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ЗАЛІЗНИЧНА КОЛІЯ

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FORECASTING OF PASSENGER TRAFFIC UPON IMPLEMENTATION OF HIGH-SPEED RUNNING

Purpose. Forecasting of passenger traffic flows in the future is an essential and integral part of the complex process of designing of high-speed network (HSN). HSN direction and its parameters are determined by the volume of passenger traffic, the estimated value of which depends on the economic performance of the country, as well as the material status of citizens living in HSN concentration area, transport mobility of population, development of competing modes of transport and so on. The purpose of this work is to analyse the existing methods of passenger traffic forecasting, to evaluate errors of the existing models concerning determination of traffic volumes and to specify the scientific approach to the development of high-speed rail transport in Ukraine. **Methodology.** The existing forecasting methods are reduced to the following ones: Delphi approach, extrapolation method, factor and correlation analysis, simulation method. The method described in this paper is based on scientific approaches such as analysis – a comprehensive and detailed study of various aspects of the known forecasting methods, comparing of existing methods for establishing differences and similarities, as well as deduction – use of general knowledge to get the new particular one. Thus, the unified indicators determined for the country as a whole, such as gross domestic product, national income, total population and others cannot be used to forecast the traffic flow on specific areas of HSN construction. Therefore, it is necessary to move from the overall forecast to traffic volume forecast on particular direction. **Findings.** The conclusions are derived from the analysis of different approaches and methods of passenger flow forecasting. It is proposed to create typical techniques of traffic flow forecasting using modern mathematical methods that would allow avoiding unreasonable decisions and shortening project development time. The resulting recommendations will help in the efficiency of design decisions, as well as will determine the quality of the project in whole and the feasibility of its implementation in particular. **Originality.** The scientific approaches to forecasting the passenger traffic volume in HSN agglomeration area were further developed. The HSN feasibility study criteria system was updated; this system takes into account passenger transit flows through Ukraine, the population of the cities covered by the high-speed network, mobility of population and other factors. **Practical value.** The data obtained by authors can be used to justify the concept of high-speed rail transport development in Ukraine, to create a high-speed network and to phase HSN construction.

Keywords: high-speed running; high-speed network; passenger traffic volume; passenger traffic flow; forecasting methods; economic efficiency

Introduction

The foreign studies on the efficiency analysis of high-speed network projects performed in different countries state that the transport corridor provided for HSN construction must have certain socio-economic characteristics. The total population of HSN concentration area must be at least 20-25 million people, and the overall total passenger

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traffic flow (in both directions), formed in this transport corridor prior to the start of HSN operation, shall be not less than 5.6 million passengers per year [17].

Significant factors that determine the success of HSN projects are economic indicators of development of the country and the specific areas of transport corridors, as well as financial situation of the citizens who live in HSN concentration area. One of the economic criteria that characterize the financial situation of citizens is gross domestic product (GDP). If the value of GDP is divided by population size, we will get the index represented in Fig. 1. Yet this average index for a country does not determine the feasibility of implementing high-speed transport. For example, in China, it is the lowest – 5.4 million dollars per person, but the country's success in HSN construction is impressive.

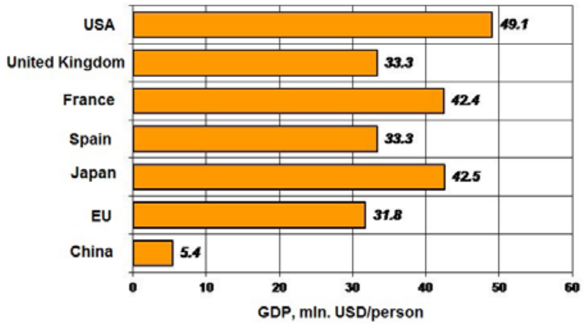

Fig. 1. Gross domestic product, per person

Thus, the HSN project efficiency must be assessed, first, in light of the financial situation of the citizens living in HSN concentration area, secondly, based on GRP indicator, which is calculated by subtracting from the total gross product (GDP) the volume of its intermediate consumption and which fully characterizes the economic activity of the city or region. Using statistics on this indicator one can predict the potential for economic development, and accordingly determine the possibility of the construction and operating conditions of future HSN network sections [9].

In Ukraine GRP is calculated using the mixed method i.e. part of the data is accumulated by regional statistical agencies and transferred to the centre and other part is collected by the State Statistics Committee and other economy sectors.

The relationship of the passenger traffic volume with the above mentioned factors allows predicting the prospective passenger flow and evaluating efficiency of introduction of high speed traffic in a particular direction.

The distribution of passenger traffic by mode of transport takes place on a market basis, depending on the cost of the trip, travel time, geographical availability of transport infrastructure and other factors. As a result, zones of efficient use of different transport means are formed. At the junctions of these areas there is competition between transport modes (interspecific competition) [15]. In addition, there is intraspecific competition (competition between individual companies representing the same mode of transport).

Dependence published by the International Union of Railways [17] and clarified with a number of additional data is shown in Fig. 2. It shows the current distribution of passenger flows between the air transport and HSN based on travel time by rail.

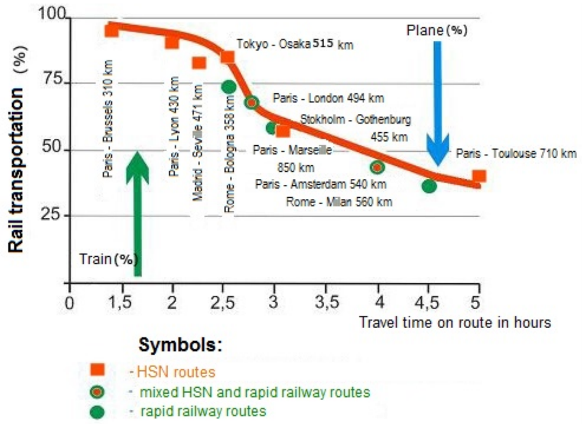

Fig. 2. Distribution of passenger traffic flow between high-speed rail and air transport

One of the important principles of ideology, which is laid in the assessment of options for the distribution of traffic, is based on forming of passenger flows and velocity of the passenger, not of the rolling stock [17].

Today there are a lot of research works that assess and consider the ways of further development of the trans-European high-speed rail network. One of these projects is NGT (Next Generation Train) developed by eight institutes of the German Air and Space Centre (DLR) [13]. The basic idea of NGT is to determine the operating domain of HSN in Europe, designed for a new generation of trains (NGT) with the speed of 400 km/h. The network model covers most of European countries, including Turkey.

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The project NGT investigated the reference direction Paris-Vienna, the model of which is extended to the entire European Union, with recommendations for further adjustments. The basic components and criteria of the model included economic centres (cities), direct rail connections, train traffic frequency and travel time. Herewith traffic volumes and density of population of cities were calculated and regional preferences of passengers by transport means and others were taken into account. The resulting transport model allowed forming the recommended operating domain of the network of new railway lines, proving feasibility of HSN construction for the speed of 400 km/h in Central Europe.

Purpose

The question is: will this European transport model work in other circumstances and in other countries, such as Ukraine? Obviously, in this case, one must take into account an individual approach to solving a complex of tasks.

The purpose of this work is to analyse the existing methods of passenger traffic forecasting, to evaluate errors of the existing models concerning determination of traffic volumes and to specify the scientific approach to the development of high-speed rail transport in Ukraine.

Methodology

HSN operating domain being the object of study can be presented as a set of peaks and links between these peaks. In their turn, the peaks are cities (metropolitan areas) that are key links in the network [3].

Both the peaks and the links between them have their own indices or evaluation criteria (social, economic, political, tourism, transport, etc.). For example, social criteria include population size, life expectancy, health conditions or pollution of the environment. Socio-economic factors determine the location of the so-called «strong points», including the intermediate ones, through which or near which HSN must pass.

Economic indicators are as follows: level of welfare, income per capita, gross regional product. Political relations are determined by the location of urban administrative centres, with their status and popularity (conducting of cultural events, conferences, sport competitions), etc. Travel links include business, cultural, recreational and other trips. Transport links are characterized by the presence or absence of certain means of transport by directions (road, rail, air, etc.), the mobility of the population, passenger traffic flow (transit and domestic), etc.

Within the large stations and units, particularly terminals, the high-speed network route should be connected to the network with other modes of transport: urban, commuter and air transport. Results of approvals from government and business entities may require changing the position of the line, even at the next stages of design.

When examining the operating domain for future HSN it is appropriate to consider the destinations that already have rail lines. Transport streams at these directions are the most intense [14]. Thus, the presence of the railway is one of the criteria for determining the areas for potential high-speed trains.

With a view to selecting of HSN feasibility study criteria assess for a specific region it is necessary to conduct deep investigation of the above factors, to develop appropriate methods of decision-making. A step in this direction is the classification of the main criteria for determining HSN destinations, specified in [10], Fig. 3.

The first group of criteria describes the agglomeration which tends to projected HSN. Stable growth and tendency of indices to the maximum possible values will ensure favourable environment for construction and in the future for operation of HSN.

The second group of criteria describes the technical and economic potential of destinations of the prospective HSN. The line length varies usually from 400 to 900 km for the purpose of being competitive with air service. [15, 16] The HSN construction cost depends on the line length and on the complexity of construction conditions. According to international estimates the average cost of 1 km of high-speed network is about 25 million Euro [18].

Forecasting of passenger traffic flows in the future is an essential and integral part of the complex process of designing of HSN. HSN direction and its parameters are determined by the volume of passenger traffic. Therefore, the methods for determining the latter are subject to analysis and refinement. Also it should be noted that increasing of passenger traffic flow will enhance the overall economic effect of the introduction of high-speed traffic.

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Many scientific papers are dedicated to forecasting of passenger flows. Deep analysis of different models and approaches is presented in [11]. It is appropriate to quote the saying by prof. M. V. Pravdin of this work: «So far, the passenger rail transport forecasting has been neglected, as a result there is no sufficiently strong justification for development of passenger high-speed transport...». It was written more than thirty years ago, but has not lost relevance today.

The existing forecasting methods are reduced to the following ones: Delphi approach, extrapolation method, factor and correlation analysis and state and event simulation method.

The first attempts to use mathematical methods appeared in the late nineteenth century, when A. Wellington (USA) and E. Lille (Austria-Hungary) attempted to establish a mathematical relationship between traffic size, population of corresponding points and distance between them. Later modifications of this model were proposed, which were called «gravity» [11].

These models are based on the assertion that there is transport «attraction» between two large settlements, which is directly proportional to the product of the population of these settlements and inversely proportional to the distance between them in degree β

$$\Pi_{ij} = \alpha_{ij} \frac{P_i \cdot P_j}{L_{ji}^{\beta}}, \qquad (1)$$

where Π_{ij} – flow from point i to point j; $P_{i,}$ P_j – population size respectively at the points i, j; L_{ij} – distance between two points; α_{ij} – proportionality factor; β – constant value.

Slightly adjusted dependence was proposed by M.I. Zahordan and F.P. Kravets:

$$\Pi_{ij} = \alpha_{ij} \frac{P_i \cdot P_j}{L_{ji}^{2}}. \qquad (2)$$

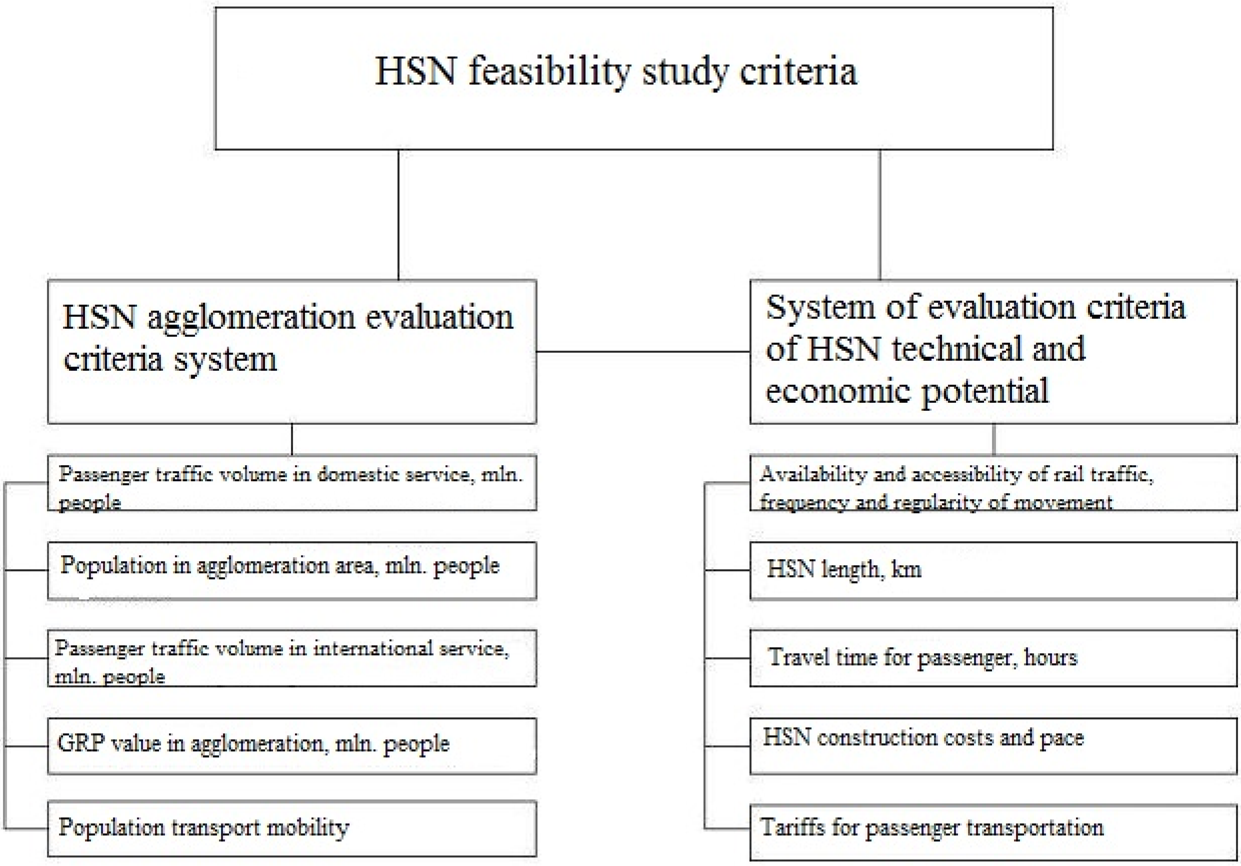

Fig. 3. Classification of the main criteria to determine promising areas of HSN construction

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They believed that the number of passengers is directly proportional to the product of population of two settlements and inversely proportional to the square of the distance between them.

In these models it is still difficult to determine the proportionality factor α_{ij} for long-range conditions, since the factor changes significantly over time. Thus, calculated on the basis of statistical data on passenger correspondence between individual points the factor ranged from 0.001 to 0.475. This is due to the effect of the statistical law of passenger behaviour that can be formulated as follows: to overcome the distance x from the point of view of a passenger it takes some reasonable time, which is associated with scientific and technological progress in transportation. Mathematically the law can be written as

$$\frac{x}{v(x,t)} = a(t), \qquad (3)$$

where $v(x,t)$ – speed, which depends on the distance of travel and technological progress (rolling stock, infrastructure) and is taken into account through the time factor t; $a(t)$ – constant value.

For example, if the average time to overcome the distance of 100 km by high speed train TGV POS climbing 35 ‰ slope is 30 min., then to overcome 1000 km the time increases not by ten, but 9 times, and on the gradient-free sections – 8 times.

The main disadvantage of this model is the high sensitivity to errors while calculating the value α_{ij} and inability to verify the reliability of the forecasted model.

A number of studies attempted to overcome some of these disadvantages of «gravity» models. In particular, they examined such factors as gross domestic product, national income and others. The linear model was proposed for forecasting, the defining parameters included national income, total population, urban and rural population. As shown above (see Fig. 1) the generalized parameters set for the country as a whole cannot be used to forecast the traffic flow in specific directions.

It should be noted that the models developed as «gravity» ones have found wide application. So, with the participation of experts of SYSTRA Company (France) in 2002 there were investigated the prerequisites for implementation of high-speed trains in Ukraine, identified possible routes for high-speed rail lines based on passenger traffic volume forecasting [12].

Passenger traffic volume was calculated according to the formula

$$F_{AB} = k_m \frac{P_A \cdot P_B}{f(L_r, T_t)}, \qquad (4)$$

where k_m – model coefficient.

The formula (4) shows that the passenger traffic volume F_{AB} between two final destinations A and B depends on the number of people living in final destinations P_A, P_B, frequency of trips f, length of the route L_r i and duration of trip by high-speed train T_t between the cities A and B.

Analysis of formulae (1) and (2) shows that they do not take into account transit passenger flow, which is advisable to transfer partially to high-speed connection. In addition, the consultant of SYSTRA does not reveal the real dependence, included in the denominator of the formula (4).

Conditions for major transit passenger flows are created due to vectors of modern relations of Ukraine with the EU, Belarus, the Baltic States, Central Asia and the Caucasus [8]. In this case, a special place is the study of *population transport mobility* index. It is believed to be the average number of trips per capita per year by all modes of transport, particularly by rail. In the rail transport segment the mobility factor is determined by the ratio of number of passengers transported by rail per year P to the average annual population of the region N, served by this rail:

$$k^p_{mob} = \frac{P}{N}. \qquad (5)$$

Findings

The authors analysed the dynamics, trends of passenger traffic and calculated the mobility indices by the formula (5) (Table 1). The forecasted population in 2020 is adopted according to JSC «Ukrzaliznytsia» [1] and the number of outgoing passengers – according to [5].

As the table 1 shows, the calculated long-distance traffic index k^p_{mob} differs significantly by rail (regions) and ranges from 0.9 to 2.28; it is in average 1.5 trips per year.

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Unlike the formula (4), used by SYSTRA, the work [2] presents the formula to calculate the forecasted passenger traffic volume, which takes into account passenger transit flows through Ukraine and the population in the cities covered by the high-speed network:

$$F_{AB} = 2\frac{(P_A + T_A)\cdot(P_B + T_B)}{P_{HSN} + T_{HSN}}\cdot k^p_{mob}\cdot k_t\cdot k_{add}\,. \quad (6)$$

where F_{AB} – forecasted annual number of passengers between two cities A and B,. ths people; P_A, P_B – population of the cities A and B accordingly, ths people; T_A, T_B – transit passenger flow through station A and reverse movement from station B, ths people; P_{HSN} – total number of people at all stations of high-speed network, ths people; T_{HSN} – transit passenger flow through all stations of high-speed network, ths people; k^p_{mob} – population mobility in Ukraine on HSN, share; k_t – coefficient taking into account travel time of passengers on a given section according to the average length of the trip – 4 hours, which varies from 0.75 to 1.25, share; k_{add} – coefficient additionally taking into account frequency of passenger's travel on a given section (business trip, change to the airplane, vacation, tourism), which varies from 0.75 to 0.9 for the regional cities with population of up to 600 thousand and the cities of Kriviy Rig, Melitopol and Mariupol, 0.9 – 1.1 for the regional cities with population of up to 600-1000 thousand and the cities of Lviv and Kharkiv, 1.3 – 1.5 for the cities of Kyiv, Simferopol and Odessa.

The coefficient k_t takes into account the travel time of passengers between specific cities and significantly affects the demand for HSN. For example, travel time from Lviv to Simferopol will be about 6 hours. At the same time, travel time between Kyiv and Dnipropetrovsk will be reduced to two hours. Because of this difference in time the demand for the use of high-speed network can vary by almost in half. These data are recorded in France and other European countries. Experience in operating speed trains in Ukraine in 2013 showed that demand for passenger transportation between Kharkiv and Kyiv 1.5 times higher than that between Donetsk and Kyiv as the difference in travel time is 1.5 hours.

Table 1

Population mobility in long distance rail traffic

Railways	Number of residents in the territory, ths people	Passengers transported, ths people		Mobility factor	
		total	long distance traffic	overall	long distance traffic
Ukraine	**42 400**	**448 436**	**62 519**	**10.58**	**1.47**
Lviv	8 493	65 223	9 133	7.68	1.08
Pivdenno-Zakhidna (Southwestern)	8 882	139 116	20 263	15.66	2.28
Pivdenna (Southern)	4 769	69 430	8 091	14.56	1.70
Pryniprovska (Near-Dnipro)	7 125	77 836	11 311	10.92	1.59
Odessa	6 894	34 580	8 021	5.02	1.16
Donetsk	6 329	62 252	5 699	9.84	0.90

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However, the factor k_{mob}^{p} that determines the population mobility needs clarifying because mobility in different regions is different.

In addition, the formula (6) is not without drawbacks. Let us consider a specific example. Fig. 4 shows two variants for high-speed lines between Kyiv and Lviv. The population that lives in urban areas (thousand people) is shown in the diagram. Transit is adopted the same for both variants – 50 thousand people per year. The results by the formula (6), i.e. the projected number of passengers, are as follows: in case of the northern variant – 1 million people a year, the southern variant – 850 thousand people a year, that is not logical as the overall population at all the stations of high-speed network in southern variant is bigger and the passenger traffic flow is smaller. So the formula (6) does not include cases where the transit passenger flow has a significant share.

Fig. 4. Variants for high-speed network
with population of cities

Currently, the most developed are extrapolation methods, involving transfer of the trends observed in the past into the future. This approach is possible due to the inertia properties of different processes.

Transport mobility of the population can be characterized either by number of trips per capita per year (mobility factor) or by the average number of passenger-kilometres per inhabitant per year – use of passenger transport services by one resident.

Volume of passenger traffic is calculated using the mobility index that takes into account the frequency of trips per year per inhabitant of the related area.

Getting of qualitatively new effect in the forecasting practice is associated with the use of factor and correlation analysis. So, to check the relation of population incomes with mobility index the work [9] presents the correlation analysis, the results of which revealed that there is quite close dependence of the mobility index on the value of disposable real incomes of the population.

The authors also believe that the most generalized and complete definition of transport mobility should be considered not the number of trips regardless the travel distance, but passenger-kilometres per capita, i.e.

$$k_{mob}^{pkm} = \frac{\sum(p_i \cdot l_i)}{N}, \tag{7}$$

where $\sum(p_i \cdot l_i)$ – passenger traffic flow of railways, mln pass.-km.

To compare trends in transport mobility and incomes, Fig. 5 and 6 show the results obtained in [7], and Table 2 and Fig. 7 – calculations performed before the year 2015. Column 5 shows the population mobility indices, calculated by the formula (7).

One of the most accurate ways to assess the economic development of the state is considered gross domestic product (GDP), and for population the real income is that cited in statistics as nominal one (reproduced at current prices of this year – c. 6) and real one (adjusted for inflation – c. 7).

The performed correlation and regression analysis showed that the correlation coefficient between them is r_{mob}=0.882. The linear regression equation, which allows calculating the average standard value of mobility (k_{mob}^{pkm}) on the value of disposable real income per capita (D), is as follows:

$$k_{mob}^{pkm} = 1046.6 + 0.00876 \cdot D, \tag{8}$$

where the regression coefficient 0.00876 represents more or less uniform chain growth of mobility in arithmetic progression. This means that the change in disposable real income per capita by 1 UAH increases rail transport mobility by 8.76 pass.-km per person. The authors of the work [9] believe that the revealed tendencies (Equation 8) can allow forecasting the disposable real incomes and mobility per person. Their forecast for 2015 is as follows: mobility per capita – 1242 pass.-km, disposable real income per capita – 20.9 thousand UAH. Comparison with factual data for 2015 showed that neither the first nor the second index was not confirmed: mobility per capita made 835 pass.-km, and the real income – about 24 thousand UAH/person.

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Table 2

Calculation of transport (by railways) mobility of the population

Years	Passenger traffic flow of railways, mln pass.-km	Total income f population, mln UAH	Population size in Ukraine, people	Population mobility, pas.- km / per person	Nominal income UAH/ per person	Real incomes, UAH/ per person
2000	51 800	128 736	49 430	1 048	2 631	2 180
2001	52 700	157 996	48 923	1 088	3 261	2 490
2002	50 400	185 073	48 457	1 040	3 855	2 938
2003	52 200	215 672	48 004	1 087	4 529	3 400
2004	51 800	274 241	47 622	1 088	5 800	4 468
2005	52 400	381 404	47 281	1 108	8 127	6 332
2006	53 400	472 061	46 930	1 135	10 120	7 771
2007	53 400	623 289	46 646	1 145	13 362	10 126
2008	53 225	845 641	46 373	1 148	18 326	13 716
2009	48 327	894 286	46 053	1 049	19 454	14 091
2010	50 240	1 101 175	45 870	1 095	24 006	17 285
2011	50 569	1 266 753	45 693	1 107	27 723	19 683
2012	49 203	1 457 864	45 577	1 080	31 987	22 711
2013	48 876	1 548 733	45 483	1 075	34 051	23 836
2014	37 065	1 516 768	43 722	848	34 691	24 284
2015	35 913	1 520 000	43 000	835	35 349	24 037

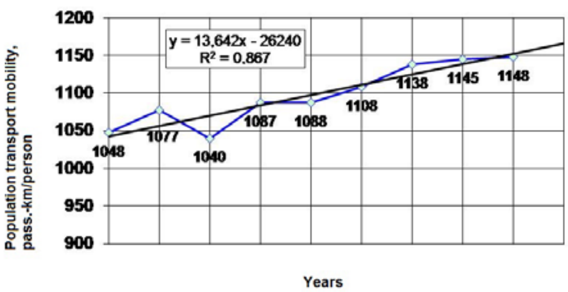

Fig. 5. Transport mobility of the population between 2000 and 2008

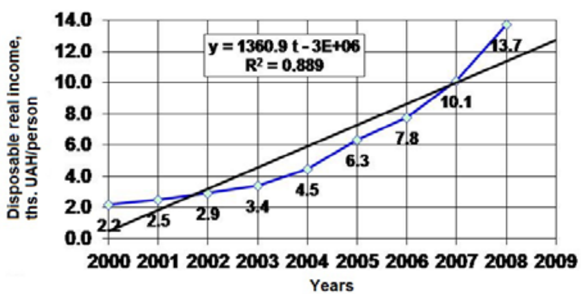

Fig. 6. Real income of the population between 2000 and 2008

This can be explained by the following (see Fig. 5 and 7): transport mobility of the population had been increasing by the year 2008, but has decreased in the following years. At the same time, the dynamic of growth of disposable income of the population was positive.

In Ukraine, the first step to improve the quality of transport services was the introduction of rapid trains (Intersiti+ trains): since May 15, 2012 on the section Kyiv – Kharkiv, Kyiv – Lviv, Kyiv – Donetsk; since November 11, 2012 the high-speed train was introduced on the section Kyiv – Dnipropetrovsk, and since May 2013 this route was extended to Zaporizhzhia; in 2014 the following high-speed directions were opened: Kyiv – Odesa, Kyiv – Ternopil, Darnytsia – Truskavets.

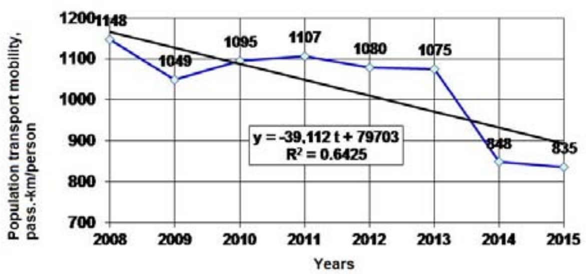

Fig. 7. Transport mobility of the population between 2008 and 2015

The main purpose of new HSN is to provide large volumes of passenger traffic between two or more regional cities and their agglomeration areas with minimal time loss by passengers. The involvement of large settlements to the chosen direction of HSN is determined by the amount of passenger traffic and revenues from the operation.

Future HSN concentration areas in Ukraine [12], including the following cities and economic and tourist centres:

– Kyiv (capital of Ukraine) and the Kyiv region, Kyiv has about 2.9 million inhabitants;

– Regions of Kharkiv and Poltava, Ukrainian cities with about 2.0 million inhabitants;

– Dnipropetrovsk (now Dnipro), Dniprodzerzhinsk (now Kamianske), Zaporizhzhia and Kryvyi Rih – about 3 million inhabitants;

– Donbas, economic activity in large cities such as Donetsk (about 1 million inhabitants), Luhansk (500 thousand inhabitants), Mariupol (about 500 thousand inhabitants), etc.

Tourist regions – Odesa (over 1 million people) Mykolaiv (500 thousand people), Kherson (300 thousand people), Sevastopol and Simferopol (about 700 thousand people).

West Region. Lviv has 730 thousand residents, while in the region – more than 2.5 million inhabitants.

Zakarpattia region is located on the edge of Western Ukraine immediately adjacent to 4 countries: Poland, Slovakia, Hungary and Romania. Zakarpattia, as of 2015 there are more than 250 resorts of different concepts and sightseeing sites of tourism and recreation.

Ukraine is among the countries with high population density (79 people per 1 km^2). This is a fairly high rate, indicating a generally favourable living conditions and high level of territory development. For comparison, the population density in Russia per 1 km^2 is 8.4 persons, in Republic of Belarus – 47.9 persons, in Kazakhstan – 5.4 persons.

When performing the forecasting calculations by directions of international transport corridors one can use the model of forecasting passenger traffic needs tried and tested within the framework of TACIS involving the companies EPV EuroprojrktVerkehr (Germany) SGTE (England), HyprotransTЭY (Russia), Transmark (England), Transpolis (Ukraine) [5].

This forecasting model, given the high uncertainty of the general economics and sociological position of the concentration area, uses statistic data and opinion of the experts, namely of the International Centre for Policy Studies (Soros Foundation).

Based on forecast data, it is estimated that in Ukraine in 2035 – 2040 about 130 million passengers will use the high-speed network annually. These traffic volumes correspond to an annual turnover of 54 billion pass.-km. One of the possible schemes of HSN development in Ukraine is shown in Fig. 8.

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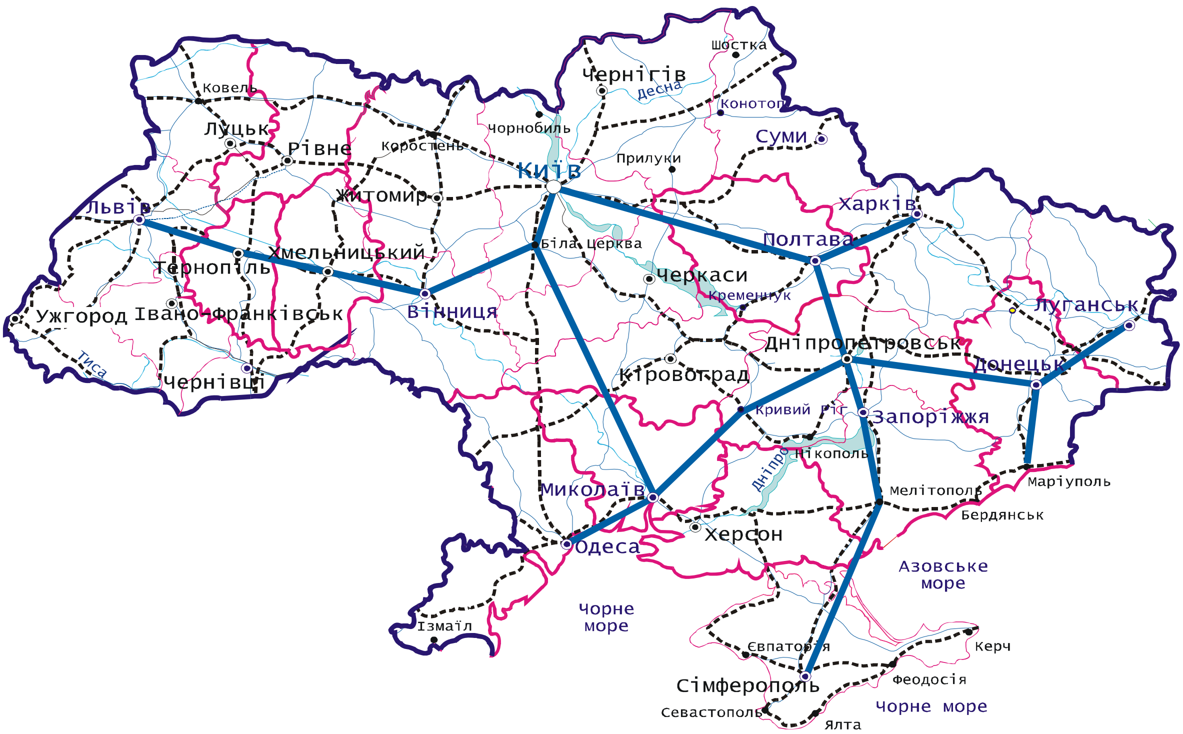

Fig. 8. The recommended variant of HSN

Originality and practical value

This work further developed the scientific approaches to forecasting the passenger traffic volume in HSN agglomeration area. The HSN feasibility study criteria system was updated; this system takes into account passenger transit flows through Ukraine, the population of the cities covered by the high-speed network, mobility of population and other factors.

The obtained data can be used to justify the concept of high-speed rail transport development in Ukraine, to create a high-speed network and to phase HSN construction.

Conclusions

Based on the analysis of the studies we can make the following conclusions:

1. To determine the rational routes of high-speed rail lines based on forecasted passenger traffic volume the widespread use is gained by «gravity» mathematical models based on the assumption that the strength of the interaction of cities and regions adjacent to the forecasted HSN is proportional to the product of qualitative and quantitative indices of the regions and inversely proportional to the distance between the cities. These mathematical models are widely used in regional analysis, during the study of expert and import relationships between regions, but should be adjusted on the basis of economic development, regional business activity, population mobility factor, the value of which may vary considerably depending on the growth of income, speed, comfort and service provided by high-speed transport.

2. Economic integration in the European Union can increase the flow of passengers in the international traffic, and the implementation of the European high-speed network expansion program in Eastern Europe and CIS will allow the railways of Ukraine to become integrated in the high-speed network of Europe. The Ukrainian routes of high-speed rail lines proposed by SYSTRA (France) in 2002 based on forecasted passenger traffic volume do not take into account the transit flow through Ukraine and the passenger mobility factor. Thus, the proposed network topology and HSN construction phasing require correction.

3. From the analysis of different approaches and techniques it follows that passenger flow forecasting requires development and use of advanced mathematical techniques, creation of common

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methods of traffic flow forecasting, which will allow to prevent unreasonable decisions and shorten project development period.

4. The studies show that to attract passengers on the distance of up to 600-800 km the lowest limit is the maximum speed of 250 km/h, at which travel time will not exceed 4 hours. Based on the fact that the average ratio between the route and the maximum speed is 0.7-0.85, it is necessary to ensure the maximum speed at the level of 300-350 km/h.

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ПРОГНОЗУВАННЯ ПАСАЖИРСЬКИХ ПЕРЕВЕЗЕНЬ ПРИ ВПРОВАДЖЕННІ ВИСОКОШВИДКІСНОГО РУХУ ПОЇЗДІВ

Мета. Прогнозування пасажирських транспортних потоків на перспективу є найважливішою й невід'ємною частиною складного процесу проектування високошвидкісних магістралей (ВШМ). Напрямок ВШМ та її параметри визначаються обсягами пасажирських перевезень, прогнозована величина яких залежить від економічних показників розвитку країни, а також від матеріального становища громадян, які проживають у зоні тяжіння ВШМ, транспортної рухливості населення, розвитку конкуруючих видів транспорту тощо. Метою даної роботи є аналіз існуючих методів прогнозування пасажирських перевезень, оцінка похибок існуючих моделей щодо визначення обсягів перевезень та уточнення наукових підходів до обґрунтування доцільності розвитку в Україні високошвидкісного залізничного транспорту. **Методика.** Існуючі методи прогнозування зводяться до таких: методи експертних оцінок, методи екстраполяції, факторного і кореляційного аналізу, методи моделювання. Методика, викладена в даній роботі, базується на таких наукових підходах, як: аналіз – всебічне і детальне вивчення різних аспектів відомих методів прогнозування; порівняння існуючих методів для встановлення відмінності та подібності; а також на дедукції – використанні загальних знань для отримання нових приватних. Так, узагальнені показники, встановлені для країни в цілому, такі як валовий внутрішній продукт, національний дохід, загальна чисельність населення та ін. не можуть бути використані для прогнозування пасажиропотоку на конкретних напрямках будівництва ВШМ. Отже, від загального прогнозу необхідно переходити до прогнозування обсягів перевезень на конкретному напрямку. **Результати.** Зроблені висновки випливають із аналізу різних підходів та методик прогнозування пасажиропотоків. Запропоновано створювати типові методики прогнозування транспортних потоків на основі сучасних математичних методів, що дасть можливість попередити необґрунтовані рішення й скоротити терміни розробки проектів. Отримані в роботі рекомендації сприятимуть ефективності проектних рішень, визначатимуть якість проекту в цілому та доцільність його реалізації зокрема. **Наукова новизна.** Набули подальшого розвитку наукові підходи до прогнозування обсягів пасажирських перевезень у зоні агломерації, що тяжіє до ВШМ. Доповнена система критеріїв оцінки доцільності спорудження ВШМ, яка враховує транзитні потоки пасажирів через територію України, чисельність населення в містах, охоплених високошвидкісною мережею, мобільність населення та ін. фактори. **Практична значимість.** Отримані авторами дані можуть бути використані для обґрунтування концепції розвитку високошвидкісного залізничного транспорту в Україні, формування мережі високошвидкісних магістралей та встановлення етапів будівництва ВШМ.

Ключові слова: високошвидкісний рух поїздів; високошвидкісні магістралі; обсяг пасажирських перевезень; пасажирообіг; методи прогнозування; економічна ефективність

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ЗАЛІЗНИЧНА КОЛІЯ

ПРОГНОЗИРОВАНИЕ ПАССАЖИРСКИХ ПЕРЕВОЗОК ПРИ ВНЕДРЕНИИ ВЫСОКОСКОРОСТНОГО ДВИЖЕНИЯ ПОЕЗДОВ

Цель. Прогнозирование пассажирских транспортных потоков на перспективу есть важнейшей и неотъемлемой частью складывающегося процесса проектирования высокоскоростных магистралей (ВСМ). Направление ВСМ и ее параметры определяются объемами пассажирских перевозок, прогнозируемая величина которых зависит от экономических показателей развития страны, а также от материального положения граждан, которые проживают в зоне тяготения ВСМ, транспортной подвижности населения, развития конкурирующих видов транспорта и т.п. Целью данной работы является анализ существующих методов прогнозирования пассажирских перевозок, оценка погрешностей существующих моделей относительно определения объемов перевозок и уточнение научных подходов к обоснованию целесообразности развития в Украине высокоскоростного железнодорожного транспорта. **Методика.** Существующие методы прогнозирования сводятся к таким: методы экспертных оценок, методы экстраполяции, факторного и корреляционного анализа, методы моделирования. Методика, изложенная в данной работе, базируется на таких научных подходах, как: анализ – всестороннее и детальное изучение разных аспектов известных методов прогнозирования; сравнение существующих методов для установления отличия и сходства; а также на дедукции – использовании общих знаний для получения новых частных. Так, обобщенные показатели, установленные для страны в целом, такие как валовой внутренний продукт, национальный доход, общая численность населения и др. не могут быть использованы для прогнозирования пассажиропотока на конкретных направлениях строительства ВСМ. Таким образом, от общего прогноза необходимо переходить к прогнозированию объемов перевозок на конкретном направлении. **Результаты.** Сделанные выводы вытекают из анализа разных подходов и методик прогнозирования пассажиропотоков. Предложено создавать типовую методику прогнозирования транспортных потоков на основе современных математических методов, которая даст возможность предупредить необоснованные решения и сократить сроки разработки проектов. Полученные в работе рекомендации будут оказывать содействие эффективности проектных решений, определять качество проекта в целом и целесообразность его реализации в частности. **Научная новизна.** Приобрели дальнейшее развитие научные подходы к прогнозированию объемов пассажирских перевозок в зоне агломерации, которая тяготеет к ВСМ. Дополнена система критериев оценки целесообразности сооружения ВСМ, которая учитывает транзитные потоки пассажиров через территорию Украины, численность населения в городах, охваченных высокоскоростной сетью, мобильность населения и др. факторы. **Практическая значимость.** Полученные данные могут быть использованы для обоснования концепции развития высокоскоростного железнодорожного транспорта в Украине, формирования сети высокоскоростных магистралей и установления этапов строительства ВСМ.

Ключевые слова: высокоскоростное движение поездов; высокоскоростные магистрали; объем пассажирских перевозок; пассажирооборот; методы прогнозирования; экономическая эффективность

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