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MODELS OF DEVELOPMENT OF THE TOURISTIC POTENTIAL OF THE REGION CONSIDERING INFRASTRUCTURES RAILWAY TOURISM

Abstract

Purpose

The purpose of this article is to create and use models of the optimal formation of the railway transport infrastructure which allow to develop the tourism potential in the region. In this the interests of all stakeholders (tourists, enterprises, businesses, state) are taken into consideration.

Design/methodology/approach

The authors used a complex of mathematical models meant for the optimal investment of the processes of creation and use of the railway transport infrastructure. These models allow to take into account different factors of planning. The specific features of these models are as follows: long-term period of realization of the infrastructure projects, many participants with special interests, which do not always coincide, a lot of factors of uncertainty connected with the choice of quantities of the calculation parameters, etc.

Findings

The authors created economic-mathematical models of the discrete optimal planning of the railway tourism operations. This takes into account conditions of risks and cooperation, and allows to determine sets of effective routes which are most profitable ones, provided they meet the established demands. The latter includes routes which meet maximum criteria of the net costs under the conditions of the established system of demands for the activity of the tourism operators.

Practical implications

The results of the realization of the developed models include the task of the succession of the tourist route introduction according to the present and future infrastructure, availability of the rolling stock, etc. In this, consideration is given to obtaining maximum profit from tourism businesses for every participant during an established period.

Originality/value

The system mentioned above will allow to choose optimal route sets for the railway transport. The application of the developed economic – mathematical models will provide optimization of planning the railway transport development. All mentioned above is due to the optimal regulation of the order of introduction of the railway tourist routes into the sphere of the operators of the railway tourism.

Key words: railway; tourism; tourist route; planning; economic-mathematical modeling

JEL Classification: C35; D61; E27; L83; R15

1. Introduction

Tourism is one of the most fast-developing and highly-profitable branches of world economies. Railway tourism has recently become especially popular among different kinds of people who are partial towards travelling. It is assumed that travelling by railway has some definite advantages compared with other means of transport: possibilities to obtain services of “bed and meals”, good environmental atmosphere, safety, relatively low fares, etc.

Nowadays tourism is one of the most fast-developing, dynamic and manifold branches of business all over the world. The profit of enterprises with tourist services is been fast growing (Aydina, 2016). Rail freightage is tightly connected with tourism, and in many cases rail freightage is multimodal.

Railways of many countries in the world use such service as railway tourism as a sustainable way to receive additional revenues. Travels by train attract both locals and foreigners. The railway excursions in old-fashioned cars on the narrow gauges are very po

pular. Among the successful railway tourist transportations are the following examples.

For example, in the *USA* operates the Georgetown railway, narrow gauge line only 7.2 km long ascends an elevation of 200 meters above the sea level. More than a century it is a very popular tourist attraction. Classic train with old-fashioned cars powered by steam locomotive traction carries passengers, gradually climbing the bridge of 30 meters height.

In *India* operates a narrow gauge mountain railway Nilgiri with a length 46 kilometers, connecting Mettupalayam and Udahanadalam. The travel takes 5 hours when going up and 3 hours when going down. Almost 46 kilometers of the railway pass through 208 turns, 16 tunnels and 250 bridges.

Another famous narrow-gauge railway in the world is the one, on which passes the tourist train «Bernina Express», the route Chur (*Switzerland*) – Tirano (*Italy*). Four-hour journey will bring great pleasure to the passengers, because at the distance of 127 km they face a big height difference.

Talyllyn Railway in *Great Britain* only 12 kilometers long connects Tywyn with the station "Nantes Guernol" that is beyond the village of Abergynolwyn. It was open in 1866.

The railway between *Thailand* and Burma or "Death Railway", which was built during the Second World War is very popular with tourists. More than 100 000 people died during construction of this railway. The length of the route is 415 km. The train when driving is almost pressed against the cliffs and crosses a few shaky wooden bridges. Tourists will get an unforgettable experience during the passage across the bridge over the river Kwai.

In *Serbia* one offers for tourists twice a day train travel "Nostalgia" at the 13-kilometer narrow-gauge railway between the stations Mokra Gora and Sharhan Vitas. During a 30-minute trip tourists will pass through 20 tunnels.

In *Hungary* there are narrow-gauge railways in cities Palhaza, Miskolc, Nyiregyhaza. Narrow-gauge network in Hungary is 380 kilometers. They pass through the mountains and valleys opening to tourists picturesque landscapes.

Railway transport in *Spain* runs on the tracks of four types: Iberian (1668 mm), standard (1435 mm), meter (1000 mm) and narrow-gauge one (914 and 600 mm). The total length of the railway network is about 15.3 thous. kilometers, 1.9 thous. kilometers of which are the narrow gauge railways. For tourists are offered several types of tourist trains from superfast to the regional or local ones.

In *England* at tourists` disposal is the smallest operating narrow gauge railway in the world "Romney", with the gauge only 381 mm. The route from the village Hythe to the settlement Dungeness with eight stations 22 kilometers long is popular among both, locals and foreigners.

The biggest narrow-gauge railway network is in *Japan*. Actually, it is a narrow gauge (1067 mm, the so-called Cape gauge) is the standard here. Thus, it does not work one of the main disadvantages of the narrow-gauge railways. However, the narrow gauge still restricts the speed of trains that is why the high-speed lines Shinkansen have the standard gauge (1435 mm).

In *Argentina* the most famous among the tourists is the so-called "Train to the Clouds," which overcomes the 940 kilometers across the Andes, connecting Chile with Argentina. During the travel the train passes 29 bridges, 21 tunnels and 13 viaducts. At this the train climbs high in the mountains to a height of 4220 meters above sea level.

If we return to the narrow-gauges of the former *Soviet Union*, the most famous is the operating narrow-gauge railway Gulbene – Aluksne in Latvia. In Kazakhstan remained a few short narrow-gauge railways. Kudemsk narrow-gauge railway is one of the few remaining in Russia. It connects Severodvinsk and the village White Lake in the Arkhangelsk region. Tourist train consists of the locomotive and two small cars, as well as two open wooden platforms equipped with seats. The train at a speed 30 km/h passes villages, forests, and lakes. The most of operating narrow gauge railways are located in Belarus. Among the former Soviet republics only in Azerbaijan and Moldova there is not one single remained narrow-gauge railway.

In Ukraine operate only four narrow-gauge railways, located in Transcarpathian region. Restoration of the narrow-gauge railways in Ukraine can be a momentum for attracting investments into potentially attractive type of business, because in the developed world countries the railway tourist transportations bring stable income to the owners of railways. Attracting additional funds will help to renew rolling stock and railway infrastructure, since today, in terms of services provided to passengers, railway transport does not meet the European requirements.

This article mainly concerns the problems of the railway usage as a basis for the development of the tourism potential in the regions. The following factors account for its significance. Firstly, from the historical point of view, railways have been forming and representing the most important social, trade, economic and industrial links among the attractors, “appeal factors” of a region. Secondly, railway transportation is safe and reliable, convenient and comfortable (“a hotel on the rails”) and this means profitability and good environmental conditions. The combination of two mentioned components allows to consider the problems of the development and effective usage of the railway infrastructure as a basis for the growth of the regional tourist potential. The railway tourism (RT), as a rule, operates internally, not internationally. However, in the contempory conditions of globalization the wide and long-term activity area can be created for the international railway transport and multimodal tourism. In our research the most attention is given to the railway transport; as for automobile transport, it is considered as a transfer means – carrying tourists from railways to the places of their interest.

2. Brief Literature Review.

A number of contemporary scientific publications are dedicated to the problems of studying and planning factors that influence tourists’ preferences and their trips (Alam & Paramati, 2016; Stauvermann & Kumar, 2017; Li et al, 2018; Dogru & Bulut, 2018; Khan et al, 2017; Chai et al, 2018).

Methods and means of providing tourism business growth in different regions, tourist's safety, ecological problems, etc, are also widely discussed 8. (Chiang-Ming Chen & Yen-Chien Chen, 2018; Sokhanvar et al, 2018; Wang et al, 2018; MacNeill & Wozniak, 2018; Dutt et al, 2018; Huber et al, 2018; Saleem et al, 2018; Niu & Qian, 2018; Jensen et al, 2015).

At the present moment, a lot of railways are being closed because of less volume of passenger transportation and, consequently, unprofitability (Guerrieri & Ticali, 2011). That is why the problem of the future of the abandoned railways is of great importance (Bertolini & Spit, 1998). In the article (Ferretti & Degioanni, 2017; Ruocco et al, 2017) versions of the railways usage are investigated with the conclusion that one of the best ways out is their re-equipment into the "green zones".

The design of personal tourists' routes plays a fundamental role in improving tourists' travel experiences and the success of tourism attractions. The authors propose a hybrid heuristic algorithm based on random simulation (RSH2A) to design a personalized day tour route in a time-dependent stochastic environment. To evaluate the performance of this algorithm, they conducted a case study at Jiuzhai Valley in Sichuan, China. Their proposed approach has the ability to design more realistic and personalized routes for tourists than previous methods. They designed an experiment to further explore how uncertain environments affect tourists with different levels of risk awareness (Liao & Zheng, 2018).

The formation of the tourist routes with regard to tourists' behaviour and their preferences is studied in (Lew & McKercher, 2006). In this research territorial and linear models are analysed. At the same time much attention is given to the transport accessibility of the tourism objects.

In the paper (Li et al, 2015) the direct dependence is established between the aim of a trip and variants of its realization. The model of the event-oriented simulation is represented which takes into account factors of uncertainty and permits to satisfy the maximum client's demand for the tourist services. At this, the travelling conditions and accommodation, the number of places of interest, travel fares, ways of payment and other factors are taken into account.

The authors define a set of meta models and transformation rules making it possible to obtain automatically a scenario model from the goal model and a business process model from the scenario model. At the same time, they define a mapping rule to formalise these models. Their proposed CIM modelling approach and formalisation approach are implemented with an MDA tool, and it has been empirically validated by a travel agency case study.

For example, in Japan, many local railway lines in regional areas are on the brink of closure due to accumulated deficits. Although railways are generally said to have their own option and non-use values compared with buses, conventional cost benefit analysis does not evaluate these values sufficiently because there have been few quantitative research studies into this issue. In the paper (Utsunomiya, 2018) the author is focuses on three different local railways in Japan, estimates railways' additional value over buses, "premium rate," using CVM. As a result, TLR and OR have their own premium rates to bus-based alternatives by around twenty percent, which could be a little lower-biased data, and WR by ten percent or more.

In the paper (Truong & Shimizu, 2017) the authors also argue that integrating transportation accessibility factors into CGE models will be a crucial factor in future research to properly assess the impact of transportation on tourism.

The book (Conlin & Geoffrey, 2014) investigates, analyzes and elaborates the relationship between railways, heritage and tourism. The book has also taken up the challenge of relating the relationship of railway heritage to tourism, the economy and sustainability. An interesting example is Chapter 5, which explores the connections between railway heritage and cruise tourism. It provides many case examples that help to explain the theoretical and historical significance of the links between railway heritage and tourism

The book (Page, 2009) provides a very useful framework for analysis which sets out the approach to transport and tourism. Here it is extended into an account of how transport plays into and through destination development. Transport offers consumers choices that are expressed in economic (price), cultural (service quality), and also temporal and spatial. The value attaching to these offers are determined by the meanings that customers place on them and the interpretations that these meanings make possible. The future of transport lies in understanding these meanings and the motivations of the potential travellers as the derivation of value will be significantly altered depending on their value systems.

In (Duval, 2007) the author shows how tourism can be linked with the rail transport, and identified two main sub-modes: inter- and intra-destination rail transport. The author studies the relationship between transport and tourism, as well as population mobility under the influence of various factors.

Of great interest for us is research (Yan et al, 2017), which deals with the assessment of the significance of the tourist potential of some heritage objects, the “appeal factors”.

To this purpose two-stage economic-mathematical model is developed. This model takes into account two criteria: (6) the significance of the objects for tourists and the future development of the tourism object. The mathematical model proposed in their study is characterized by different weights allocated to different indicators for tourism potential, based on resource values and development state. Applying the proposed model allows the assessment results of heritage sites to be compared, as the tourism potential of each site is represented by the value (0-1).

The role of “appeal factors” as essential components influencing the choice of tourists’ routes is under the analysis in the paper (Nilnoppakun & Ampavat, 2015). Here the importance of the factors of safety, comfort, entertainment and such like is marked too. The issues of safety, quality of police operation in particular, as one of the main components of the high service level, are represented in the paper (Tyagi et al, 2016).

Moderate fare costs, the novelty of impressions, provision of new services in the trains, safety and comfort typical of railway tourism, are in the focus of attention in the article (Su & Wall, 2009).

The paper (Robson et al, 2018) reviews the full range of CGE models that have been applied to transport issues and discusses their role in transport appraisal. CGE models for transport have been developed in urban, regional and environmental economics as well as other fields, and each field has applied its own theory, assumptions and practices to represent the relationships between transport and the economy relevant to the field. That paper also discusses the general role of CGE modelling in transport appraisal, as well as theoretical and practical concerns regarding CGE modelling practice.

In the paper (Diaz et al, 2017) the authors propose a new mathematical programming model for integrating production and procurement transport planning decisions in manufacturing systems in a unique optimization model. This proposal simultaneously considers material, production resources capacities and procurement transport planning decisions with different shipping modes (such as full-truckload, less-than-truckload and milk-run) in the supply chain to avoid suboptimal results, which are usually generated due to sequential and independent plans.

TIMES-DKEMS is a novel methodology (Salvucci et al, 2018) paving the way for applying elasticities of substitution to incorporate transport modal shift into TIMES (The Integrated MARKAL-EFOM System) models. Substitution elasticities are defined for four transport demand aggregates, each corresponding to a different distance range class. Within an aggregate, modal demands can adjust their levels according to the defined substitution elasticity and in response to changes of their shadow prices relative to a reference case. Results show that in 2050, 11% of car mobility demand is substituted by more efficient and less costly modes such as train and coach.

In the article the authors (Lingaitis et al, 2014) analyzes the methodological aspects of evaluating the social and economic influences of a passenger transport system. Passenger transport by railway is regarded not only as a business but also as a social function. In order to evaluate the relations of passenger transport by railway and the macroeconomic processes of a country or region, the macroeconomic social turnover indicators, that characterize the passenger transport activity, are chosen, the methods of economic statistical analysis are used. The interconnection of passenger railway transport's indicators and Lithuania's macroeconomic indicators are measured by calculation. The topic of interoperability installation in the Lithuanian railways is presented as well, and the benefits and costs of activities of the main stakeholders in railway transportation are projected.

The Yield Management System (YMS) described in the article (Berto et al, 2018) has been developed by IBM for Trenitalia, main Italian and 3rd European railway undertaking, with 24 Million passengers and more than 260 High Speed Trains ("Frecce") offered per day on average in 2017 first half, delivering good results in a period of raising competition. The YMS forecasts the unconstrained demand, using an additive method with an emphasis and a multiplicative correction, to account for censored data, allowing a capacity allocation optimization per Origin-Destination (O&D), and fare cluster. The system has been implemented gradually to most trains "Frecce" at Trenitalia, and since 2005 it has forecasted and optimized approximatively 4 Million model instances: nearly 120 Billion train-date-class-O&D-fare decisions.

Using fuzzy comprehensive evaluation method (Ma & Gao, 2016) the passenger transportation structures before and after optimization are evaluated. The evaluation method is adopted to estimate the passenger transportation structure which is both from optimization model and the actual situation.

A realistic road–rail intermodal transport system can be suitably modeled as a hub-and-spoke (H&S) network for which the parameters are subject to fuzzy uncertainty: demand, cost and time (Wang et al, 2018). For modeling uncertainty, we present a bi-objective optimization formulation for the hub-and-spoke based road–rail intermodal transportation (HS-RRIT) network design problem by taking into account the expected value criterion and the critical value criterion. Using the weighted sum method, we reformulate a single-objective mixed-integer linear programming (MILP) model to solve the equivalent HS-RRIT network design problem.

The paper (Konovalova & Zarovnaya, 2017) presents a mathematic model elaborated to determine expedient investor's shares and probable profits which may be earned from projects associated with improvements of road traffic safety.

The paper (Cranenburgh & Chorus, 2017) is the first to study to what extent decision rules, embedded in disaggregate discrete choice models, matter for large-scale aggregate level mobility forecasts. Such large-scale forecasts are a crucial underpinning for many transport infrastructure investment decisions. Authors show, in the particular context of (linear-additive) utility maximization (RUM) and regret minimization (RRM) rules, that the decision rule matters for aggregate level mobility forecasts. They find non-trivial differences between the RUM-based and RRM-based transport model in terms of aggregate forecasts of passenger kilometers, demand elasticities, and monetary benefits of transport policies.

In the paper (Ozturk & Patrick, 2018) present a decision support framework for the problem of urban freight movement by rail together with mathematical methods for the optimal distribution of goods. The problem we consider has a single rail line on which some stations can be used as loading/unloading platforms for goods. First, they started with the case of two stations for which an approximation algorithm and a pseudo-polynomial dynamic programming algorithm are presented.

The formation of the individual routes is one of the most important tourism issue. In the article (Zheng et al, 2017) the algorithm of forming individual tourists' routes is proposed with the bias on preferences and real tourists' possibilities (e. g. restrictions as for age, health and tiredness). The development of individual routes for separate tourists is analyzed in (Rodriguez et al, 2012). The task is realized with the help of the mathematical model of multi-criteria choice.

In (Palmisano et al, 2016) the model of planning aimed at the choice of the best "green" route is developed with the help of the method of the multi-level hierarchy. At this, 4 groups of the interested people, 7 criteria, and 21 subcriteria of choice are taken into account. This model (Palmisano et al, 2016) with some addition and changes can be used while forming and choosing the best (from the point of view of all the interested sides) tourist routes with the usage of different transport means, railway transport included.

In the article (Barbosa et al, 2018) the factors influencing both individual and collective population mobility are under the analysis. The model proposed by the authors makes it possible to research migration regularities and to foresee volumes and directions of the traffic. In order to analyse the population mobility, the authors propose to use different – sometimes non-standard – ways (with the help of the trajectory of banknotes, mobile operators or GPS devices). The model developed in means constructing a set of streams of tourists' trips with the restrictions of different kinds taken into account. It is stated that people's trips are not accidental, and in most cases can be easily predicted.

The analysis of the literature on the theme allows us to state that interaction of railway and automobile transport is rational both from the point of view of safety and ecology of multimodal travelling. On the continent these kinds of transport are rather convenient and accessible as for the price parameters.

It should be mentioned that in the contemporary scientific literature the problems of formation and development of the tourist infrastructure have not been completely investigated yet. At the same time formation of the new tourist routes which can be attractive for all the stakeholders (tourists, enterprises tourism businesses, and state) is a topical issue nowadays.

Having analysed about 600 tourists railway routes all over the world (Martseniuk & Polyshko, 2016), we have stated the following:

1) tourism is a way to expand man's/women's outlook and life space it improves his/her moral state, being a kind of "antidepressant";

2) for tourists the priority is with the travel safety, then tour fares, the service level; trip duration and others;

3) the popularity of tourist trains does not depend on the width of the gauge;

4) both relatively cheap short-term trips, which cost several hundred US dollars, and long-term elite tours, which cost about twenty thousand US dollars are in demand nowadays;

5) tourists are inclined to visit more advertised tourist objects.

The problems and development methods concerning railway tourism reconstruction and capital repairs of the present railway lines are under the analysis in (Pshinko et al, 2017; Barash et al, 2017). The latter includes construction of the new railways not far from the places of tourists' interest. In those papers the economic – mathematical models of multi-stage discrete planning of railway tourism are developed with due regard for different risk factors. The algorithm of the choice of the regular succession of the tourist routes introduction is used with the aim of the fastest and the most profitable results. The maximum profitability and net value are proposed as criteria of the tourist routes choice (Pshinko et al, 2017; Barash et al, 2017).

The proposed (Pshinko et al, 2017; Barash et al, 2017) economic-mathematical models have passed the approbation period successfully in Ukraine. In those articles some complex issues, which should be solved while developing models, are noted. Taking into consideration some recommendations of the law-abiding character, the complex research is done as for the development of the tourist branch of economy in Ukraine. Firstly, the full revision of all narrow-gauge railways (of 750 mm) has been made in Zakarpatsky region. Secondly, the analysis of the places of tourism and recreation has been performed with the calculation of the visit numbers for year. Thirdly, the tourist rolling stock has been designed, that consists of contemporary carriages of different application. Fourthly, ten tourists routes of different length have been developed for the designed tourist ring. The planning model, mentioned above, is designed for substantiation of the step-by-step introduction of the proposed tourist routes with the aim of the most profitability from their usage.

3. The purpose of the article includes development and future elaboration of the model tourist potential of the region. This should be performed with regard for the formation of the tourist railway infrastructure. Being different from the known models, the content-mathematical models, proposed by us, are designed for the effective development of the tourist business on the basis of formation and application of the railway infrastructure. These models take into account several factors. First of all, some members of the project who are highly interested in it, then long-term period of the infrastructure project realisation, and a lot of factors of uncertainty of different categories, which may be present in the project. As for the grounds for the planning models of tourism development, the following procedures are included: to determine interested parties in the project fulfilment and to establish models of their interaction at the different stages of the project realization; to form tourist routes with the bias on the "appeal factors"; to choose the succession of the "route" introduction (the present and future infrastructure, availability of the rolling stock, etc. are taken into consideration). This should be performed to maximize every party's planned profit from the tourist activity for an established period of time.

4. Results

The issues of the purpose, subject-matter, customers, activities, technical and infrastructural devices, service categories, etc., are investigated in the papers (Zorin & Kvartalnov, 1999; Ilina, 2003; Khojaeva, 2012; Dergoussova, 2012) concerning the railway transport. On the grounds of their analyses it is orated that the railway tourism is a specified kind of tourism, which is realized on the specialized rolling stock according to the established routes and provision of the wide range of services both with the rolling stock and with the infrastructure objects.

The authors propose further development of the purpose exploitation of the railway transport as a separate kind of the economy with the provision of the classification of the main types of the railway tourism: cruise and sightseeing ones, transfer transportation on the wide and narrow-gauge lines.

The authors to construct a «railway tourism ring» in Ukraine on the narrow-gauge line according to the route: «Svalyava-Mukachevo-Irshava-Beregovo-Vinogradovo-Khust-Mizgirya» (Fig. 1).

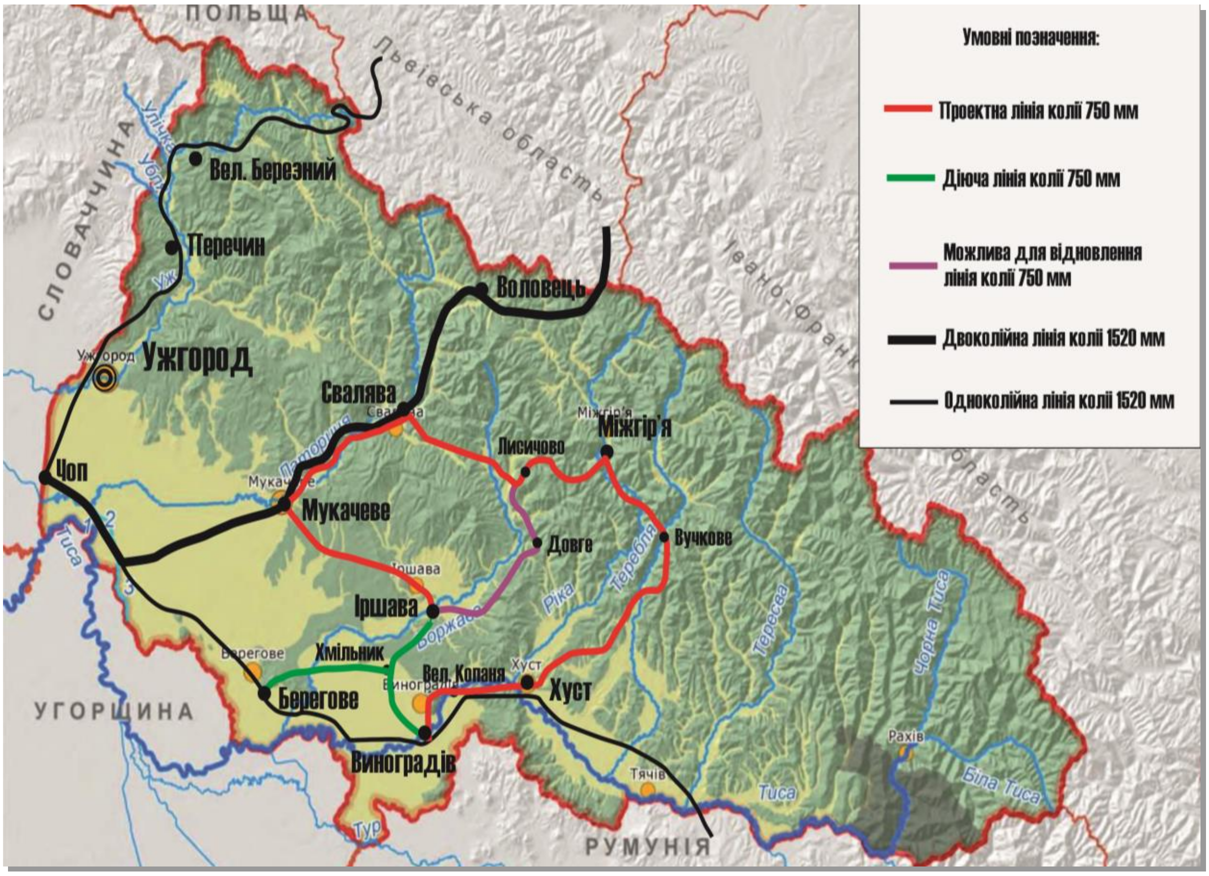

Fig. 1. The scheme of the present and recommended narrow-gauge lines for construction in the Zacarpatsky regions of Ukraine. The source – the author's development.

Statement of the task of the railway tourism formation. The paper is a first one in the railway tourism sphere to put under research a task of making an economic-mathematical model of discrete optimal planning. The latter is elaborated for determining sets of effective routes, which are the most profitable ones while meeting the established system of requirements, that restricts tourist operators' activity. The preconditions of such a task are determined by the following. On the railway polygon there usually exists a track of 62 km long, in addition, it is planned to put 198 km of narrow gauge. Such measures will allow to include into the zone of the tourist railway a majority of tourist objects which are located in the stations of Beregove, Khmelnik, Vinogradiv, Irshava, Khust, Vuchkove, Mizhgirya, Lusuchovo, Svalyava, Mukachevo, Dovge in Ukraine. The main characteristics of the project components are supposed to be known; namely, general cost of the passenger carriages, restrictions as for the general cost of the locomotives, carriages of the first class, carriages of the second class, carriage-buffets, special carriages, rail mobiles (Table 1).

In (Pshinko et al, 2017; Barash et al, 2017) ten variants of the possible tourist routes are developed, as well as train structures and the potential number of tourists on the polygon of the narrow gauge railway, some of them are represented in Table 1. It is supposed that main conditions and restrictions as for organizing tourist activity should be studied. First of all, it concerns the number of potential tourists on the polygon per year. Secondly, the duration of the tourist trip on the route must not be more than 4 days. Thirdly, the maximum number of trips for one tourist train is established depending on the route duration. Besides, the structure of the train is determined, which cannot include more than 7 carriages. Some other output data include costs of trip in different routes depending on the comfort conditions of the rolling stock and expenses per one tourist.

The characteristics mentioned above determine the system of model restrictions for the development of the railway tourism sphere. While formulating a model, the variants of the railway tourist routes are considered to be known. The variants of the categories of the possible solutions should be studied. These depend on the environment conditions and the type of the output information.

Variant B 1. The result of the optimal planning is one route which is the most profitable per year.

Variant B 2. The realization of the one variant choice of the tourist route with all the accounted possible additional expenses because of the project uncertainly. The solution is one route.

Variant B3. The choice of a group of routes (not one), which all together meet resource restrictions. The solution is a group of routes.

Variant B4. The choice of not one but a group of routes which all together meet the requirements for resources with risks taken into account.

Variant B5. Formation of the model of coops of operators (routes), which provides maximum profitability under the condition of routes combination (every route from the optimal group has its own calculated frequency of realization, but the maximum general profitability level is provided). The solution is a group of routes together with the usage frequency.

In the planning model tourist routes (Table 1) are represented by separate binary variables. From the content point of view, the task of the optimal planning includes determination of such variable values which meet the model restrictions and provide maximum evaluation of the profitability index (or another economics index of the tourist activity efficiency).

Table 1.

Variants of the possible routes, train structures and the potential number of tourists

Route number	Route Name	Route dura-tion	Rolling stock					Total after the first stage introduction
			The number of month, units.	Type	The number of units	The number of trips per year.	Coeffi-cient of Usage	
	Svalyava-Lusuchovo-Mizhgirya-Svalyava	1	24	Railmobile	2	300	0,8	11 520
	Svalyava-Mizhgirye-Khust-Lusuchkovo-Svalyava	2	50	Train of 4 carriages (2 carriages of the second class)	2	150	0,8	12 000
	Svalyava- Mizhgirya-Khust-Beregove (one way)	2	64	Train of 5 carriages (2 carriages of the 2 nd class, 1 car of the first class	2	150	0,8	15 360
	Svalyava- Lusuchovo-Mizhgirye-Khust-Vinogradiv-Khmelnik-Beregove-Vinogradiv (one way)	3	56	The train “Pearl of Carpathians” (4 cars of the first class)	2	100	0,9	10 080
	Svalyava- Lusuchovo-Mizhgirye-Vuchkive-Khust-Vinogradiv-Khmelnik-Beregove (one way)	3	100	Train of 6 carriages (4 carriages of the second class)	2	100	0,9	18 000

Source: development of authors

As for the calculation of the potential tourists number, the authors propose different methods for the railways of different gauges. Thus. For the wide-gauge line the authors suggest the use of the following formula:

$$ПКТ = КПТ \cdot K_{поп} \cdot K_{нзі}$$

In this ПКТ is the proposes of the tourist number;

КПТ - the tourist number in the reported year who used any kind of tourism according the state statistic service, in the tourist number;

$К_{поп}$ – the coefficient which includes an annual demand for the railway trips. It is calculated according the result of the anonymous questionnaire.

$К_{нзі}$ – the coefficient which includes the present railway infrastructure as for the tourism objects. This is determined provided the time of the tourist bus transportation is no more than an hour.

The prospective number of tourist who will use narrow-gauge lines can be calculated according the formula:

$$ПКТ = ПКВГ \cdot K_{тур.річ} + ПКПР \cdot K_{пр.річ} + ПКММ \cdot K_{м.річ}$$

In this ПКТ is a prognosis of the tourist number in the railway transportation who will use local hotels, private apartments and railway transfer during the year.

$К_{тур.річ}$ – a prognosis coefficient which includes fluctuations of the tourist number during a year.

ПКПР – a prognosis number of the staff which will work at the tourist object and which will use railway transportation during a year.

$К_{пр.річ}$ – a prognosis coefficient which includes fluctuations of the number of the service staff during a year.

ПКММ – a prognosis number of the locals residents who will use railway transportation during a year; it is determined according to the population number in the zone of the transportation with taking into account a coefficient which included a part of the population which will use this railway, the number of people.

$K_{м.річ}$ – a prognosis coefficient which includes fluctuations of the local residents who will use the railway during a year.

The proposed scientific approach as for determining the prospective number of potential tourists allows estimating long-term amount of the passenger transportation, the structure of the railway rolling-stock, the fleet of rail mobiles and automobile transfers. Nowadays this approach is not present in Ukraine because railway tourism on the narrow-gauge lines is a single character.

The methods of parameter calculation of the economic-mathematical model.

The papers (Pshinko et al, 2017; Barash et al, 2017) represent in detail the methods of determining parameter evaluation in the planning models.

In the methods of parameter evaluation the numeric dependencies are established for characteristics mentioned above which are divided into income and expenses. At the bottom line in the planning model the indices of income (1) and expenses (2) are used, correspondingly

$$P1 = I – E \qquad (1)$$

$$P = P1/E * 100\% \qquad (2)$$

The formation of the models and algorithms of the optimal planning of the tourism activity. We are to analyze the structure formation and models components for planning variant B1 will be determined. On its basis other statesmentsB2-B5 will be formed. Under the conditions of existence of the determined variant B5, tourist routes R1, I E R 1 (Table 1), will be formed. Any kinds of optimal plans realization consist of calculation numbers of indices or any subnumber of routes R1.

We determine binary changes which correspond to any route by $x_i \in \{0,1\}, \left(i = \overline{1, m}\right)$, where т – the total number of tourist routes, and value x_1=1 means a solution as for including a route into an optimal plan. That means that the total vector of planning tasks solutions B1-B6 is as follow

$$\bar{X} = \left(x_1, x_2, \ldots, x_m\right). \qquad (3)$$

To establish connections between a railway and realization of the possibility to serve routes with one and the same rolling stock, we should give a matrix of connections

$$CX = \left[c_{ij}\right] m \times m. \quad (4)$$

In the formula (4) $c_{ij} = 1$ if the corresponding routes are connected, in the opposite case it equals 0. Correspondingly connected (4) routes M_i (directly or as transit by means of other ones) can be served by one and the same rolling stock.

In every route M_i some variants of the tourist activity Z_i are proposed, they differ in duration and service class, which is determined as

$$z_{ik} \in Z_i, \; i \in MI. \quad (5)$$

In the total case for every M_i, sets of Z_i are formed separately. The same concerns calculation of the costs of the tourist service variants

$$s_{ik} \in S_i, \; i \in MI. \quad (6)$$

The matrixes Z_i and S_i fully determine activities of the tourist operators in the route M_i, $i \in MI$.

To form the total model of the tourist activity we give an objective function and tasks of the optimal planning correspondingly

$$\left\{\Phi\left(\bar{X}\right) = R_1\left(\bar{X}\right)\right\} \Rightarrow \max_{X \in G_X}, \qquad (7)$$

in which G_X - an area of allowed routes of plans parameters, determined on the of basis $\bar{X}$ (3). In the criteria (7), $R_1\left(\bar{X}\right)$ corresponds to the index of optimality of the variant *B1*, and $\Phi\left(\bar{X}\right)$ - any other indicator of model of optimal planning.

The restriction system G_X of the model (7) consists of the following conditions of tourist activity provision:

$G_T\left(\bar{X}\right)$ – provision by traction rolling stock;

$G_V\left(\bar{X}\right)$ – carriage park;

$G_C\left(\bar{X}\right)$ – requirements as for the length of the railway tourist routes;

$G_t\left(\bar{X}\right)$ – conditions as for the time restrictions;

$G_I\left(\bar{X}\right)$ – requirements as for the completion of infrastructure;

$G_P\left(\bar{X}\right)$ – investment requirements.

In the general case, requirements G_X are represented in the following way

$$G_k\left(\bar{X}\right) \le 0, k \in \{T, V, C, t, I, P\}; \quad (8)$$

$$x_i \in \{0,1\}, \left(i = \overline{1, m}\right); N_X = 2^m. \quad (9)$$

The economic-mathematical model of the optimal planning of the railway tourism development as a choice of one route from the plurality M_i, $i \in MI$. This provides the largest value of the optimality index (2) under the conditions (3), (7)-(9). The equation (9) determines the general number of the possible variants of plans, among which the optimal one is defined according to the criterion (7).

The model (3), (7)-(9) refers to the category of the discrete mathematical programming; taken with (9), it may be realized by means of comparison. The analytical view of the objective function and the model restrictions are given below. In (Pshinko, Barash, Skalozub, Martseniuk, 2017) profitability is used as an index (2). In the present research the index of the given net cost is analysed.

Models and algorithms of the multi-staged optimal planning of the investment to the to tourist activity.

The set of economic-mathematical models of investment and planning of railway tourism is developed. These models focus on the possibilities of the changes of project realizations, restrictions of the uncertainty factors as risks and investors cooperation as well. First, we are to form the investment model of planning according to variant B1 as a choice of one tourist route from the plurality M1; iΣM1, which is the best as for the index of the given net cost. The equation (9) points the number of the possible plan variants. By means of the choice of the variables (3) this model represents a model of discrete mathematical programming (Ermoliev et al, 1979; Heets et al, 2005; Yakhyayeva, 2008). Taking into account (1), it can be potentially realized by means of comparison. At the same time, the variants of B3-B6 should be taken into consideration. In B3- B6 the route groups, set in order of their preparation, are defined along with the investment provision. Because of such representation of the optimum decision, the linear choice of variants used in (Yakhyayeva, 2008) becomes insufficient in the group decisions.

We are to give an analytical representation of the objective function (index NPV) and the criterion of the choice TM.

$$NPV = \sum_{t=0}^{T} \frac{\left(Д_t - В_t\right)\left(1 - \frac{\gamma}{100}\right) + A_t \frac{\gamma}{100} - K_t}{\left(1 + E_m\right)^t} + R \rightarrow \max, \quad (10)$$

In this NPV is given net cost, (hryvnia.);

D – annual profit that tourist companies can obtain from all kinds of activities in different scenarios, hryvnia.;

Bt – total annual expenses in all kinds of activities in different scenarios, hrv.; before the amortization deductions, hryvnia.;

Y – the value of the income tax, %

A t – amortization deductions;

Kt – annual investments for railway tourist transportation in different scenarios, hryvnia.;

T – the number of the accounted year, t=0,1,2 … (T is a term of the realization of the railway tourist transportation.

17) R – reversion, or investment that gives profit after it has been justified.

E_m – real, or modified discount stake.

In the model the general criterion (7) of the optimum planning takes the form (10); the calculated parameters and restrictions are given below. While forming the algorithm of the realization of the discrete optimization model, the following methods and approaches are proposed: the principle of indict independence on the separate routes (groups of routes) which allows to construct additive calculation models; the requirement as for the connection of the routes on all the railway polygon (provision of the resources concentration, possibilities to perform tourist activity with one rolling stock park).

To form the algorithm of the numerical realization of the model (3)-(6), (7)-(10), the data structure for separate routes is as follows:

$$St_i\left[M_i, Rw_i, l_i, T_i, SP_i(t), Z_i, S_i, RTur_i\right], \qquad (11)$$

In this Mi – tourist route identificator;

RWi – list of the railway hubs belonging to M1:

Li – length of the route;

T_1 – duration of the route;

SP_i (t) – evaluation of the necessary expenses for M introduction before functioning for t period;

Z_1 – variants of realization corresponding to (5);

S_i – variants of calculated costs for tourism service corresponding to (12);

BTur – the planned number of tourists on the route M; *(Table 1)*

We are to study an introduction of every railway route as a project Pr_i(t).

In order to establish the optimal succession of the tourist routes introduction into the development project Pr_i(t), we are to form the following matrix of the economic expediency of the investments and operations in the stages.

$$E(\Pr, t) = \left|e(i,t)\right|. \ (12)$$

In this, elements e (i, t) determine efficiency for (11) project concerning routes M_i, if they start in the period t. It is necessary to stress that in the matrix (12) all the elements e (i, t) are calculated due to the number of realization variants Z+K according to the matrixes Zt, Zik E Zt. That is in (12) the best characteristics of routes, introduction according to the plan are saved. Following the principle of the route independency, matrix rows (12) can be set into order according to the reduction of the efficiency indices e (i, t). Then the matrix of the efficiency of the routes order (12) is used for the formation of the optimal realization variants of the multi-stage investment model of the development of the potential planning in the railway tourism included. In this, the order of routes or the group of routes is determined with the period index t.

The general scheme of the algorithm of the model realization (3) – (6), (7) – (12) for the variant B consists of the following:

1. To determine the initial values of the variables and the evaluation of the objective function.

$$\bar{X}(0) = (x_1 = 0, x_2 = 0, \ldots, x_m = 0); \quad NPV_{1*}(\bar{X}) = NPV_{1\min}; \quad \bar{X}_{opt} = \bar{X}(0).$$

2. To determine the initial values of the calculator of the variants CN $_x$ =0. It is important that the binary representation of the number CN $_x$ gives a variant of the tourist activity realization x; E {0, 1}, (I = 1, m).

3. To generate the number of the order of the variant CNx+1; in case CN $_x$ +1 is more than N $_x$ = M to finish the optimization procedure (p. 9).

4. To form a current vector of activity variants on the basis of CN $_x$. In it the value x_1=1 testifies to the introduction of the route "i" into the current plan (for

B1 the variants with one chosen route are used, numb ($\bar{x}$(i)=1).

5. To determine a calculator of the number of the realization variants for every x1=1, according to the matrixes Zt, Zik E Zt.

6. To calculate the indices of the model (7) – (11), (12).

7. To revise the restriction system (8). In case of non-correspondence to the requirements, move to p. 3.

8. To compare the previous value of the objective function NPV$_1$($\bar{x}$) with the current NPV$_1$($\bar{x}$). With $NPV_{1*}(\bar{X}) < NPV_1(\bar{X})$ to change NPV$_1$($\bar{x}$) to remember x $_{opt}$ = $\bar{x}$. Move to p.3.

9. Delivery of the results of the optimal planning

$$\left\{\bar{X}_{opt}; NPV_{1*}\left(\bar{X}_{opt}\right)\right\}.$$

The given algorithm scheme is used for calculating models of all the representations B1–B6.

As for the content, the simplified algorithm scheme is as follows:

- for the chosen route M; in the matrix (12) the first element e (i, t) is taken; the conditions for the permissible solution (8) are performed;

- the obtained index (10) is compared with the previous one according to p. 8.

The group tasks substitutions the general algorithm scheme is saved, and the plurality of the elements of the optimal route groups is taken into account. That is:

- for generated scheme of the variants according to p. 3, p. 4 the route groups are determined for the revision of the permissibility according to (8), and efficiency according to (10);

- for every project of the railway route Pr_i (t), which is included into the group of the generated variant, the best variants are chosen from (12) according to the order of the efficiency;

- for the variants chosen at the previous stage, the conditions of the permissible solution (10) are revised;

- if in performing the restriction system the result is obtained for the generated variant, the transition to p. 8 should be made. If the variant is not permissible for the plurality of the routes M of the plan variant, in the matrix (12) the next variant as for efficiency realization from the order e (i, t) is determined. The latter in its turn is revised as for permissibility that is the transition to the previous point is made.

Because of the limit of the routes number and the previous order (12), the optimal solution is calculated for the final number of iterations, the algorithm is always finished. We should note that several algorithms can be formed that meet additional requirements in the process of the optimal solution search. They can be formed on the basis of putting routes into order as for their efficiency in the different stages of introduction.

The models of the route choice as for the conditions of risks and cooperation. We are to analyze the task of planning and the choice of the succession of the route introduction in calculating stochastic factors $\theta = \theta_1, \theta_2, \ldots, \theta_s$. That is the plurality of the sporadic states, which determine a certain foreseen scenario of the denial realization (disturbances in the processes of gauge development, purchasing rolling stock, lack of timely investment, etc.) Such planning models can occur under the risk conditions when probabilities (or subjective probabilities) are known concerning possible state disturbances or system parameters; representation variants B2, B4 (Ermoliev et al, 1979; Heets et al, 2005). In forming models in this case for every possible disturbance the denial scenarios V_k are determined, which will be described with the separate template, that is Hk (V_k, H_n, P_k). While modeling optimal planning, the values of the specific parameters of the uncertain conditions are determined along with evaluation of additional expenses H_n.

The latter is necessary for the compensation of disturbances and their probability P_k. The value $\{P(\theta_i)\}$ established by the expert way is considered known. While states θ of disturbances will be determined as ranges $[d_i^1, d_i^2]$ of the values of some deviations of the totality of plan indices,

$$\theta_i = \left\langle \left[d_i^1, d_i^2 \right], h_i\left(\theta_i\right), p\left(\theta_i\right) \right\rangle; \ \sum_i p\left(\theta_i\right) = 1, \quad (13)$$

In this $h_1(\theta_i)$ we ask evaluations or the additive expenses for plan correction under the conditions θ_i, $\theta = \theta_1, \theta_2 \ldots\ldots \theta_3$ and functions of the additional expenses formalize representations of the two-stage tasks of railway tourism planning. The two-stage planning model can be generally presented in the way of

$$\left\{ \Phi\left(\bar{X}\right) = NPV_1\left(\bar{X}\right) + M\left[f_h\left(\bar{X}, Y\left(\bar{X}, \theta\right), \theta\right) \right] \right\} \Rightarrow \max_{X \in G_X}. \quad (14)$$

$NPV_1(\bar{x})$ – the determined function – cost evaluation of the planning vector;

$f_h(*)$ – the function of the additional expenses, which are necessary for plan realization under conditions of θ_i Y(X, θ);

M[*] – the sign of the mathematical expectation while realizing (14) by means of the stochastic programming (Yakhyayeva, 2008) for any $X^1 \varepsilon Y_x$ and for every $\theta_1 \varepsilon \theta$ we should calculate and generalize every P(θ) value $f_h(X_1^1 Y_1^1 \theta)$, which together with ЧDD(x) gives $X^1{:}\Phi(x^1)$, that calculate the quality $X^1 \varepsilon Y_x$ in the two-stage planning (14).

Correspondingly (14), the optimal development $\bar{x}_{opt}$ ensures maximum index of the given net value under the conditions of the expectations of the additional expenses in the disturbances (13) it the processes of railway tourism realization. Other model components and realization algorithm of representation B2 meets (3), (7)–(10), (12).

The models of the choice of optimal routes under the risk conditions and in routes generalized criterion (14) with the aim at the maximum general income. It should be noted that the choice of optimal routes group under the determined parameters or under the risk conditions (variants B3, B4) can be realized if the restriction system is performed simultaneously for all the chosen routes, that is under provision of the routes connection, availability of the rolling stock, infrastructure and such like. Abiding to the principle of independence of the economic indices of the optimal routes, every tourist route of the plan variants is to maximalise its efficiency index, permits to consider the restriction system totally and additively.

In the above given algorithm the model B1 realization can be also used for the numerical realization of representations B2–B6. The latter is provided due to p. p. 3 and 4 of the algorithm, which generate all the possible variants of the route groups.

Because all the representations, analysis models and successions of the railway routes are constructed by means of the simple connection of all the decision variants (5), (6) and resources restrictions (8), the forms of criterion in the determined case BC are as follows:

$$\left\{\Phi\left(\bar{X}\right)=\sum_{k} NPV_{k}\left(\bar{X}\right)\right\} \Rightarrow \max_{X\in G_X}, \quad (15)$$

Under the conditions of risks B4 are as follows:

$$\left.\begin{array}{l}\left\{\Phi\left(\bar{X}\right)=\sum_{k} v_{k}\left(NPV_{k}\left(\bar{X}\right)+M\left[f_{kh}\left(\bar{X}, Y\left(\bar{X}, \theta\right), \theta\right)\right]\right)\right\} \Rightarrow \max_{X\in G_X}; \\ \sum_{i} v\left(\theta_{i}\right)=1. \end{array}\right\} \quad (16)$$

Route numbers are represented with the index K in (15), (16). Those route members are included into the group of the optimal route numbers. All the other planned models (15), (16), which are indicated, save the values, which were established before. It is necessary to note that the model (16) can also be cooperated with the routes (CR) for providing the maximum of the given general net cost. The model CR differs in the frequencies of the trip numbers per year in every route that is included into the optimal group. The frequencies of the trip realization are calculated for the tourism routes in which the maximum general index level is saved NPV (x). In (16) the condition of norming $\sum_i v(\theta_i)=1$ meets those route variants from the variable vector which are included into the optimal plan X opt. The task of the linear programming, as for determination of the optimal number of the separate routes realization, is formed for calculating optimal values of the frequencies $\sum_i v(\theta_i)=1$ It is necessary to choose separate roots in the optimal cooperative plan X opt with the optimal values mentioned above.

Multi-criteria multi-stage planning.

The given planning models of the railway tourism regional development are formed provided there are definite conditions of interests of the united investment center. That is why the maximum values of the total income are represented as optimum criteria. The models mentioned above do not envisage participation in the project and competition with several investors (UH(K)) who are interested in the urgent development of the different tourism routes. We are to consider briefly some problems of formalization of the competition mechanisms and their efficiency analysis. First of all, the given criteria are based on the rule of the external solution of the conflicts among UH (K). In this case, the mechanism of the redistribution of the obtained maximum income is established outside the planning model. The creation and realization of such a mechanism is connected with the solution of many non-formal problems, which are not discussed in this paper. The game principle of the guaranteed result (Zirka, 2014) is offered to be used as a method of conflict solution UH (K), which realize the demand of the equality of the infrastructure investors

$$F_C(V) = \max_V(\theta = \min_k(V_k / D_k)) = \theta_C\,, \qquad (17)$$

where V – is a value of K-investor′s income, and Dn- the volume of their investment. The realization of the planning model with the criteria (17) permits to choose tourists routes and the trip frequencies which provide income UH (K) corresponding to their contribution in the project of the railway tourism development. We are to analyze the numerical realization of the calculation algorithm of the choice of the tourism routes variants in the conventional example (Tables 2-5).

Table 2

The example of the calculation of income in the tourism routes variants.

The results of the calculated net value of the given routes according to the Table 3 and the formula $NPV = -I_0 + \sum (\Pi_k - B_k)/(1+i)^n$ are given in Table 2. In this, *i* is a discount stake, an accepted *i = 11*.

Table 2

The route number	Money flow before and after re-distribution of the annual expenses, in thousands, US dollars	
1	93 081	36 204
7	534 739,53	-143 456,79

Source: development of authors

Thus, the re-distribution of the planned annual expenses and money flows results in substantial changes of the given net value of every project for tourism route development.

Table 3

The route number	I_0	B_1	B_2	B_3	B_4
1	22 478	50 000	50 000	91 000	35 483,2
7	15 000	500 000	500 000	2 000 000	837 737,6

Source: development of authors

Table 3 (continued)

The route number	I_0	Π_1	Π_2	Π_3	Π_4
1	22 478	20 000	27 560	175 000	100 000
7	15 000	500 000	1 128 800	800 000	1 200 000

Source: development of authors

We are to give a conventional calculation as for two-stage models in order to choose an optimal variant. For example, it is necessary to choose a better route from two chosen ones taking into consideration uncertainty of the number of tourists (Table 4).

Table 4

The route number	Expenses, in thousands, US dollars	The number of tourists, people		
		1000–3000	3000–8000	8000–12000
		Certainty=0,2	Certainty=0,1	Certainty=0,7
		Income 1, dollars	Income 2, dollars	Income 3, dollars
1	226 483,2	80 640	161 280	322 560
7	2 839 737,6	907 200	1 814 400	3 628 800

Source: development of authors

Table 5

The route number	The money flow with the account of the uncertainty of the tourists quantity, thousand dollars
1	31 564,8
7	63 302,4

Source: development of authors

The results of calculations in Tables 2 and 5 represent considerable planning possibilities of tourism operators′ activities thanks to the optimal choice of the succession of routes introduction. It should be performed on the basis of the models of the tourism potential development which are proposed in this paper.

5. Conclusions

In this paper the tasks of the development of the tourism potential are solved on the basis of the construction and implementation of the models of the optimal formation of the railway tourism infrastructure. In this, the topicality of the problems of railway usage is substantiated in its aspect as an important component of the tourism potential. The safety and reliability, convenience and comfort, economical and ecological advantages are underlined as significant properties of the railway transport. Moreover, nowadays the tasks of constructing new railway tourism routes are attractive for all the stakeholders (tourists, enterprises, tourism businesses, state).

In this research the elaboration and development of the complex of the mathematical models are performed aimed at the optimal investment into the processes of construction and usage of the railway tourism infrastructure. On the whole, the developed models take into account the manifold planning factors. The peculiarities of these models are as follows: considerations of the long-term period of the infrastructure projects realization, involvement of many parties whose interests do not always coincide, a lot of the factors of uncertainty connected with the choice of the values of the calculation parameters, etc.

The results of our planning models realization include the task of the succession of the railway tourism routes due to the present and future infrastructure, availability of the rolling stock etc, which provide maximum planned income for every participant in the tourism operation for a definite period. The calculation samples, which are represented here, show certain possibilities of the proposed models for the choice of the succession of the railway tourism routes as a factor of the development of the regional tourism potential.

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