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## **HUBS AS A KEY TOOL FOR IMPROVING THE QUALITY OF THE SERVICE AND DEVELOPMENT OF MULTIMODAL PASSENGER TRAFFIC**

**Summary.** This article stresses the need to develop multimodal passenger transport. Particular attention is paid to the construction of HUBs based on railway stations. HUB is the transport interchange node, passenger complex, which redistributes passenger flows between transport modes and directions. They allow to optimize transportation processes, as well as to create an infrastructure for convenient and fast passenger transfer between different transport modes. The preconditions for creating organizational conditions to ensure the sustainable development of the passenger railway transport sector are outlined. In the near future, combined passenger transport with the participation of several modes of transport will attract tourists from around the world. The authors' concept of the term "passenger comfort zone" is proposed, which takes into account all the needs of modern tourists. The mechanism of multimodal transportations of passengers by railway transport in interaction with other participants of the servicing process is presented. A model of institutional support for the development of multimodal passenger railway transport is proposed to create conditions for integrated transport services for passengers by the passenger railway transport complex. The expediency of forming a system of railway passenger HUBs in Ukraine is vital to attracting investments to improve transport and tourism infrastructure, as well as to roll stock and a range of services for the benefit of all stakeholders in the transport sector (e.g., the state, investors, and passengers).

### **1. INTRODUCTION**

In spreading the processes of globalization and intensification of passenger flow, the key direction of the maintenance of transformation of the passenger service system is the modernization and development of contemporary multimodal passenger complexes. Today, for passenger transport services to be provided with full quality and comfort, they must be performed in a combination of different modes of transport. This confirms that one of the requirements of the Association Agreement between Ukraine and the EU is to ensure the spread of multimodal communication, both in the freight and passenger sectors.

Passenger rail transport brings significant public benefits in the form of rapid movement, reduced congestion on highways, and decreased environmental pollution. Governments of developed countries

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invest heavily in the development of the passenger rail network, but the railways are not equally developed in all countries, and some of them need to do much to reach the European level. For example, in Ukraine, it is necessary to improve the system of passenger rail transport by developing multimodal passenger transport. This technology allows the advantages of each type of transport to be combined, thus making it as efficient as possible and creating the necessary conditions for the development of intermodal tourism.

A key role in the efficient functioning of the passenger railway transport sector is played by the construction of modern transport interchanges, or HUBs, which will provide interactions between railway carriers and other participants in the passenger transport industry. The purpose of the present article is to explore how to create organizational conditions for the sustainable development of the passenger rail transport sector, provide a rationale for the formation of rail passenger HUBs in Ukraine, and improve the system of passenger rail transport for multimodal passenger traffic.

## 2. REVIEW OF SCIENTIFIC SOURCES

At present, publications on the organization of HUBs are widely represented only in the foreign literature. Many scientists from different countries have paid attention to the organization of multimodal passenger transportation and mass transit stations. Some have focused on building a smart city with convenient transport infrastructure and interchange, while others have focused not only on local residents but also on tourists. A common feature of this research is that they aim to improve the basic transportation services provided to passengers. Attention is also paid to additional related services and potential benefits to investors, among other issues.

For example, a study conducted in France [1] explained the development of a utility model for organizing multimodal passenger transport that accounts for the two most important flows: passengers and vehicles. Spanish scientists [2] rightly noted that tourism is developing rapidly, and as a result, the needs of tourists are growing. Therefore, the tourism industry needs continuous innovation. The researchers used the example of the Spanish city of Gandia to suggest making cities “smart” and, thus, attractive to tourists. This, in turn, would increase the mobility of the population by harmonizing the transport infrastructure with existing attractions and places of recreation.

A study in Latvia presents a comprehensive analysis of the planned multimodal public transport HUB. The authors [3] proposed a method by which the authorities can bring the system of public transport to a stable state and explore some aspects of decisions on the network of planning passengers in Riga as part of the Rail Baltic of Riga’s main multimodal public transport center.

The main issue in this example is the extent to which the planning of multimodal transport requires an assessment of the factors influencing accessibility and how they are currently taken into account in planning. Some scientists have written about the need for “smart transport systems” to ensure the safety of passengers. For example, scientists from Russia [4] have indicated that the rapid growth of different types of vehicles requires the construction of intelligent transport systems. The global transport system, consisting of heterogeneous transport flows, also requires the intellectualization of vehicles and transport infrastructure to ensure their effective management and improve the quality of services. The authors expressed that creating a cognitive multimodal transport system will significantly reduce the average time of passenger transportation and increase safety.

A study by scientists from Romania [5] revealed that reducing transit time through intermodal terminals is critical to making public transport more attractive. Their work presents a model for designing intermodal passenger terminals that encourage modal transfers. The framework of their model provides the ratio of schedules of transport modes, the placement of platforms so that the movements between them are as short as possible, the integration of tariffs, and the use of unique tickets, among other innovations.

Scientists from China [6] described the specifics of the organization of HUBs in Lanzhou, Ningbo, Chongqing Railway Station. In addition to high-speed rail, the transport HUB usually combines other modes of transport, including subways, buses, taxis, and even air transport. The transport HUB is considered an important city flagship, where passengers and cargo are exchanged between different

modes of transport. Therefore, in accordance with the usual scope of passengers, the relevant service facilities are developed around the transport HUB. Regarding high-speed railway stations, when designing a transport HUB, several factors should be considered, including the renewal of the city, which connects underground and surface transport, and a combination of high-speed rail, subway, and land transport. In Ukraine, this issue is studied only at scientific conferences and among the staff of JSC "Ukrainian Railways." However, it requires further study due to the high urgency.

### 3. STATEMENT OF BASIC MATERIALS

Despite global trends of deepening cooperation between transport modes in passenger service chains, multimodal passenger transportation has not yet become widespread in Ukraine. Most researchers studying the development of multimodal transport point to various reasons that decelerate the implementation of European standards of multimodality in the field of transport services in Ukraine. Nevertheless, all countries understand that the provision of better transport services to passengers requires the development of multimodal passenger transportation based on a system of so-called combined passenger transportation based on the principle of "train-bus (car)," "train-bicycle," "train-plane," and "train-motor ship." Therefore, there is an urgent need to clearly organize passenger transportation services and modern logistics systems in general.

Active reforms have been implemented in the market of transport services of Ukraine for more than five years. However, a number of negative factors continue to hinder the development of multimodal transport. The most notable of these factors are described below.

First, there is a low level of competition between transport modes in the services market; despite the reforms, competitive relations have not yet been introduced in railway transport. The low level of competition between transport service operators (transport organizations) has led to a lack of incentives to improve the quality of services and reduce tariffs.

Second, the technological backwardness of most transport modes remains unsolved. Due to the low level of investment in the renewal of fixed assets, most transport companies have a critical level of wear and tear of their rolling stock and infrastructure, which reduces the service quality.

Third, the level of implementation of informational systems and integrated technologies for passenger and cargo owners is insufficient. In particular, it does not allow to plan, coordinate and monitor the transportation process at the level of European countries as well as it does not provide an informational support to passengers during transportation.

Fourth, there are disparities in the level of transport infrastructure development. For example, there are insufficient numbers of transport and logistics centers, passenger HUBs, and areas with speed limits; also, the depth of some seaport areas does not meet passport characteristics.

Fifth, institutional support for the development of multimodal transport in the country is unsatisfactory [24]. The main reasons for the low level of multimodal transport development in Ukraine are an imperfect legal framework, tremendous risks for multimodal operators, a lack of coordination among all participants in the multimodal process, a low level of staff competence for organizing multimodal transport, infrastructural disparities, and the non-compliance of traffic rules with the standards and regulations of the EU.

According to scientists, the most important factor hindering the development of multimodal transportation in Ukraine is the lack of proper institutional support. This is critical, as such support is needed to determine the methods and principles of supporting and stimulating the development of cooperation between modes of transport in passenger service. The low level of development of multimodal transportation is the result of the unresolved legal issues of the organization of mixed transportation for both goods and passengers [7]. When analyzing the institutional conditions required for the development of multimodal transport in the country, it should be noted that the main international document establishing legal relations in the field of multimodal transport is the UN Convention on International Mixed Transport, developed in 1980. In addition, the development of multimodal passenger transport in Ukraine is constrained by the lack of specialized infrastructure capable of providing multimodal services during passenger transport.

In developed countries, modern multimodal passenger complexes are developed by creating a system of passenger HUBs, which implement the principles of quality assurance on the basis of modality in passenger service. The passenger's trip should be as convenient, comfortable, and quick as possible. Recently, the criteria for the provision of passenger services changed, especially owing to the pandemic and permanent quarantine conditions. Passengers are interested in the price of the trip, their safety, the speed of the transportation method, comfortable conditions, the quality of the services provided, and awareness of the service. Thus, it must be asked what a passenger's ideal comfort zone is (i.e., what a passenger needs to feel comfortable and confident).

**The comfort zone** is an area of living space in which a person feels confident and safe. In other words, it is a state of psychological security that arises through a sequence of habitual actions and obtaining the expected result [8]. The concept of the "comfort zone" defines not only the territory that is positively perceived by a person. It also determines the quality of human life, and one's quality of life can be determined by the same benefits that are available to a person that he can provide. This is also a certain level of his comfort zone. If a person wants something new, new sensations, or new impressions, then they need to go beyond their comfort zone to acquire these new things. Such an opportunity can be provided by the economic aspect of the manifestation of the comfort zone, which determines the latest technologies, the development of the digital economy, and so on.

During transportation, passengers are most interested in the comfort, quality, price, service, and safety associated with their journey. Previously, passengers had a smaller comfort zone, which included a comfortable journey in lux-class compartment cars, the availability of bed linen, the presence of a dining car in a train, air conditioning, and additional services at stations and trains. However, this comfort zone has changed, especially owing to the conditions of the quarantine. Passengers are no longer satisfied with a comfortable trip, clean linen, and tea or coffee. They want a safe, fast, comfortable trip at a good price, with good service, hot food, Internet, and additional information about various additional services provided by different modes of transport. They also want to be able to receive preferential transportation and high-quality service, among other demands.

The notion of the "*passenger comfort zone*," its description, and the importance of its expansion are explored in the following paragraphs.

"*Passenger comfort zone*" is the state when a passenger receives the maximum range of services by various modes of transport (possibly with a single ticket). Without leaving their home, the passenger can use a smartphone or tablet to easily get complete information about the trip (e.g., the price, travel time, convenient modes of transport, individual routes, and service packages).

The most important aspect of the "*passenger comfort zone*" is the level of satisfaction of the consumer's needs; the greater the need, the greater the "*passenger comfort zone*." Digitalization is the key innovative trend in the development of railway transport, which determines the directions and tools for the growth of passenger transportation. Therefore, the introduction of new technologies, methods, strategies will increase the interest of passengers in these services.

Therefore, to increase the "*passenger comfort zone*," multimodal passenger transportation and the introduction of HUBs need to be developed to provide new opportunities for quality, comfortable services with new capabilities. Every year, with the development of all modes of transport and increasing demands of passengers to the quality of service (e.g., the formation of the need for multimodality of transportation), the formation of passenger HUBs is being implemented more actively. Today, HUBs operate not only in places with high concentrations of passenger traffic but also for various other modes of transport to improve the quality of service.

In particular, this model of service, both for passengers and cargo, is actively used in marine transport. According to statistics, more than a third of all cargo flows in the world are served by powerful HUB ports that perform the function of the transshipment of goods. According to the principles of the HUB, such ports of international and regional importance that are currently in operation include those in Rotterdam, Hamburg, Klaipeda, Valencia, Riga, Gandia, Tallinn, and Sagunto [9]. As a category, the term "HUB" is now used in various areas of economic activity such as transport, production, innovation industry, agriculture. According to Wikipedia, a HUB is a transport node where traffic flows converge [10-11]. Scientists have interpreted the HUB category as a place where passenger traffic is concentrated and where passengers are transferred from one transport mode to another [12-13]. In

particular, J. Camp Bell defines a HUB as a node-type considerable scale transit airport located at the intersection of strategic passenger routes [15]. This paper, basing on the above-mentioned definitions, considers a passenger HUB as a transit point where passengers can change their direction, transportation mode or transportation service.

The study of world experience in the implementation of infrastructure development projects in the passenger transport sector justifies the feasibility of forming a system of railway passenger HUBs in Ukraine as a complex for the implementation of multimodal rail passenger transport. This issue is extremely important not only for Ukraine; some countries have already experienced transport interchanges in completely different ways. Illustrative examples of the organization of passenger HUBs can be seen in the creation of the Skolkovo transport HUB, which combines rail and road infrastructure, urban transport, as well as offices and shopping malls. The main goal of this multimodal transport HUB was to enhance passenger comfort and safety by reducing the time spent on the road and providing various services [16]. A very interesting example of a transport HUB is the Shinjuku HUB, located in one of the central districts of Tokyo. It includes interregional lines belonging to the speed transportation system (the Shinkansen - Tokaido line), regional lines (four express and regular railway lines) as well as public transport (two subway lines). Due to the organization of route traffic on the subway lines, 10 different lines of high-speed off-street transport, city passenger transport, buses, and taxis pass through the HUB.

The Shinjuku HUB contains a large multifunctional center, which is one of the focuses of the center of the Japanese capital. The platform ensures the connections of pedestrians between them and a pass to infrastructure. It contains front groups for each mentioned passenger transport, ticket offices, waiting rooms, and associated service facilities (e.g., retail stores, cafes, information services) [17]. All information is provided to passengers through a single system of dynamic boards, information desks, and terminals. Much attention is paid to the safety of passengers and staff at the transport HUB. There are also police patrols, video surveillance systems on all parts of the unit, and special safety measures (e.g., blast-resistant containers, smoke detectors). Another example is the Termini (Stazione Termini) train station, which is the largest in Rome. Every day, it serves hundreds of domestic and international destinations, connecting the capital with other cities in Italy and Europe. The Termini is not only the main railway junction of Italy (and travel around the cities of Italy by train is incredibly simple, convenient, easy, and inexpensive), but it also allows passengers to quickly get to the airport via the Leonardo express or go to the outlets on special shuttle buses that are sent from here. There are convenient pharmacies, shops, cafes, banks and exchanges, restaurants, supermarkets, social care centers, fitness centers, lockers and luggage checkpoints, a post office, a police department, cash registers, travel agencies, and other services. Rome's Termini station serves more than 480,000 people a day and has an annual passenger traffic of more than 150 million.

Kazakhstan also actively supports the initiative to create multimodal HUBs. In particular, in 2018, a multimodal transport HUB of the port of Kuryk was opened, which is located along the Trans-Caspian international transport route and serves road and rail ferries regardless of the season [19].

The development of HUBs in developed European countries is seen as critical to improving the quality of services and the development of multimodal transport, as their creation promotes effects with national and narrow industrial importance.

In Ukraine, in 2017, JSC Ukrzaliznytsia planned to create a railway passenger HUB in Mukachevo to improve passenger services with EU countries. The initiative provided connections to the Mukachevo railway passenger station via a combined track crossing, where work was to be carried out to arrange comfortable areas for boarding trains to Hungary, Slovakia, and Romania. However, the project still remained unrealized due to a lack of free funds [20].

Ukraine is an important transport corridor for European and Asian countries, as well as an attractive tourist center. Thus, creating passenger HUBs could significantly develop the efficiency of the passenger railway transport sector. However, HUBs are needed for the development of multimodal passenger and tourist transportation not only in Ukraine but also in other countries. Furthermore, railway stations can become the heart of such a transport HUB in conjunction with all other transport modes. The scope of the interactions of the main railway HUB with other modes of transport is presented in Fig. 1 [21].

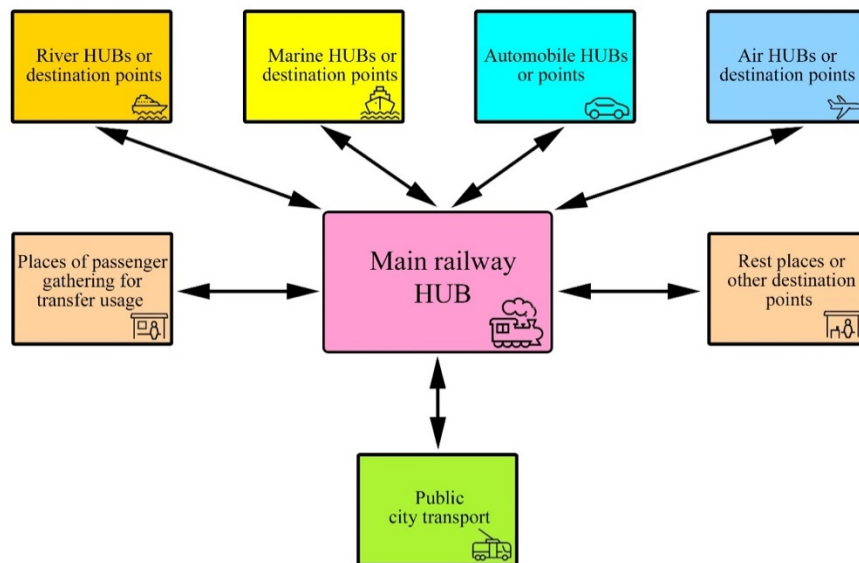


Fig. 1. The scope of a main railway HUB's interactions with other modes of transport (Developed by Charkina T.Yu.)

However, it is necessary to first decide what functions a HUB will perform. Presently, railway stations provide a range of secondary services. At HUBs, passengers are transferred from one direction to another, but the process of transferring passengers from long-distance passenger transport systems to high-speed and suburban trains and back has not been optimized. The additional interlinking of specified train schedules is necessary. It demands reduction of the general term of passenger movement from trains to all possible local transport means (e.g., subways, trams, trolleybuses, buses). It will allow to bring them home or to other local stations. This function is now performed by local authorities. A systematic approach was followed to address this issue by determining the scope of the necessary functions of the railway passenger HUB.

Foreign cases show that the additional functions of railway HUBs include providing trade, entertainment, and information services for the organization of comfortable living conditions for passengers waiting for their chosen mode of transport; organizing transfer transportation for passengers for their further travel by other modes of transport (e.g., buses, planes, river and sea steamers.); organizing the transfer transportation of passengers' luggage for their further travel by other modes of transport; and providing passengers with travel services via different modes of transport within a single ticket [21].

The basic and advanced functions that will be implemented within the railway passenger HUB should be identified. The basic functions of the railway passenger HUB include the following [21]:

- services in the process of on-boarding and off-boarding, as well as moving passengers within a single ticket; this includes, namely, the organization of transfer of passengers for their further travel by other modes of transport, the transfer of passengers from one mode to another (from long-distance to suburban or local vehicles or vice versa), the movement of passengers from train arrival platforms to ticket offices or rest places (e.g., waiting rooms, hotels), the registration of travel documents (e.g., cash halls, mobile applications, electronic cards);
- sanitary and hygienic services (e.g., medical centers, pharmacies, toilets, and showers);
- leisure services (e.g., waiting rooms, hotels, hostels);
- organization of cargo and postal operations (e.g., storage rooms, luggage terminals), including reception, storage, and issuance services; the movement of hand luggage; the registration of documentation on luggage; the packing of luggage; and luggage cart rentals;
- information and reference services (e.g., digital navigation, help desks, virtual agents, service applications, electronic scoreboards).

The extended functions of the railway passenger HUB include the following:

- shopping and entertainment services for passengers while they wait through the organization of retail trade in shopping centers and quickly erectable structures (small buildings of auxiliary socio-cultural, commercial, household and other purposes used to improve the aesthetic appearance of public places and urban facilities, the organization of space, complementing the composition of houses, buildings and their complexes);
- cultural and educational events (e.g., exhibitions, fairs, concerts, museums, cinemas);
- food services (e.g., restaurants, fast food outlets), including the ability to order food on the train, reserve seats in a restaurant, or pre-order food from fast food outlets;
- insurance services (e.g., insurance companies) for passengers and cargo, the registration of insurance policies, and compensation for losses;
- tourist services (e.g., tourist companies), including railway tourist trips and other types of tourist services;
- household services (e.g., repair shops), including repairs for clothing and household appliances;
- financial and legal services (e.g., banks, investment and law companies);
- additional services (e.g., taxis, parking, car and bicycle rentals).

The main function of HUBs is to optimize the schedule of passenger trains of different types of communication to reduce the length of stay of passengers at railway stations in anticipation of other trains and transfers. Thus, it is important to understand the optimization of the schedule of passenger trains. Suburban trains must arrive at the railway station in advance of the arrival of a passenger or high-speed train while taking into account the period of their delay. In this case, it is possible to introduce a single ticket on the railways for the convenience of passengers, allowing them to travel simultaneously by two types of trains or different modes of transport. All these measures will reduce passengers' total travel times.

Currently, some travel companies in Ukraine use transfer services to deliver tourists from individual cities to the main modes of transport (e.g., airports, railways, river and sea stations). All this is included in the ticket price. However, this function can be included in the main functions of the railway HUB. They can also perform an additional service for carrying passengers' luggage for further travel by other modes of transport; this service is currently performed by airports in Ukraine [21].

Previously, a person who traveled a lot, rested, went on business trips, and performed various tasks, often used several modes of transport. The process was long and extremely inconvenient, as the passenger sometimes wasted a lot of time waiting. However, passenger centers began to be built in large cities of different countries to increase the comfort of transportation and significantly reduce travel time by linking the schedules of planes, trains, and other modes of transportation and services for passengers to use while waiting for further travel (e.g., hotels, lounges, restaurants, cafes, shops, entertainment venues).

Landing terminal of the transport interchange node - one or more structures in the transport interchange node are specially created, designed to optimize the pedestrian flows of passengers performing the transfer with the possibility of visiting or passing the service facilities.

An important issue in forming a theoretical and methodological basis for developing railway passenger HUBs in Ukraine is the establishment of requirements under which a station can be considered as a HUB. Currently, there is a certain set of criteria that determine the compliance of a HUB's transport infrastructure. According to M. Aranchiy and D. Aranchiy [22], the following matters should be considered during the HUB formation:

- optimal use of railway infrastructure, including station areas and buildings;
- availability of infrastructure for organizing multilevel passenger flows within the station (e.g., crossings, lifting equipment);
- the possibility for constructing multilevel car parks for the long-term placement of cars;
- the possibility of using the space of railway tracks, especially their upper part;
- the possibility of providing comprehensive services by expanding the functions of stations and the organization of additional services [19].

Considering the opinion of the above-mentioned scientists, we believe that the following principles and conditions must be observed for the construction of railway transport HUBs [21; 23].

1. The presence at this railway station comprising a large number of trains of different categories traveling in different directions from which passengers transfer to other trains and modes of transport for further travel;
2. A transport railway HUB must combine all types of general and urban modes of transport. If the provision of transport railway HUBs by urban modes of transport (e.g., subways, trams, buses, trolleybuses, taxis) is considered, it is almost impossible to bring together airports, bus stations, sea and river stations. However, it is possible to offer transfer services that will work in conjunction with the above stations and the cost of services that must be included in a single ticket.

Given the above discussion, a rail transport HUB can have an improved terminological meaning. It can mean a large railway transport interchange center that arranges convenient travel for passengers and their luggage, which offers several modes of transport based on agreed common single route timetable within one ticket. It includes all service type costs and provides a full comfort to passengers waiting for the next trip [23]. Therefore, it can be argued that the sphere of the railway HUB is a set of socio-economic relations associated with the movement of passengers by various modes of transport and transfer, as well as their associated services of social infrastructure to provide a full range of services throughout passengers' travels [23]. It follows from the above statement that a railway transfer center cannot exist without transfer traffic, a general schedule, and a large number of passengers. This is because there is almost always a certain distance between the railway transfer center and the airports, river and sea stations, which many passengers want to cover quickly so they can travel further.

The creation of railway passenger HUBs will reduce the travel time of passengers and provide comfortable conditions (which is achieved by organizing a trip with a single ticket and agreeing on a common schedule between the modes of transport involved in transport). Therefore, the key to ensuring their efficiency is a comprehensive mechanism for the interaction of modes of transport involved in the organization of multimodal passenger traffic within the HUB. Thus, it is advisable to present a mechanism for the implementation of multimodal passenger transport by rail in cooperation with other participants in the process of passenger service (Fig. 2). Therefore, such rail transport transfer centers need to be established in large cities with a developed infrastructure and large numbers of passengers and tourists to be transferred from one direction to another. Examples of such cities include Kyiv, Kharkiv, Dnipro, Lviv, and Odessa.

Based on the above research, the following conclusions can be drawn [21]:

1. The organization of HUBs based on large railway stations of Ukraine is expedient and necessary, as it will reduce the total travel time of passengers and significantly improve the quality of service. At the same time, it will increase the efficiency of railway transport and generate additional revenues from the provision of new services.
2. In each city, it is necessary to consider existing features of construction of the transport infrastructure, to the organization of HUBs individually, and to use only some of the possible offered functions.
3. The implementation of new functions of transport interchanges will allow the management of the JSC Ukrzaliznytsia to create additional conveniences and comfort for passengers by optimizing the train schedule, reducing travel time, providing additional transfer of passengers and luggage, and offering shopping and entertainment services.

Railway transport is gradually losing its value, while road transport is increasing its traffic. This trend is very harmful to the environment and human health. According to the European requirements for the development of the country's transport sector, the leading mode of transport in Ukraine should be railway transport, as it is more environmentally friendly than other modes of transport. In addition, passenger railway transport is socially oriented, it transports a large percentage of the country's population, and it is the cheapest mode of transport. Thus, it needs to be developed with the help of the government.

Modeling the phenomenon is of great importance for modeling the passenger transportation demand. Earlier, when railways were only being developed as a central mode of transport, the transport services market was characterized by limited supply and fragmented development of the transport system, which provided only minimal consideration of the needs of consumers of transport services. Then, with the



formation of an extensive railway network, there was an increase in the number of train routes, and competition emerged in the transport market. Thus, a unified transport system focused on meeting all modern requirements of passengers was formed. This situation has contributed to the emergence of a progressive service that provides an expanded range of services in accordance with the requirements of particular consumer groups. In turn, increased competition in the transport services market and changes to consumer demands have led transport companies to consider the principle of multimodality in the provision of transport services and focus their attention on the need to meet the needs of passengers in integrated transport services. This level of service is called multimodal transport and was implemented based on the formation of a wide range of optimized transport routes.

In conditions of digital principles of business entity development, competition in the railway passenger transport market and an efficient multimodal transport system, railway companies actually are focused on achieving digital leadership in passenger transportation market. It can be achieved by meeting passenger needs in multimodal services and service digitalization. The last factor has contributed to the formation of a multimodal digital service, which is implemented through the creation of individual multimodal routes and digital services. Today passengers want comprehensive transport services. It, first, will enable passengers to choose alternative routes based on the door-to-door principle (main service). Second, it will provide passengers an access to a personal service package (related services) formed during a passenger service by a railway company. At the same time, an extremely important requirement for creating a comprehensive transport service is the formation of a digital environment, primarily by providing a mobile application to serve as a technological solution for passengers to manage their trips.

The present article describes a model for passenger traffic creation based on a model of demand for multimodal transportation. By applying the experience of countries around the world in the construction of high-speed highways, we use foreign cases to develop models that can be adapted to Ukraine. The parameters considered when building the model include population size, forecast demand for multimodal transportation, and gross national product volume, among others. This model is a regression-type model. The parameters included in this model that potentially explain the changes are the number of people in the district of transport gravity, modes of transport, participants of multimodal transportations, and the passengers and tourists who continue to travel by railway transport [25, p. 16].

The main parameter of population activity when using multimodal transportation is their solvency. The positive investment climate, the attractiveness of the region to tourists, and the geopolitical location of the transport HUB are very important aspects of the decisions to be made based on the demand for multimodal transport.

The demand for multimodal transportations also depends on the degree of development of digitalization of all transport modes, availability of digital platforms which ensure a clear interaction of all transportation participants. Another factor influencing multimodal transportation is the presence of economic centers and their capital intensity in the area of gravity of the transport interchange node.

Another important indicator to consider when forecasting transportation demand is the available passenger traffic by direction and its division by mode of transport. Such a division is important due to the introduction of multimodal transport, which requires main and additional passenger flows to be distributed between transport participants.

The process of adaptation in this model (which takes into account foreign experiences) has been occurring for a long time. It accounts for features such as the traditional preferences of Ukrainian passengers and the degree of governmental support of transport. Taking into account foreign experiences, the definition of passenger flows includes demographic and social factors that affect the mobility of the population, thereby determining the demand for a particular mode of transport.

When forecasting the demand for transportation, the relationship between the magnitude of passenger traffic and the socio-economic characteristics of the transport interchange node is determined. These variables can be reduced to one multifactor regression model [25, p. 17], the result of which is given in the following equation:

$$Y = V_0 + V_1 \cdot X_1 + V_2 \cdot X_2 + \dots + V_n \cdot X_n + \dot{p} \quad (1)$$

where:  $Y$  – change in transportation (passenger flow) demand;  $V_0, V_1, V_2, V_n$  – parameters of linear regression (passenger flows in the directions: long-distance, suburban, high-speed and  $n^{\text{th}}$  destination  $X_1$ ,

$X_2, X_n$  – independent variables (price, population, gross national product volume);  $\dot{p}$  – indicator of random observation errors.

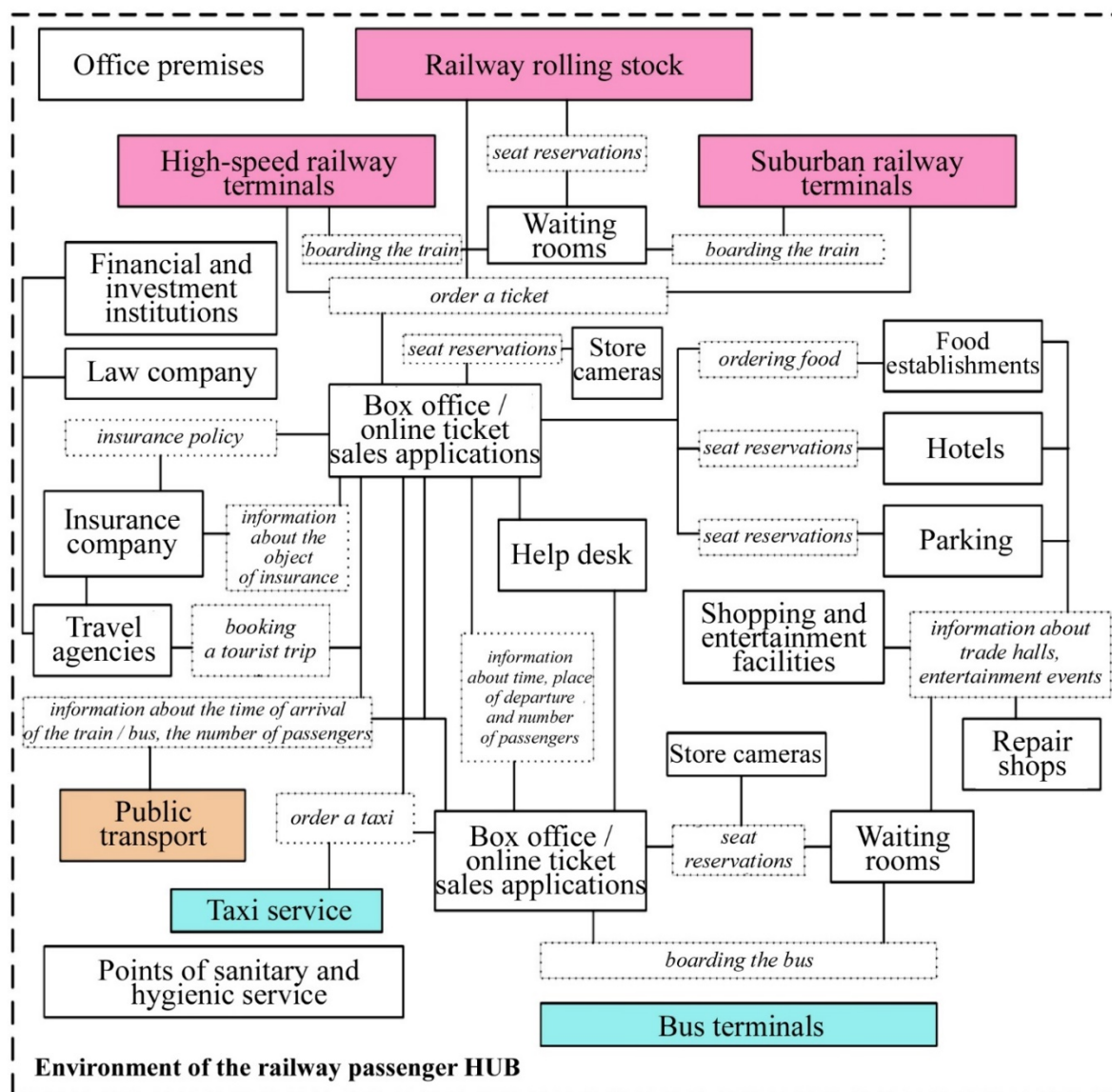


Fig. 2. The realization of multimodal transportations of passengers by railway transport in combination with other participants of the servicing process (development Charkina T. Yu.)

The purpose of the present article was not to determine specific forecast calculations. Thus, the results of forecast calculations will be presented in further studies.

One of the problems in the market of transport services is the harmonization of state, national, and private interests of transport entities of Ukraine. There is currently a lack of legislation to regulate the development of multimodal passenger transport and clearly defined mechanisms for the development of relations between different modes of transport involved in their organization. Thus, according to the authors' point of view, to promote the formation and effective functioning of railway passenger HUBs, it is first necessary to ensure the development of multimodal passenger transport at an institutional level.

Institutional support involves determining the norms of political, legal, and socio-economic natures, which must be taken into account between the development of certain relations. Therefore, the institutional support for the development of multimodal passenger transport by rail will be considered from the standpoint of establishing legal, financial, investment, organizational, and socially valuable influences on the processes of formation of the system of railway passenger HUBs. With this

in mind, a model of institutional support for developing multimodal passenger transport by rail has been developed. This model enables the creation of a system of railway passenger HUBs. Unlike existing models, this one reveals the stages and institutions of their formation and development, as well as support and incentives to create conditions for integrated transport services for passengers per the passenger complex of railway transport (Fig. 3).

According to the developed model, a system of railway passenger HUBs should be created according to the following procedure.

Stage 1. In particular, at stage 1, the requirements and standards of passenger services should be identified, and the goals of forming a system of railway passenger HUBs should be developed on this basis.

Stage 2. The plane of interaction and the formation of a system of operational relationships between participants should be determined, including the subjects of a multimodal service environment that will be formed within the HUB. At this stage, all measures aimed at the integration of entities involved in the organization of multimodal transport within the HUB should be carried out (namely, those related to the coordination of powers and responsibilities, risk-sharing, and joint investment to maintain the viability of the HUB).

Stage 3. A functional model of the railway passenger HUB and the strategy of their formation in the system of digital passenger corridors should be developed. The key issue of this stage is the coordination of the HUB architecture, as well as construction and repair work, which are intended to ensure the infrastructure of existing stations adheres to the developed architectural plan of the HUB.

Stage 4. The project should be directly implemented to create a system of railway passenger HUBs. The project should also involve the monitoring and control of the effectiveness of the HUBs' operation. At this stage, all infrastructure elements and the HUB are put into operation, and multimodal passenger services begin to be carried out.

It is expedient to ensure the efficiency of the creation and functioning of the system of railway passenger HUBs by means of two groups of institutional mechanisms. The first group of institutional mechanisms combines regulatory and legal and organizational support of the formation and development of the system of railway passenger HUBs. It also includes the development of a strategy for the development of the system of railway passenger HUBs; the adaptation of legislation to EU norms and standards in the field of passenger transport services (including the development of legislation on the development of multimodal passenger transport in the country); the improvement of customs, tax codes, reporting standards, quality, sanitary rules, norms, and technical standards; the development of rules and partnership agreements between the subjects of interaction within the HUB; the formation and acceptance of technical conditions of activities and service procedures, including the development of agreed-upon schedules of different modes of transport; and, finally, the establishment of qualification requirements for staff and developing a system of their material incentives.

The second group of institutional mechanisms for managing the processes of support and stimulation of the creation of railway passenger HUBs combines financial and investment support and social and value orientations. These include the development of a procedure for protecting and supporting the investors of infrastructure projects; the development of public-private partnerships; the formation of the system of the state social order; the development and implementation of a system of customized pricing; the introduction of targeted financing instruments; the development of a special regime of taxation and subsidies; the development and adoption of a code of culture for passenger services; the introduction of a digital platform for information and analytical support; the development of a PR company and measures for developing external communications; the organization and conducting of business training; and the development and adoption of standards of openness and reporting.

#### 4. CONCLUSIONS

Under the conditions of globalization and the intensification of passenger traffic, the primary means of ensuring the transformation of the passenger service system is the modernization and development of modern multimodal passenger complexes. The study of foreign experiences of the implementation of

infrastructure development projects in the passenger transport sector allowed us to justify the feasibility of forming a system of railway passenger HUBs in Ukraine as a complex for the implementation of multimodal passenger railway transport.

The system of institutional support for the development of multimodal passenger railway transportation plays a primary role in the development and maintenance of the efficient functioning of railway passenger HUBs.

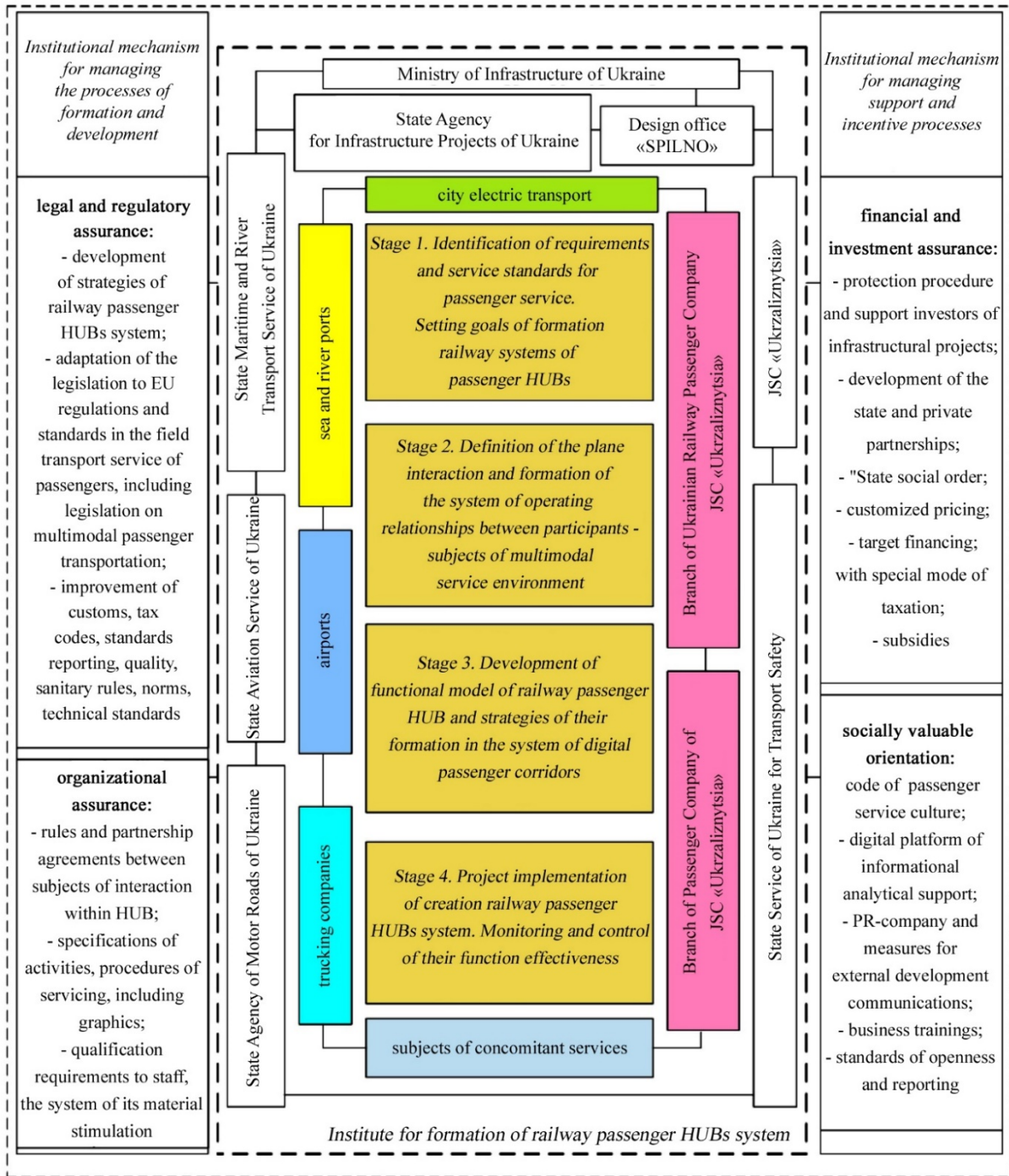


Fig. 3. Model of institutional support for the development of multimodal passenger transport by rail (developed by Charkina T.Yu.)

To coordinate work with other modes of transport, we revealed the scope of interactions of the main railway HUBs and their functional purpose. We also revealed the conditions and principles of their formation, which allowed us to present the mechanism of multimodal passenger railway transport through cooperation with other participants in the service process.

The principles and conditions that we proposed as necessary for the construction of railway transport HUBs will aid the organization of an effective logistics process for their operation. The terminological meaning of the railway transport HUB has been improved; it not only takes into account not only the transit purpose of passenger HUBs, but it also indicates that a HUB should be a comfortable place for passengers to stay, and it should offer a sufficient range of services.

The authors' concept of the term "passenger comfort zone" is proposed, which takes into account all the needs of modern tourists. We have developed a mechanism for implementing multimodal passenger railway transport with the cooperation of other participants in the service process. A model of institutional support for the development of multimodal passenger railway transport has been proposed. This model reveals the stages and institutions of formation and development while supporting and stimulating the process formation of a system of railway passenger HUBs to create conditions for integrated passenger service. This model can be adapted to EU countries.

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