such temporary housing for refugees, internally displaced persons in places where they are evacuated can be tent (**Fig. 1.10**) or modular (**Fig. 1.11**) camps, but the requirements for any such temporary housing are the same: they must be able to quickly deploy, populate if necessary, move to another place, and they must be provided from the very beginning with everything necessary for the safe stay of people in them. That is, the issues of their food, household, medical and other types of provision should be comprehensively resolved, and this is impossible without effective logistics solutions. One possible solution is suggested below.

Fig. 1.10 Tent camp for refugees from Ukraine near Prague [12]

Fig. 1.11 Modular camp for refugees near Lviv [13]

Let's start with a regulatory document that defines that "Logistics support for evacuation consists in organizing the maintenance and repair of vehicles in the process of evacuation, supplying fuel and lubricants, spare parts, water, food and essentials, providing evacuation agencies with the necessary property" [14]. This document contains standards for food supply, water consumption for drinking, cooking, providing sanitary and living conditions, as well as for calculating the needs for various types of fuel for heating during the cold season (**Tables 1.1–1.3** of Appendix 2 of the regulatory document [14]).

The mentioned standards became the basis for calculating the minimum necessary "set" of food, water, property, equipment and other things that is necessary for the rapid deployment of a tent camp for the evacuees and their living there in acceptable conditions with supplies of water, food, etc.

The calculation was made for 100 evacuees and its results showed that all items of the specified set (set) can easily be placed in a standard 20-foot container, while there is still a reserve of its carrying capacity and volume of approximately 20 % (**Table 1.8**).

As needed, in the same containers, it is later possible to deliver the resources necessary for its inhabitants to the tent city and pick up containers, the contents of which have been used. With proper organization of such logistics, it is necessary (the so-called exchange fleet of containers will not be so large, it will depend on the frequency and distance of deliveries).

Table 1.8 Contents of a 20-foot container (for 100 people for the 1st week)

Name	Items	Mass 1 item, t	Volume, 1 item, m^3	Bulk mass, t/m^3	Mass, t	volume, m^3
Army tent (UST-56, for 20 people)	5	0.26	0.6	0.433	1.30	3.00
Diesel generator 8.5 kW	1	0.17	0.46	0.370	0.17	0.46
Solid fuel stove	5	0.04	0.07	0.571	0.20	0.35
Blanket, mat, accessories – set	100	0.003	0.006	0.500	0.30	0.60
Folding furniture – set	5	0.2	0.5	0.400	1.00	2.50
Food, dishes, cutlery – set	1	1	0.9	1.111	1.00	0.90
Water, tank	1	8.9	9	0.989	8.90	9.00
Medicines, first aid kits, equipment – set	1	1	1	1.000	1.00	1.00
Tools, materials, spare parts	1	1	1	1.000	1.00	1.00
Fuel for the stove (6.4 kg/person-day), pallets	1	4.5	6	0.750	4.50	6.00
Other (if necessary)						
TOTAL					19.37	24.81
Maximum carrying capacity and capacity of a TEU Standard container					24.00	32.10
RESERVE, %					19.3	22.7

Such a container can be transported by any means of transport, delivered to the deployment site of the tent camp by road. To remove it from the vehicle, crane equipment is not even required, there are other solutions for this – manual (**Fig. 1.12**) or electric jacks (**Fig. 1.13**) for removing containers from the vehicle and loading onto the vehicle.

Such jacks for removing or loading a container on a vehicle require 4 pieces, and their overall dimensions and weight (one jack weighs up to 200 kg) allow them to be placed in addition to that indicated in **Table 1.8** sets in the same container.

A stock of such containers (possibly in several configurations) should be stored in warehouses, it is advisable to create in the system of the State Emergency Service of Ukraine or other specific departments, organizations. Determining the rational value of such a reserve is a theoretical task that must be formulated and solved taking into account the restrictions and conditions of martial law or other emergency situations that require separate studies.

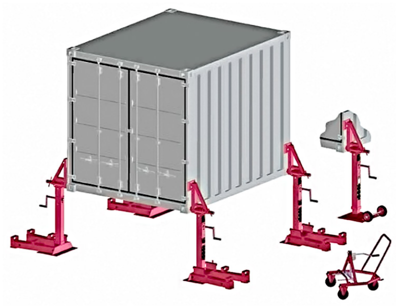


Fig. 1.12 Manual jacks for containers [15]

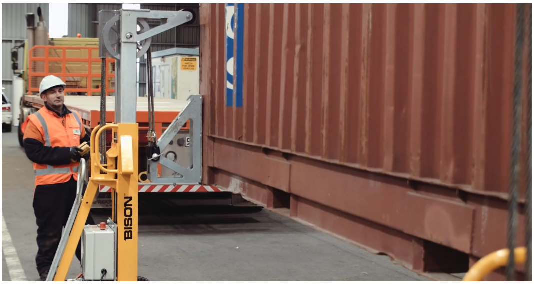


Fig. 1.13 Electric jacks for containers [18]

The problem of rational dislocation of such compositions according to different optimality criteria can theoretically be solved by different mathematical methods and tools. But here it should be noted, taking into account the experience of the war and the constant enemy strikes on various kinds of warehouses, logistics bases, that this deployment should not be permanent, it should change taking into account military risks. These risks should be taken into account in the relevant mathematical models and calculation methods.

As an **intermediate conclusion**, it should be noted that the application of the ISO container described here for the logistics and logistics of internally displaced persons and other victims of war and emergencies allows to "connect" to any multimodal transport and logistics systems, not only regional, national, but and international, global scale, as discussed below.

1.2.3 RADICAL LOGISTICAL MULTIMODAL SOLUTIONS – FOR WAR AND PEACE

In previous years, the authors emphasized the need and the great role of the new Ukrainian railway on the European track 1435 mm to ensure the defense capability of the state [17].

At the time, this argument had no economic support. Unfortunately, they appeared only as a result of the war launched by russia against Ukraine on February 24, 2022. The World Bank estimates that a russian invasion will reduce Ukraine's economy by 45 percent this year [18]! These losses could be less and how many lives could be saved if:

– the logistics of the aggressor troops, focusing mainly on rail transportation, would be significantly complicated by a different track width;

– Ukrainian troops could destroy large concentrations of troops and weapons of the aggressor on our northeastern border, in places of reloading on another route;

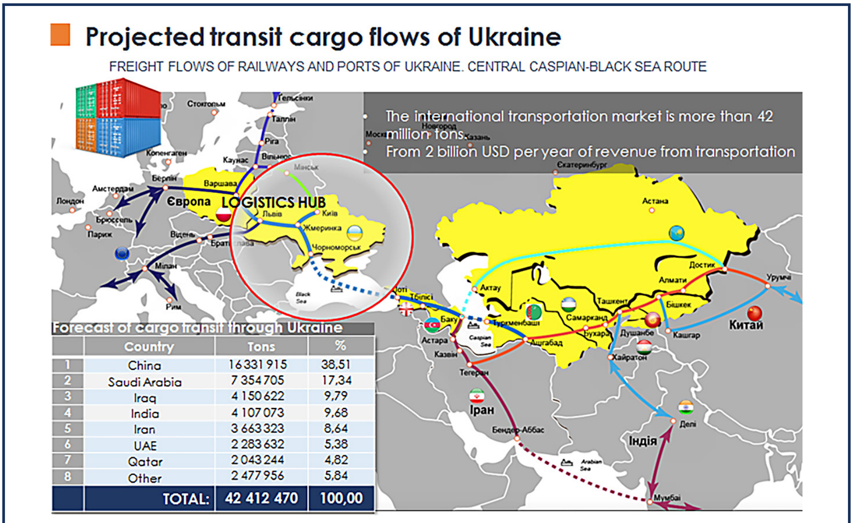
– NATO countries could quickly and massively provide with any assistance without delay on our western borders.

Now these "ifs" do not raise any objections, because there is a bitter experience of the war, which changed priorities. Therefore, when making government decisions to restore the country's infrastructure after the war, a program for the transition of Ukrainian railways to the 1435 mm gauge standard must be provided.

Moreover, this fully coincides with the course towards accelerated European integration of Ukraine and the tasks it faces in the transport industry in accordance with the Association Agreement with the EU, in particular, "improving the movement of passengers and goods, increasing the turnover of transport flows between Ukraine, the EU and third countries in the region by removing administrative, technical, border and other obstacles, improving the transport network and modernizing the infrastructure, in particular, on the main transport axes connecting the Parties" [19].

Now it is obvious that the transition of Ukrainian railways to the 1435 mm standard has no alternative, but it should be justified and phased. To begin with, it is necessary to revive the infrastructure of the "normal" European route, which already exists, but is hardly used. It is very important to develop projects for laying a combined track 1520/1435 mm. Where appropriate, it is possible to install gauge changers (available at Mostyska-II station of the Lviv railway, possibly at other stations) – to use the technology of transportation in wagons on bogies with variable gauge. These and other technologies and the organizational measures necessary for their implementation are the subject of separate studies.

Due to the almost complete blocking of the transit of goods between China and the EU by the so-called Trans-Siberian route, russian and belarusian railways, Ukraine is simply obliged to offer its own Caspian-Black Sea route, no longer than the specified one, but not through seven transit countries, but through five, which will reduce the number of delays at the borders (**Fig. 1.14**). The authors have repeatedly spoken about this (for example, [17]). Within Ukraine, this should be a new high-speed railway (HSR), designed for maximum speeds of more than 250 km per hour, which will be operated on the principle of sharing [20] by both passenger and freight, intended for urgent delivery of goods.



	Country	Tons	%
1	China	16 331 915	38,51
2	Saudi Arabia	7 354 705	17,34
3	Iraq	4 150 622	9,79
4	India	4 107 073	9,68
5	Iran	3 663 323	8,64
6	UAE	2 283 632	5,38
7	Qatar	2 043 244	4,82
8	Other	2 477 956	5,84
	TOTAL:	42 412 470	100,00

Fig. 1.14 New Ukrainian high-speed railway of 1435 mm gauge in the system of global transport links

Returning again to the experience of the war, it should be noted that the railway must also be designed taking into account the rapid evacuation of the population, the delivery of personnel and military goods, including dangerous goods. The international Caspian-Black Sea multimodal route shown in **Fig. 1.11**, has the advantage not only in a smaller number of transit countries, but also allows to connect through Poland with the future 1435 mm rail Baltica [20].

When considering alternatives for the transition strategy to the 1435 mm track standard, it should be taken into account that in Ukraine industrial access roads, also of the 1520 mm standard, have a large length. It is necessary to organize their technological interaction with the 1435 mm gauge, gradually developing the system of multimodal terminals.

Therefore, the technology of using wagons on bogies, which can change the width of the track, is also being considered. The width of the track is changed by passing the train through the overpass device. We will not delve into the technical details of this technology, which are quite fully covered in the literature, for example [21].

Approach to the economic evaluation of alternatives.

How can these alternatives be evaluated economically in order to make an informed decision about the use of variable gauge trains for freight traffic and the terminal system for servicing railway users at the junctions of different gauges?

To do this, it is necessary to compare two options for organizing the transportation of a variant by railways of different ways:

I – delivery of cargo to/from the terminal closest to the Ukrainian importer/exporter, where railway systems of different track widths interact, with rolling stock of 1435 mm track and its reloading onto rolling stock of 1520 mm (or other track width);

II – delivery from a foreign sender to a recipient by rolling stock on wheelchairs with a variable gauge.

These options serve as the basis for building an economic-mathematical model.

After determining the value of θ_i – the turnaround time of the *i*-th type of rolling stock (1435 mm wagons, 1520 mm wagons or carriages on wheelchairs with a variable track width), it is necessary to calculate the required amount (in wagons) to organize the transportation of cargo volumes Q_D (tons per day):

$$n_i^w = \frac{Q_D \theta_i}{4p_i^{AL} - W_i^T},$$

where *i* is the designation corresponding to the subscripts 1435, 1520 and GC for the respective types of wagons; p_i^{AL} is the axle loading of a 4-axle wagon of the corresponding type, tons per axle; W_i^T is the tare weight of a 4-axle wagon of the corresponding type, tons.

Some results of the calculation of wagon fleets for various volumes and options of transportation technologies are shown in **Fig. 1.15**.

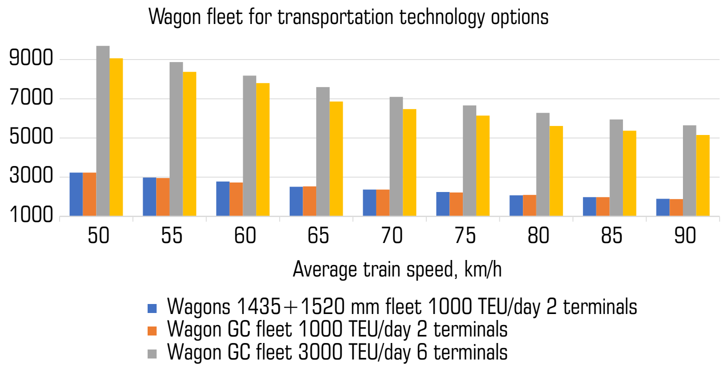


Fig. 1.15 Wagon fleet required for different volumes and technologies of transportation

As can be seen from **Fig. 1.15**, the use of wagons on bogies with varying track widths requires the largest fleet of wagons. This is explained by the longest time of circulation of such wagons noted above. Compared with the use of the fleet of 1435 mm and 1520 mm gauge vehicles and the organization of interaction at the terminals, in total this fleet is 5–11 % less (curve second from the top) than the required fleet of wheelchair vehicles with variable gauge, with the same traffic volume. The top two curves correspond to a high volume of traffic, 3000 containers per day, which are handled at the network's six terminals. With relatively small volumes of transportation (1000 containers per day, 2 terminals), there is practically no difference in the number of required wagons depending on the transportation technology (within ±1 %).

These conclusions refer to the cases of a travel distance along the route of 1435 mm, which is equal to 2000 km. With an increase in this distance to 3000 km, calculations show that up to 4 % less wagons on bogies with varying track widths are required than the total number of wagons of 1435 mm and 1520 mm tracks when organizing interaction at the terminals. However, this advantage is leveled by the fact that wagons on bogies with variable gauge are much more expensive than conventional ones and have a large tare weight. And an increase in the distance of transportation across Ukraine along the 1435 mm track is achieved by deeper introduction of it deep into the country, that is, it requires the creation of new terminals for interaction with railways of the 1520 mm track and other modes of transport.

Conclusions. The performed calculations show that the technology of transportation in wagons on bogies with a variable track width can be used with relatively small volumes of traffic, and with their growth (and in order to increase them), one should focus on the development in Ukraine of a network of railway lines of 1435 mm and systems of multimodal logistics terminals for interaction with 1520 mm railways, access roads of enterprises and other modes of transport.

Developing the proposed mathematical model, supplementing and refining the set of controlled variables – model parameters, as well as having reliable economic data, we can proceed to the construction of a more comprehensive economic and mathematical model, on the basis of which the optimal stages and geography of the gradual transition of Ukrainian railways to the 1435 mm track will be substantiated up to our eastern border.

At the same time, provision should be made for the use, where appropriate, of wagons on bogies with variable gauge. Due to the large dimension and complexity of this problem, it is obvious that its solution to the level of obtaining practical conclusions and recommendations requires a separate study.

1.3 DIGITAL INFORMATION ORGANIZATIONAL AND EDUCATIONAL SYSTEM FOR MANAGING THE SAFETY OF RAILWAY TRAFFIC AT THE ENTERPRISE

The war in Ukraine with russia, which began on February 24, 2022, has brought to life many new digital systems for rapid learning, testing and knowledge control. These developments were used as military aid and concerned mainly the training of military operators to control various types of weapons. Considering that the new weapons that the partners were transferring to Ukraine are highly intelligent, integrating the initial information of several digital communication devices and systems, it was impossible to train operators using traditional "classroom" methods and static simulators. That is why various online training complexes have been widely used, operating in a digital network 24/7. Such simulators can be used both in stationary mode and in the "field".

These systems showed high efficiency, significantly reduced the training time, the military personnel of the Armed Forces of Ukraine demonstrated a high ability to use and operate such systems and devices.

Therefore, it was concluded that it is necessary to use them to train specialists not only for military purposes, but also for civilian life, for example, in transport systems and at enterprises using technological transport. And this is the majority of enterprises in Ukraine and Western Europe.

1.3.1 PROBLEM STATEMENT

At the end of 2021, the "Regulations on the traffic safety management system in railway transport" were put into effect in Ukraine [22]. This Regulation has been developed in accordance with European concepts and regulations (for example [23]), corresponds to the Association Agreement between Ukraine and the EU. The new traffic safety management system (TSMS) has significant differences from the TSMS that existed in Ukrainian Railways JSC. Its action extends to the sphere of railway transport and, except for railways, these are all Ukrainian enterprises that have or use infrastructure and railway rolling stock (before the war it was almost 3,000 enterprises). In addition, the new Regulations on the TSMS have an option for the development of the TSMS at each enterprise, the study and certification of personnel for the TSMS.

The purpose of this section is to substantiate the structure and functionality of the enterprise traffic safety management information system (ETSMIS) for the implementation of the Regulation [22], which would solve the following tasks:

– creation and updating of the TSMS at the enterprise;

– automatic creation of certain documents;

– training, testing and preparation for certification of the enterprise personnel;

– management of risks associated with the operation of railway rolling stock and infrastructure at the enterprise;

– communication with central executive authorities;

– work on the Internet;

– implementation of the principles of aggregation and functional expansion.

In the course of the study, it was found that Ukrainian railway transport enterprises do not have a unified information system for the safety of railway traffic, which significantly affects the transmission, processing, and analysis of information in this area.

1.3.2 PRESENTATION OF THE MAIN RESEARCH MATERIALS

It was proposed to develop a model of a unified information system for traffic safety management at the enterprise, which consists of two systems: the information system for traffic safety management (ISTSM) "RAILWAY PORTAL" and the information system (IS) "TECHNICAL EDUCATION". The structure of a single system is shown in **Fig. 1.16**.

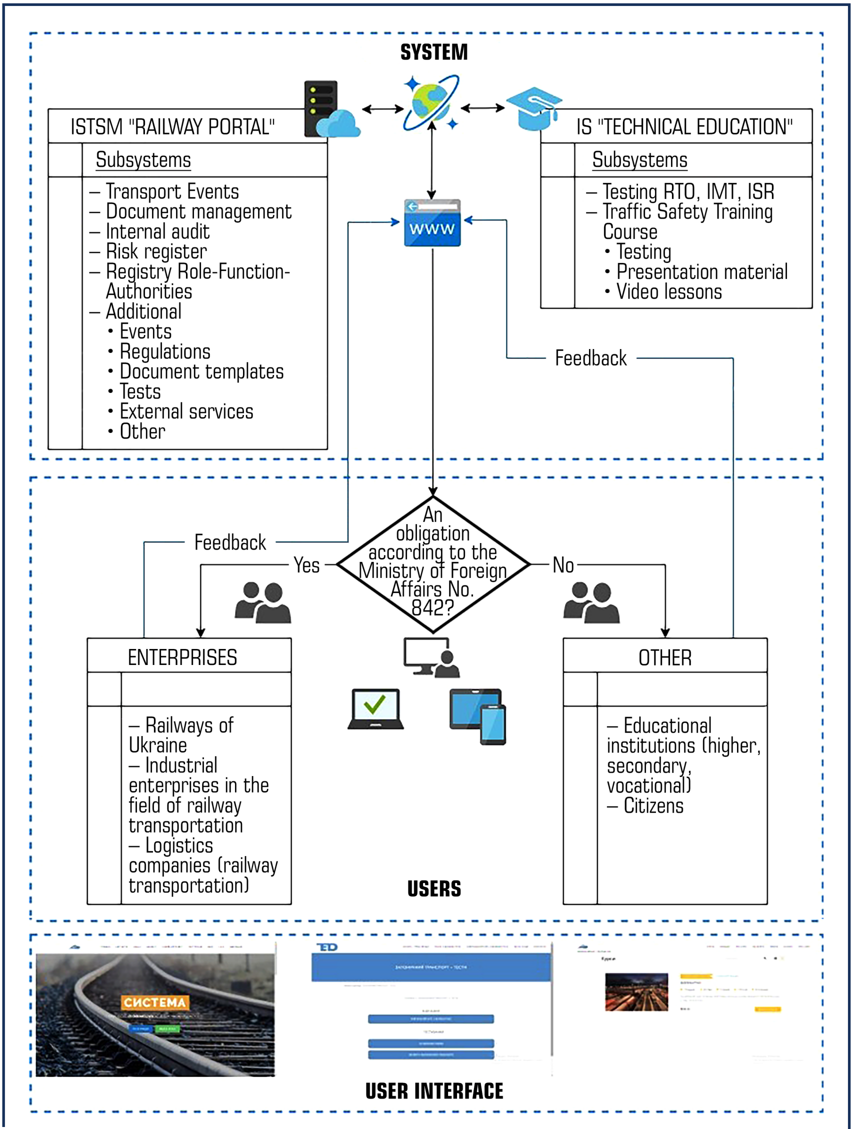


Fig. 1.16 Model of a unified information system for traffic safety management at the enterprise

After analyzing the state of affairs with the existing information systems in the field of railway transport, it was found that all of them are narrowly specialized, heterogeneous and do not perform the necessary operations for collecting and processing data in the field of traffic safety.

When designing and developing the terms of reference for the future ISTSM "RAILWAY PORTAL", its functional subsystems, according to **Fig. 1.1**, were the following subsystems: transport events; document flow; internal audit; risk register; registry role-functions-permissions; additionally (events; regulations; document templates; tests; external services), others.

Considerable attention in the design and development of ISTSM "RAILWAY PORTAL" was riveted to the compliance and functionality of subsystems with the Regulations [22] and other legal acts regulating the activities of railway transport enterprises (for example [24]).

It was also proposed to develop the functionality of information exchange with other information exchange systems (IES), which will positively affect the speed of rapid response to transport events by all participants in the process.

In addition to the ISTSM "RAILWAY PORTAL", the site RAILWAY PORTAL was created and is available on the Internet at the link http://subr.in.ua/ [25], the site of the IS "TECHNICAL EDUCATION" – http://ted.in.ua/trains/ [26], and the sub-site of the subsystem "TRAFFIC SAFETY TRAINING COURSE" of the IS "TECHNICAL EDUCATION" is available on the Internet at the link http://br.ted.in.ua/ [27]. The task of the "RAILWAY PORTAL" website is to inform the railway transport enterprises about changes in the current legislation, to popularize preventive measures for traffic safety among them, to receive official interpretations from the central executive authorities of Ukraine and other government agencies, about the current legislation and to acquaint users of the site with them in their sections (**Fig. 1.17**).

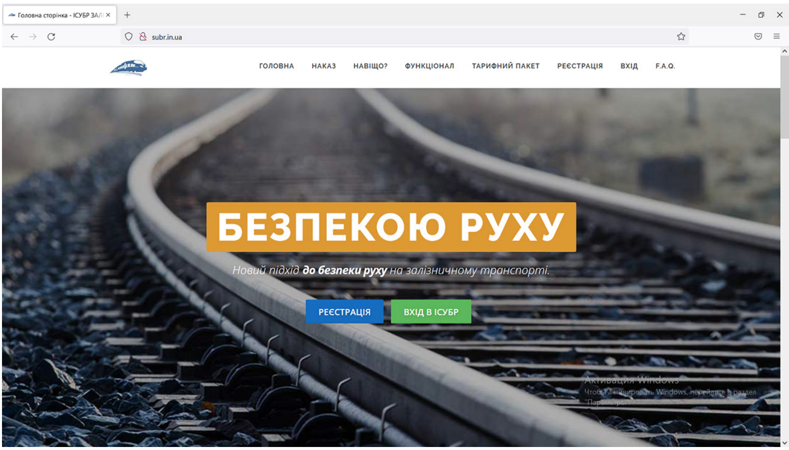


Fig. 1.17 General view of the site http://subr.in.ua/ [25]

1.3.2.1 ISTSM "RAILWAY PORTAL" SUBSYSTEMS

"Transport Events" subsystems. When creating this subsystem, an analysis of the existing bases of transport events, current legislation and the relevance of centralized accounting of transport events was used. It was found that there is only one system for recording traffic accidents in railway transport "ARM Sirena", which is used by JSC "Ukrzaliznytsia" to record its own traffic accidents. However, this automated workplace does not take into account the events that occurred due to the fault of enterprises that are not part of JSC "Ukrzaliznytsia". Accordingly, more than 90 % of the percentage of traffic events that occurred on sidings due to the fault of railway transport enterprises that own such tracks (own or leased) or through the fault of rolling stock owners are not taken into account systematically.

Thus, the proposed and implemented subsystem aims to create a unified national electronic information system for recording traffic accidents that occurred at railway transport enterprises.

In addition, in the course of the research, it was found that part of the transport events that occurred at the railway transport enterprises were hidden by the railway workers and, accordingly, the national statistics of transport events has significant accounting shortcomings. In addition, analyzing the accounting of transport events in railway transport, carried out in accordance with the legislation of the State Service of Ukraine for Transport Safety (Ukrtransbezpeka), it becomes obvious that it is impossible to establish the causal chains of these events.

These shortcomings and challenges were taken into account when developing the "Transport Events" system. The data set, which will be taken into account in the subsystem as a national one, will make it possible to systematize and automatically classify all events that will be entered by railway transport enterprises, forming interactive information sledges and tables. For example, the "Location coordinates" field will allow to display all declared events on an interactive map, which will allow to quickly identify dangerous places and take appropriate management measures to prevent traffic events in such places (such as identifying places of mass unauthorized passage of citizens across railway tracks).

Separately, it should be noted the accounting of locomotives, wagons, trains, which is proposed to be personalized, which in the future will allow creating predictive models for accidents with one or another type of rolling stock.

In the "Transport events" subsystem, drop-down lists/directories are used to the maximum (for example, "Description according to the classifier", where the Classifier of transport events [24] was used), which will allow analyzing information about traffic incidents in a multi-vector plane.

The subsystem takes into account that, according to paragraph 10 of section XII [22], the accounting of transport events is kept in the book of accounting of transport events on the territory of railway transport enterprises in paper or electronic form. The regulation also establishes the form of the book for accounting for transport events, and the subsystem (**Fig. 1.18**) takes into account and implements the mandatory fields of this book, namely:

– date, time of commission;

– type of transport event;

– the scene of the incident (station, stage, kilometer, picket);
– train number, series of locomotive or other traction rolling stock;
– the circumstances of the incident;
– identification of the structural unit and enterprise in the field of railway transport;
– the persons who conducted the internal investigation;
– the date of drawing up the act of the official investigation of the transport accident;
– the requirements of regulatory documents (name, paragraph, subparagraph) are violated;
– other.

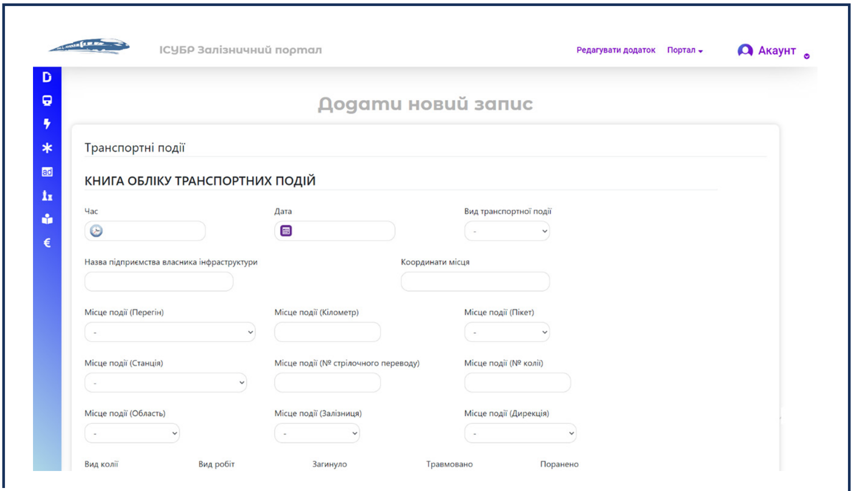


Fig. 1.18 General view of the "Transport events" subsystem

"Document management" subsystem. According to paragraphs 1–4 of section XI [22], the information of the TSMS is subject to documentation. For this purpose, the Document Management subsystem was developed, whose tasks include registration, accounting, classification and storage of documents related to traffic safety at enterprises.

During the development of this subsystem, it was found that a significant part of railway transport enterprises do not have a system for documenting information (paper or electronic) related to traffic safety. Thus, a subsystem was proposed and developed as the basis of a nationwide one.

"Internal audit" subsystem. According to clause 5 of section XIII [22], the process of carrying out an internal traffic safety audit is subject to documentation. For this purpose, the "Internal Audit" subsystem was developed, whose tasks include registration, accounting, storage of documents (acts, instructions, entries in the books of identified violations, etc.) that relate to internal audit measures, as well as classification of violations in the context of the provisions, norms and requirements of the relevant regulatory legal acts.

In addition, this subsystem establishes a clear mechanism for tracking the implementation of mandatory instructions and comments through the Events subsystem, which allows managers to quickly analyze and influence the current state of affairs in the field of traffic safety.

"Risk register" subsystem. According to paragraph 1 of Section VI. The procedures for identification of hazardous factors or threats, risk assessment, risk management [22], identification of hazardous factors or threats and risk management are the basic processes of traffic safety management at the enterprise. In order to implement this requirement, the "Risk Register" subsystem was developed, which allows using unified lists: sources of hazardous factors or threats containing the risk of negative consequences, probable causes of hazardous factors and risk assessment in terms of their frequency and severity of consequences.

The creation of unified risk registers makes it possible to analyze them at the national level and develop comprehensive measures for their management. In order to manage and prevent risks, railway transport enterprises form, approve and distribute among the personnel of the enterprise involved in traffic safety a risk register. This allows timely identification and assessment of risks that have not yet been in the field of view of the personnel of the enterprise, as well as effective management of already assessed risks. The risk register contains the following fields: source of the hazard or hazard; a dangerous factor (event) containing the risk of negative consequences; the likely cause of the hazard; negative consequence; estimated probability of occurrence of an event or conditions for its occurrence; estimated risk severity or likely consequences; risk index; management activities; the residual probability of the occurrence of the event or the conditions for its occurrence; residual risk severity or likely consequences; residual risk index.

"Registry Role-Function-Authorities" subsystem. In accordance with paragraph 3, clause 1 of Section X. Information exchange measures [22], the exchange of information on traffic safety is carried out in order to bring to the attention of the personnel of the enterprise information regarding their role, functions and powers to comply with traffic safety. ISTSM "RAILWAY PORTAL" solved this problem by creating the "Role-Functions-Authorities" subsystem, which gives railway transport enterprises the opportunity to create a unified register for a systematic presentation of information about a structural unit. This Register contains the following fields: card number; structural subdivision of the railway transport enterprise; position according to the staff list; full name; mobile phone; email address; the role of the structural unit; zone of distribution of powers; unit functions; division capabilities.

The input map in the "Role-Functions-Authorities" subsystem has several directories (Role, Distribution Zone, Functions, Authorities). The Function Directory, for example, contains the following options:

– conducting internal traffic safety audits;

– monitoring the state of traffic safety at the enterprise;

– control of the state of traffic safety in the structural subdivision;

– coordination of actions during the liquidation of the consequences of transport accidents and other emergencies;

– review and approval of internal documentation on traffic safety;

– participation in the investigation of transport events;

– organization of briefing of employees on traffic safety;
– control over the organization of technical training of employees;
– checking the knowledge of employees on traffic safety;
– coordination of activities at the enterprise in monitoring the state of traffic safety;
– coordination of work plans and preventive work plans;
– identification of hazardous factors (risks);
– notification of managers about possible transport events;
– implementation of normative acts and technical regulations on traffic safety;
– development of measures to improve the level of traffic safety;
– making proposals to improve the level of traffic safety;
– consideration of the circumstances of transport events;
– notification of subjects of information exchange about transport events;
– reporting of traffic accidents;
– accounting of transport events;
– implementation of traffic safety measures;
– personnel management of the enterprise;
– publication of mandatory instructions on traffic safety;
– development of a draft traffic safety budget;
– organization of compliance with licensing requirements in the field of transportation;
– control over the development of the TSMS at the enterprise;
– informing about the state of traffic safety;
– introduction of the TSMS at the enterprise.

The Authorities directory contains information about the activities of the traffic safety service and contains the following options:

– to demand the provision of information about traffic accidents;
– give instructions on the elimination of violations of traffic safety;
– freely visit the structural divisions of the enterprise at any time;
– prohibit the operation of rolling stock, infrastructure facilities and the performance of work that poses a threat to people and the environment until the violations of traffic safety are eliminated;
– make proposals for the removal of employees from work;
– submit proposals on the inconsistency of the position of officials who violate traffic safety requirements;
– organize and conduct conferences, seminars, meetings on traffic safety;
– check compliance with the requirements of the law and internal regulations regarding the timing, execution procedure, truthfulness and completeness, as well as the efficiency of business processes and operations;
– make decisions on the financing of traffic safety.

This approach allows to create and disseminate information about the persons responsible for traffic safety at the railway transport enterprise in the context of the functions and powers of each official. Usually, railway transport enterprises, on the basis of the data generated in the subsystem, create, approve and distribute at the enterprise the Register "The role, functions and powers of each employee of the railway transport involved in traffic safety". This allows to establish a clear, well-coordinated mechanism for the interaction of the personnel of the enterprise in matters of traffic safety.

"Additional" subsystem. Regulation [22] contains many different requirements regarding the format of data in case of their request, maintaining a list of relevant legal acts, checking knowledge before and after basic training, availability of up-to-date reporting forms and internal regulatory documents (procedures, policies, regulations, procedures, the like).

The "Additional" subsystem was created for the convenience of railway transport enterprises. It combined external services for imposing a qualified electronic signature, a list of regulations in force in the field of railway transport, templates (drafts) of documents, etc.

1.3.2.2 "TECHNICAL EDUCATION" INFORMATION SYSTEM

This system includes several subsystems implemented on different sites:

– "Testing" subsystem (http://ted.in.ua/trains/, **Fig. 1.19**) includes a set of automated tests, which in turn are divided into general ones (Rules for the technical operation of railways (RTO), Instructions for the movement trains (IMT), Instructions for signaling on the railway (ISR)) and by profession (The next station (for administrative use), Compiler of trains, Duty switch post, Head of a passenger train);

– "Traffic Safety Training Course" subsystem (http://br.ted.in.ua/) is an online learning platform that combines presentation material, video lessons and test questions.

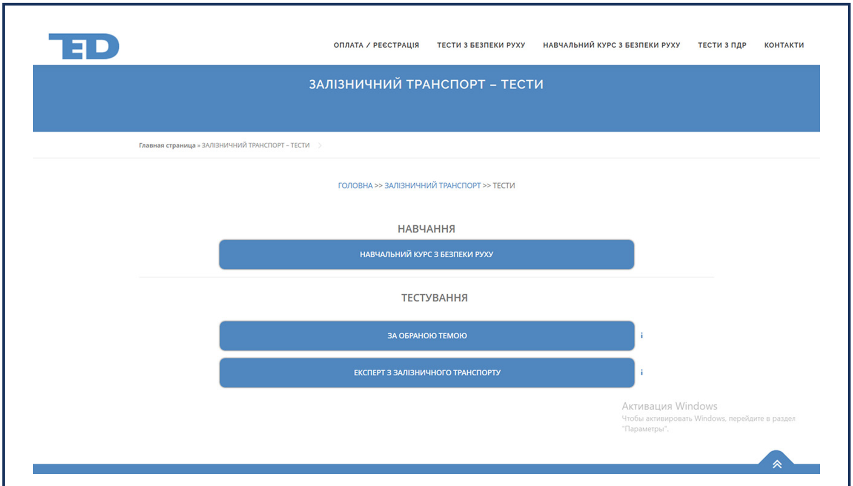


Fig. 1.19 General view of the "Testing" subsystem

The "Traffic Safety Training Course" subsystem is an introductory course and basic training, includes basic information about traffic safety, including the influence of human and organizational factors. Training guarantees the training and qualification level of the company's personnel to perform their duties in the field of traffic safety.

This course is held for managers of enterprises, traffic safety services and all personnel of the enterprise, and is carried out on the job.

The prerequisite for the creation of the subsystem "Training course on traffic safety" of the IS "TECHNICAL EDUCATION" was Section IX. Programs and procedures for training the personnel of the enterprise on traffic safety to ensure the maintenance of personnel competence [22]. The training course includes 12 thematic presentations and video lessons presented in **Table 1.9**.

Before the start of training and after its completion, the following tests are taken:

– primary check of the level of knowledge;

– checking the level of knowledge after completing the training course;

– each of which consists of 64 questions and thus achieves the goal of obtaining a slice of knowledge at the beginning of training and after its completion. As a result of passing the course, the system generates a certificate, the form of which is shown in **Fig. 1.20**.

Table 1.9 List of topics and questions of training in the "Traffic Safety Training Course" subsystem

No. of topic	Topic	Issues under consideration
1	**2**	**3**
1	Safety analysis	– fundamentals of the analysis of the state of traffic safety. Essence of analysis; – statistics of violations as the basis for determining the state of traffic safety; – causal relationships: events, causes, prerequisites; – recommendations for conducting an analysis of the safety posture in an organization
2	Railway traffic safety policy	– traffic safety policy at the enterprise; – purpose and tasks of the TSMS; – classification of traffic accidents on the main railway transport; – accounting for the type, nature and activities of the enterprise
3	Requirements of national and European legislation on traffic safety	– international organizations of transport activity on railways; – EU rail safety policy; – state of Ukrainian legislation on train traffic safety
4	Familiarity with national and European traffic safety legislation	– documents aimed at harmonizing existing EU standards and policies; – general principles of traffic safety management, as defined by the Regulation on TSMS; – regulatory framework for the safety of rail transport in the EU
5	Process of ensuring traffic safety at the enterprise. Organization of work, functions and duties of personnel	– structure and functioning of the traffic safety management system (TSMS); – the process of ensuring traffic safety at the enterprise; – the concept and policy of traffic safety at the enterprise; – work organization; – functions and responsibilities of the personnel of the enterprise to ensure traffic safety

Continuation of Table 1.9

1	2	3
6	Report on transport incidents and possible threats	– exchange of information on traffic safety at the enterprise; – mandatory reporting procedures
7	Hazard identification and risk management	– general concepts of hazards and risks; – identification of hazards and risks; – management of risks; – an example of risk identification
8	Basic principles of traffic safety management	– What is safety management and why is it important? – general principles of traffic safety management, as defined by the Regulation on TSMS; – development and control of management decisions in the field of traffic safety
9	Powers of the Ministry of Infrastructure and Ukrtranssafety	– powers of the Ministry of Infrastructure of Ukraine in terms of traffic safety; – powers of Ukrtranssafety in matters of traffic safety in the field of railway transport
10	Investigation of transport events and audit of TS state of BR at the enterprise	– procedure for investigating transport events; – traffic safety audit: what is it; – internal audit; – state traffic safety supervision
11	Distribution of functions and duties of the personnel of the enterprise in the field of traffic safety	– What personnel of the enterprise belong to the field of traffic safety (TS)? – What is the difference between functions and responsibilities? – functions, powers and duties of the personnel of the enterprise in the field of traffic safety
12	The constituent elements of the enterprise TSMS	– What is TSMS? – S TSMS components

Fig. 1.20 Certificate generated by the "Traffic Safety Training Course" subsystem of the IS "TECHNICAL EDUCATION"

Conclusions. The developed information organizational and educational system for managing railway traffic safety provides a ready-made prototype of an information management system for any enterprise in the field of railway transport, for which the creation and operation of a traffic safety management system is regulated. The system is implemented in accordance with the Regulations on the traffic safety management system in railway transport, approved by the order of the Ministry of Foreign Affairs dated December 24, 2020 No. 842 and operates on the Internet.

The developed system is the basis for the formation of a nationwide information database of traffic safety in the railway sector both for peacetime and during crisis situations [28].

CONCLUSIONS

Russia's war against Ukraine:

– led to the destruction of more than 1/3 of the railway infrastructure and led to a drop in the country's GDP by 45 %;

– showed the great importance of logistics for the defense of the state and alleviate the victims and suffering of its population from military operations;

– proved that there is no alternative to the course towards real integration of Ukraine with the Trans-European transport network TEN-T, including the transition to the 1435 mm track standard.

The provision of emergency humanitarian and military assistance requires the development of multimodal logistics technologies (primarily container transportation), as well as the introduction of interoperable (operationally compatible) rail transportation, the only high-speed and high-speed railway network with the neighboring EU countries of the track width standard 1435.

The networks of 1435 mm gauge lines should provide for the deepest possible introduction of them into the territory of the country and the creation of multimodal logistics terminals on them. The network of new Ukrainian high-speed and high-speed railways 1435 mm should be operated on the principle of shared use (shared use) both for the transportation of passengers and certain categories of goods with high added value, and be part of international transit routes, such as the Silk Road, Three Seas Initiative, continuation Rail Baltica to the Black Sea, etc.

For the interaction of new and modernized 1435 mm railways with the 1520 mm railway network, it is necessary to build a system of logistics hubs – multimodal terminals; it is possible to simultaneously use other technologies, in particular, carriages of the fleet on wheelchairs with a variable gauge, which together will allow faster full integration with the railway networks of the EU and NATO countries.

The developed information organizational and educational system for managing railway traffic safety is a prototype of an information management system at an enterprise in the field of railway transport, as well as the basis of a nationwide information database for traffic safety in the railway sector both for peacetime and during crisis situations.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

REFERENCES

1. Novyny viiny v Ukraini za liutyi-berezen 2022 (2022). Delo.ua. Available at: https://delo.ua/uk/politics/novini-viini-v-ukrayini-za-lyutii-berezen-2022-400056/
2. Bespiatov, T. (2022). Viiska RF posyleno obstriliuiut ahlomeratsiiu Sievierodonetska: poshkodzheno ponad 20 budivel, ye zahybli. Delo.ua. Available at: https://delo.ua/uk/incidents/viiska-rf-posileno-obstrilyuyut-aglomeraciyu-sjevjerodonecka-poskodzeno-ponad-20-budivel-je-zagibli-foto-394880/
3. Molodan, V. (2022). Za chas oblohy Mariupolia u misti zahynuly blyzko 5 tysiach liudei – mer. Delo.ua. Available at: https://delo.ua/uk/incidents/za-cas-oblogi-mariupolya-u-misti-zaginuli-blizko-5-tisyac-lyudei-394879/
4. U Mykolaievi vnaslidok vorozhoho raketnoho obstrilu zahynulo dvoie liudei, postrazhdalo semero – holova OVA Kim (2022). Interfax-Ukraine. Available at: https://interfax.com.ua/news/general/862580.html
5. Safeer, M., Anbuudayasankar, S. P., Balkumar, K., Ganesh, K. (2014). Analyzing Transportation and Distribution in Emergency Humanitarian Logistics. Procedia Engineering, 97, 2248–2258. doi: https://doi.org/10.1016/j.proeng.2014.12.469
6. Ozkapici, D. B., Ertem, M. A., Aygüneş, H. (2016). Intermodal humanitarian logistics model based on maritime transportation in Istanbul. Natural Hazards, 83 (1), 345–364. doi: https://doi.org/10.1007/s11069-016-2318-9
7. Habib, M. S., Lee, Y. H., Memon, M. S. (2016). Mathematical Models in Humanitarian Supply Chain Management: A Systematic Literature Review. Mathematical Problems in Engineering, 2016, 1–20. doi: https://doi.org/10.1155/2016/3212095
8. Pro zatverdzhennia Poriadku provedennia evakuatsii u razi zahrozy vynyknennia abo vynyknennia nadzvychainykh sytuatsii (2013). Postanova Kabinetu Ministriv Ukrainy No. 841. 30.10.2022. Available at: https://zakon.rada.gov.ua/laws/show/841-2013-п#Text
9. Evakuatsiia zi skhodu: yak pratsiuvatyme "Ukrzaliznytsia" 12 bereznia? (2022). Hromadske radio | Slukhaite. Dumaite. Available at: https://hromadske.radio/news/2022/03/11/evakuatsiia-zi-skhodu-iak-pratsiuvatyme-ukrzaliznytsia-12-bereznia
10. Lebych, U. (2022). Ukrzaliznytsia zapuskaie novi potiahy do Polshchi (spysok). Sehodnia. Available at: https://economics.segodnya.ua/ua/economics/transport/ukrzaliznycya-zapuskaet-novye-poezda-v-polshu-spisok-1606979.html
11. Pro zatverdzhennia Norm vytrat palyva i mastylnykh materialiv na avtomobilnomu transporti (1998). Nakaz Ministerstva Transportu Ukrainy No. 43. 10.02.1998. Available at: https://zakon.rada.gov.ua/rada/show/v0043361-98#Text

12. U Prazi vidkryly nametove mistechko dlia ukrainskykh bizhentsiv (2022). Volynski novyny, nezalezhna hromadsko-politychna hazeta "Volyn". Available at: https://volynonline.com/u-prazi-vidkryly-nametove-mistechko-dlya-ukrayinskyh-bizhencziv
13. Rodak, K. (2022). Tak dobre, koly ne treba bilshe spaty na pidlozi. ZAXID.NET. Available at: https://zaxid.net/tak_dobre_koli_ne_treba_bilshe_spati_na_pidlozi_n1542435
14. Pro zatverdzhennia metodychnykh rekomendatsii (2015). Nakaz Derzhavnoi Sanitarno-Epidemiolohichnoi Sluzhby Ukrainy No. 42. 27.03.2015. Available at: https://zakon.rada.gov.ua/rada/show/v0042834-15#Text
15. Lifting Equipment Store. Container Support Jacks. Available at: https://www.liftingequipmentstore.com/product/container-support-jacks
16. Bison A Series – Automated Container Lifting Jack System. Bison. Available at: https://www.bison-jacks.com/container-lifting/automated-lifting-jack-system/
17. Myronenko, V., Samsonkin, V., Rudkovskyic, S., Diomind, R., Feldman, A. (2017). Ukraine in system of transport links. International Journal of Engineering Research and Development, 13 (9), 1–6.
18. Russian Invasion to Shrink Ukraine Economy by 45 Percent This Year (2022). World Bank. Available at: https://www.worldbank.org/en/news/press-release/2022/04/10/russian-invasion-to-shrink-ukraine-economy-by-45-percent-this-year
19. Uhoda pro asotsiatsiiu mizh Ukrainoiu, z odniiei storony, ta Yevropeiskym Soiuzom, Yevropeiskym spivtovarystvom z atomnoi enerhii i yikhnimy derzhavamy-chlenamy, z inshoi storony, Uhoda Ukraina (2015). Available at: https://zakon.rada.gov.ua/laws/show/984_011#Text
20. Nash, A. (2003). Best Practices in Shared-Use High-Speed Rail Systems. San Jose: Mineta Transportation Institute College of Business San José State University, 115.
21. Usamah, R., Kang, D., Ha, Y. D., Koo, B. (2020). Structural Evaluation of Variable Gauge Railway. Infrastructures, 5 (10), 80. doi: https://doi.org/10.3390/infrastructures5100080
22. Pro zatverdzhennia Polozhennia pro systemu upravlinnia bezpekoiu rukhu na zaliznychnomu transporti (2020). Nakaz Ministerstva infrastruktury Ukrainy No. 842. 24.12.2020. Available at: https://zakon.rada.gov.ua/laws/show/z0351-21#Text
23. Rail Safety Management System Archives – Laing O'Rourke. Laing O'Rourke. Available at: https://lorhsems.com/safety_category/rail/
24. Pro zatverdzhennia Polozhennia pro klasyfikatsiiu transportnykh podii na zaliznychnomu transporti (2017). Nakaz Ministerstva infrastruktury Ukrainy No. 235. Available at: https://zakon.rada.gov.ua/laws/show/z0904-17#Text
25. ISUBR Zaliznychnyi Portal. Available at: http://subr.in.ua/
26. Zaliznychnyi transport – testy – IS Tekhnichna osvita. Available at: http://ted.in.ua/trains/
27. Bezpeka rukhu. Available at: http://br.ted.in.ua/
28. Samsonkin, V. M., Nikolaienko, I. V., Bulhakova, Yu. V. et al. (2021). Inzhynirynh kryz ta ryzykiv transportnykh posluh. Kyiv: Talkom, 312.