Economic and mathematical models of development of the railway tourism

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Abstract. 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. 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. 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.

Introduction

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 [1]. Rail freightage is tightly connected with tourism, and in many cases rail freightage is multimodal. This article mainly concerns the problems of the railway usage as a basis for the development of the tourism potential in the regions.

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 [2-4]. Methods and means of providing tourism business growth in different regions, tourist's safety, ecological problems, etc, are also widely discussed [5-7]. At the present moment, a lot of railways are being closed because of less volume of passenger transportation and, consequently, unprofitability [8].

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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 is a topical issue nowadays.

Results

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

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

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

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.; B_t – 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; K_t – 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); 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 of the optimum planning takes the form (1); the calculated parameters and restrictions are given below.

The data structure for separate routes is as follows:

$$St_i\left[M_i, Rw_i, l_i, T_i, SP_i(t), Z_i, S_i, RTur_i\right], \tag{2}$$

In this M_i – tourist route identificator; RW_i – list of the railway hubs belonging to M1: L_i – length of the route; T_i – duration of the route; SPi (t) – evaluation of the necessary expenses for M introduction before functioning for t period; Z_1 – variants of realization; Si – variants of calculated costs for tourism service; RTur – the planned number of tourists on the route M;

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.

$$E(\Pr, t) = \left|e(i, t)\right|. \tag{3}$$

In this, elements e (i, t) determine efficiency for (2) project concerning routes M_i, if they start in the period t. It is necessary to stress that in the matrix 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.

The general scheme of the algorithm of the model realization for the variant B consists of the following:

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

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

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, ($\bar{x}$ (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. To revise the restriction system. In case of non-correspondence to the requirements, move to p. 3.

8. To compare the previous value of the objective function NPV1($\bar{x}$) with the current NPV1($\bar{x}$). With $NPV_{1*}(\bar{X}) < NPV_1(\bar{X})$ to change NPV1($\bar{x}$) 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.

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 are known concerning possible state disturbances or system parameters; representation variants B2, B4 [9; 10]. 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).

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,

$$\theta_i = \left\langle \left[d_i^1, d_i^2 \right], h_i\left(\theta_i\right), p\left(\theta_i\right) \right\rangle; \ \sum_i p\left(\theta_i\right) = 1, \tag{4}$$

In this $h_1(\theta_i)$ we ask evaluations or the additive expenses for plan correction under the conditions θ_i, $\theta = \theta_1$, θ_2 ...... θ_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

$$\left\{ \Phi\left(\bar{X}\right) = NPV_1\left(\bar{X}\right) + M\left[f_h\left(\bar{X}, Y\left(\bar{X}, \theta\right), \theta\right)\right]\right\} \Rightarrow \max_{X \in G_X}. \tag{5}$$

$NPV_1(\bar{x})$ – 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 $Y(X, \theta)$;

$M[*]$ – the sign of the mathematical expectation while realizing (5) by means of the stochastic programming [11] for any $X^1 \varepsilon Y_x$ and for every $\theta_1 \varepsilon \theta$ we should calculate and generalize every $P(\theta)$ value $f_h(X_1^1 Y_1^1 \theta)$, which together with NPV(x) gives $X^1 : \Phi(x^1)$, that calculate the quality $X^1 \varepsilon Y_x$ in the two-stage planning (5).

Correspondingly (5), 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 (4) it the processes of railway tourism realization. In the above given algorithm the model B1 realization can be also used for the numerical realization of representations B2–B6.

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 and resources restrictions, the forms of criterion in the determined case BC are as follows:

$$\left\{ \Phi\left(\bar{X}\right) = \sum_k NPV_k\left(\bar{X}\right) \right\} \Rightarrow \max_{X \in G_X}, \tag{6}$$

Under the conditions of risks B4 are as follows:

$$\left.\begin{aligned} &\left\{ \Phi\left(\bar{X}\right) = \sum_k v_k \left(NPV_k\left(\bar{X}\right) + M\left[f_{kh}\left(\bar{X}, Y\left(\bar{X}, \theta\right), \theta\right)\right]\right)\right\} \Rightarrow \max_{X \in G_X}; \\ &\sum_i v\left(\theta_i\right) = 1. \end{aligned}\right\} \tag{7}$$

Route numbers are represented with the index K in (6), (7). Those route members are included into the group of the optimal route numbers. All the other planned models (6), (7), which are indicated, save the values, which were established before. 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 (7) 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 [11] is offered to be used as a method of conflict solution UH (K), which realize the demand of the equality of the infrastructure investors

$$F_C(V) = \max_V (\theta = \min_k (V_k / D_k)) = \theta_C \, , \tag{8}$$

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 (8) 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.

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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