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MODEL FOR OPTIMAL PROJECT PORTFOLIO FOR THE CONSTRUCTION OF RAILWAY INFRASTRUCTURE ON CORRIDORS V AND X

ABSTRACT

The construction of railway infrastructure should be dealt with as a national strategic development programme, which — due to technical, geographical, logistical, and other requirements — is carried out through a number of projects and represents a complex multiple project operation for investors, contractors, and other influential players. The national strategic development programme for the construction of railway infrastructure is connected — through programmes in the neighbouring countries and EU member states — to Trans-European networks (TEN) that strategically regulate the construction within the community. In the Republic of Slovenia, the construction of railway infrastructure within TEN programmes is carried out on the pan-European traffic Corridors V and X within individual projects for the construction of sections and a number of supporting projects. The technical requirements, deadlines, and other TEN requirements as well as national strategic requirements and financial possibilities of the state represent the basic criteria that should be taken into consideration in setting up a strategic project plan, with optimal project classification achieved through the implementation project portfolio. The current paper has utilised the method of multiple-criteria decision analysis to prepare the portfolio, taking into account the macroeconomic and infrastructural criteria. Consequently, the results represent the basis for the preparation of an optimal financial plan with regard to financing possibilities of the Republic of Slovenia and the European Union. The paper also summarises the research results regarding the formation of the project implementation process of the TEN-T network construction in the Republic of Slovenia.

KEY WORDS

national strategic development, railway infrastructure construction, railway Corridors V and X, project portfolio, multiple-criteria decision analysis, Republic of Slovenia

1. INTRODUCTION

The construction of railway infrastructure (RI) is a multiple project process as it includes a number of projects or project programmes that should be carried out in accordance not only with the strategies to develop traffic networks in the EU member country that plans and implements the construction, but also with those in the neighbouring countries and of the entire transportation system in the wider area — e.g., the Trans-European network (TEN) — as well as TEN in the Trans-European traffic network (TEN-T) and the Pan-European traffic Corridors [1]. This process requires strategic and multilateral interconnectedness that incorporates a number of factors, ranging from the developmental strategy of this traffic network to technical, environmental, and nature conservation requirements as well as the needs of the economy and population.

For all EU member states and non-member states through which the TEN-T and the Pan-European traffic corridors pass, the process indicates an obligation to prepare national strategic developmental programmes for the construction of RI and to prepare and implement the projects. In trying to fulfil their obligations regarding planning projects for the construction of traffic corridors, new EU member states are facing problems related to national priorities for the construction of traffic systems TEN-T deadlines (e.g., in the Republic of Slovenia, the priority following independence in 1991 focused on building motorway networks, rather than the construction of RI). The consequence of this priority and of the limited financial sources of the Republic of Slovenia has been the delay in the construction of Corridors V and X. Other needed resources for the construction can be assured. This means that the plan of projects including the construction of the railway infrastructure with the emphasis on Corridors V and X, TEN-T should be optimal with regard to the foreseen financial possibilities, the EU requirements, and the national strategic development orientations of the entire traffic system of the country.

2. PAN-EUROPEAN TRAFFIC CORRIDOR AND TRANS-EUROPEAN TRAFFIC NETWORK (TEN-T)

Pan-European traffic corridors include road networks, railway networks, waterways, and combined transportation routes identified during a number of Pan-European conferences according to which the EU authorities adopted decisions and generated strategic developmental documents for the development of this network. The purpose of building pan-European corridors is to connect transportation routes in West European countries (i.e., TEN-T network) with the countries in Central, Eastern, and South-eastern Europe, where pan-European traffic corridors exist. TEN-T sets the guidelines for the building of a network of road and rail links, combined transportation, waterways, and airports.

2.1 EU strategic goals for establishing Trans-European transport network

Strategic goals for establishing TEN-T are designated to facilitate permanent mobility of goods and passengers among member countries of the EU and the neighbouring countries, removing bottlenecks or completing missing links on the main transportation routes of TEN-T, thereby ensuring increased network efficiency and safety primarily by encouraging transportation via railways, inland waterways, and sea transports. The goals related to improved productivity and competitiveness among European businesses on the global market and strengthened economic, social, and territorial cohesion have been emphasised.

Regarding TEN-T strategic goals, the priority tasks include:

- constructing and developing primary and connecting transport links necessary for the elimination of bottlenecks, building missing sections and main traffic routes by emphasising cross-border sections, crossing natural barriers and improving interoperability on the main routes;
- establishing and developing infrastructure in order to improve national networks;
- gradually constructing the interoperable railway network;
- promoting shipments by the sea;
- connecting railway and air transport, especially via railway connections to airports;
- making the best possible use of capacity utilisation and effective existing and new infrastructure, connecting different modes of transport;
- improving safety and reliability of TEN-T;
- including safety and environmental interests in designing and setting up TEN-T; and
- developing sustainable mobility of persons and goods in accordance with the EU goals and with regard to sustainable development.

Countries can obtain funds for the implementation of national programmes and projects on pan-European corridors TEN-T from the EU Cohesion Fund, which was established in 1999.

2.2 Pan-European Corridors V and X

The development concept of the railway network in the Republic of Slovenia relies on the development of the main railway transport axis, represented by Corridors V and X and consequently on the development of the regional railway lines, which are linked with these two corridors. Regarding characteristics of the terrain of the Republic of Slovenia, the national needs as well as the requirements of TEN-T, the base for the strategy of the railway infrastructure construction is the maximal average transport speed, which is 160km/h, the intermodal centres and adequate connections with Corridor V in Koper, Ljubljana and on the entry/exit from Hungary. On Corridor X such centres are both entries/exits from and to Austria and Croatia and the centre of Ljubljana. The priorities of the construction of the railway traffic system are subordinated to these conceptual requirements, not only of lines, but the complete logistically connected system of the state. This requires harmonised planning and implementation of the projects and appropriate financial policy.

Pan-European Corridors V and X pass through the Republic of Slovenia, which include roads, railways, and combined transport, ports, and required infrastructure (*Figure 1*). Pan-European Corridor V connects Italy and Hungary, running through Venice, Trieste/Koper, Ljubljana, Maribor, Budapest, Uzhhorod, Lviv, and Kiev and including four branches—namely, Rijeka–Zagreb, Croatian/Hungarian border–Budapest, Bratislava–Žilina–Uzhhorod, and Ploče–Sarajevo–Osijek–Budapest. Meanwhile, Pan-European Corridor X connects Austria and Croatia, running through Salzburg, Ljubljana, Zagreb, Beograd, Niš, Skopje, and Solun and including four branches—namely, Graz–Maribor–Zagreb, Budapest–Novi Sad–Beograd, Niš–Sofia (Dimitrovgrad–Carigrad via Corridor IV), and Veles–Bitola–Florina via Egnatie. These routes should be taken into account when planning bilateral connections as well as preparing and implementing projects. *Figure 1* indicates the projects for sections with P; the corridor is stated in brackets, marked by V or X. In cases where there are two corridors (V, X), the section of the line is the same for both corridors.

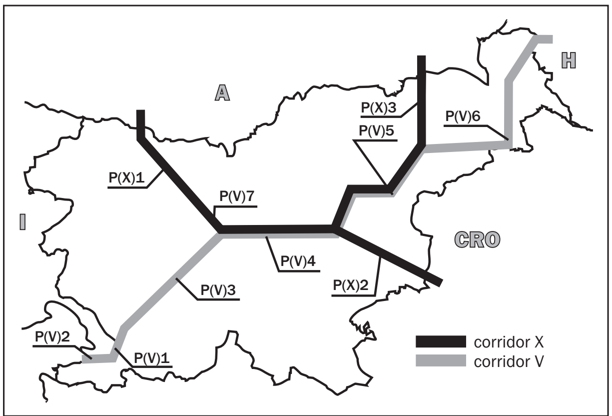

Figure 1 - Pan-European Corridors V and X in the Republic of Slovenia

In order to obtain EU funds, each member country has to ensure its own financial assets and private investments or other financial resources in order to ensure that the project can be carried out in accordance with the TEN-T construction deadlines. Regardless of the possibility of drawing from Cohesion Fund resources, the majority of new EU member states have problems finding their own and other financial resources. Therefore, it is necessary to prepare a comprehensive strategic implementation, which should incorporate the following criteria for project classification:

- deadlines for the construction of TEN-T,
- deadlines for the construction of pan-European traffic corridors within the member states and deadlines for the construction of entrance–exit connections with neighbouring countries,
- strategic financial plan, including national priorities, the state's financial possibilities, EU co-financing, and other financial resources, and
- all criteria to be included in the project preparation and implementation as determined in TENT-T and that comply with national requirements.

It is necessary to prepare an implementation plan based on the optimal project classification for the entire project implementation process for RI construction strategy related to pan-European traffic corridors in the light of these criteria as the basis for the preparation of all implementation plans.

3. PROJECT IMPLEMENTATION OF RI CONSTRUCTION STRATEGY

The process of implementing railway infrastructure construction strategy (RIC) (*Figure 2*) [2] includes the strategy formation phases in which individual projects, project programmes, or project portfolios are determined, together forming multiple project operations. Preparing traffic development strategy should incorporate strategic sustainable inputs, namely, country strategy development and national strategic developmental programmes in the EU member states, strategic-developmental EU documents for TEN and TEN-T, and strategic developmental programmes for the development of traffic in the neighbouring countries.

The execution of the first phase of the strategy project implementation process represents strategic development programmes, which are given different names in practice but should include at least the initial project identification. With regard to RI in the Republic of Slovenia, the national programme for the construction of public railway infrastructure since 1996 included initial validation until 2005 and resolutions to determine further timelines. Project identification represents a record of the initial project stage (e.g., indicative implementation deadlines, estimated project costs and effects, perceived risks, certain technical and technological solutions to be determined, locations for project implementation to be set) as project documents have not been prepared; yet, it is necessary to make a project selection and prepare an implementation plan as well as determine a project portfolio [3], [4], [5]. During the preparation of this portfolio, it is necessary to take into account the following criteria:

- requirements of strategic sustainable inputs, such as construction deadlines, technical and other implementation requirements, environmental requirements, and interoperability;
- limitations, including the ability of the state to finance the project of corridor construction;
- duration of corridor project implementation and supporting projects;
- influential factors that can inhibit or support the project effects on the environment;
- forms of EU co-financing and deadlines for the submission of applications; and
- the influences of entrance and exit corridors to the neighbouring countries.

The next phase in the project strategy implementation process is the preparation of the project start-up to the level where it becomes possible to initiate project implementation according to the strategic project plan. Prior to the formal implementation, a new project portfolio is likely to be prepared due to the increased level of project concretisation, because of possible new conditions for project implementation, or - last but not least - due to changes that have occurred. This may result in a resolution of the national RI development programme (if it coincides with the end of the period of validity of the previous national programme). Following approval, a decision is made regarding whether a suitable law is needed for the construction of the corridors; if yes, the project for the preparation and adoption of the law is initiated, followed by further preparation tasks usually financed from the budget or EU funds.

Due to the changes that may appear when obtaining appropriate financial funds, carrying out the preparation tasks, and/or dealing with influential factors and changes in national development strategies, it is likely to become necessary to review the strategic and financial plan, thereby necessitating a new project portfolio formation. This refers to a dynamic implementation project portfolio. In order to manage the process of project implementation of RI construction, integral controlling should also be introduced.

The project of the railway infrastructure construction requires a reorganisation of the Slovenian railway system, which is in the phase of implementation. The aim of this reorganisation is to assure successful implementation of the projects, which refer to Corridors V and X as well as of other projects, which proceed from the national programme. The completion of the project organisation at the level of the Ministry of Transport is being implemented in the sense of a special company. It will assure better strategic and project decision-making on the level of the Government of the Republic of Slovenia as well as the designing and implementation of the Act on construction of Corridors V and X. Therefore, this requires the most suitable plan of projects, regarding the foreseen financial possibilities of the Republic of Slovenia. It deals with the project portfolio, which is the result of this research. Parallel to this, the reorganisation of SŽ – Slovenian Railways, which are at the moment the only national railway carrier, is in

Table 1 - Project data for the construction of Corridors V and X

Project description	Projects on corridors	Length of project sections		Duration of project documentation (years)		Duration of building	Total project value
				Cost (mio EUR)		Cost	
Corridor V Corridor X	Junctions	km	% length	DPN	PGD	G-O	value (mio EUR)
P(V)1	Koper-Divača (KP-DV)	27	8	4	3	5	1,200
				21.6 mio	86.4 mio	1,092.00	
P(V)2	Trst-meja- Divača (TS-SLO)	12	4	4	3	5	800
				14.4	57.6	728 mio	
P(V)3	Divača-Ljubljana (DV-LJ)	95	29	3	2	8	1,840
				30 mio	170 mio	1,640 mio	
P(V,X)4	Ljubljana-Zidani Most (LJ-ZM)	45	14	5	4	9	1,300
				20 mio	100 mio	1,180,00	
P(V,X)5	Zidani Most-Pragersko (ZM-PR)	65	20	4	3	10	700
				12 mio	51 mio	637 mio	
P(V)6	Pragersko-Ormož-Murska Sobota (PR-MS)	80	25	3	2	6	230
				4.0 mio	16.0 mio	210 mio	
	Total Corridor V	324	100				6,070
P(V)7	Ljubljana-vozlišče (LJ-VZ)	10		4	2	5	710
				12.8 mio	51.2 mio	646.00	
P(X)8	Jesenice-Ljubljana (JE-LJ)	62	36	3	3	8	700
				12 mio	51 mio	637 mio	
P(X)9	Zidani most –Dobova (ZM-DOB)	51	30	5	3	6	700
				12 mio	51 mio	637 mio	
P(X)10	Maribor- Šentilj (MB-SEN)	12	7	3	2	5	200
				3.6 mio	14.4 mio	182 mio	
	Total Corridor X	170	100				2,310

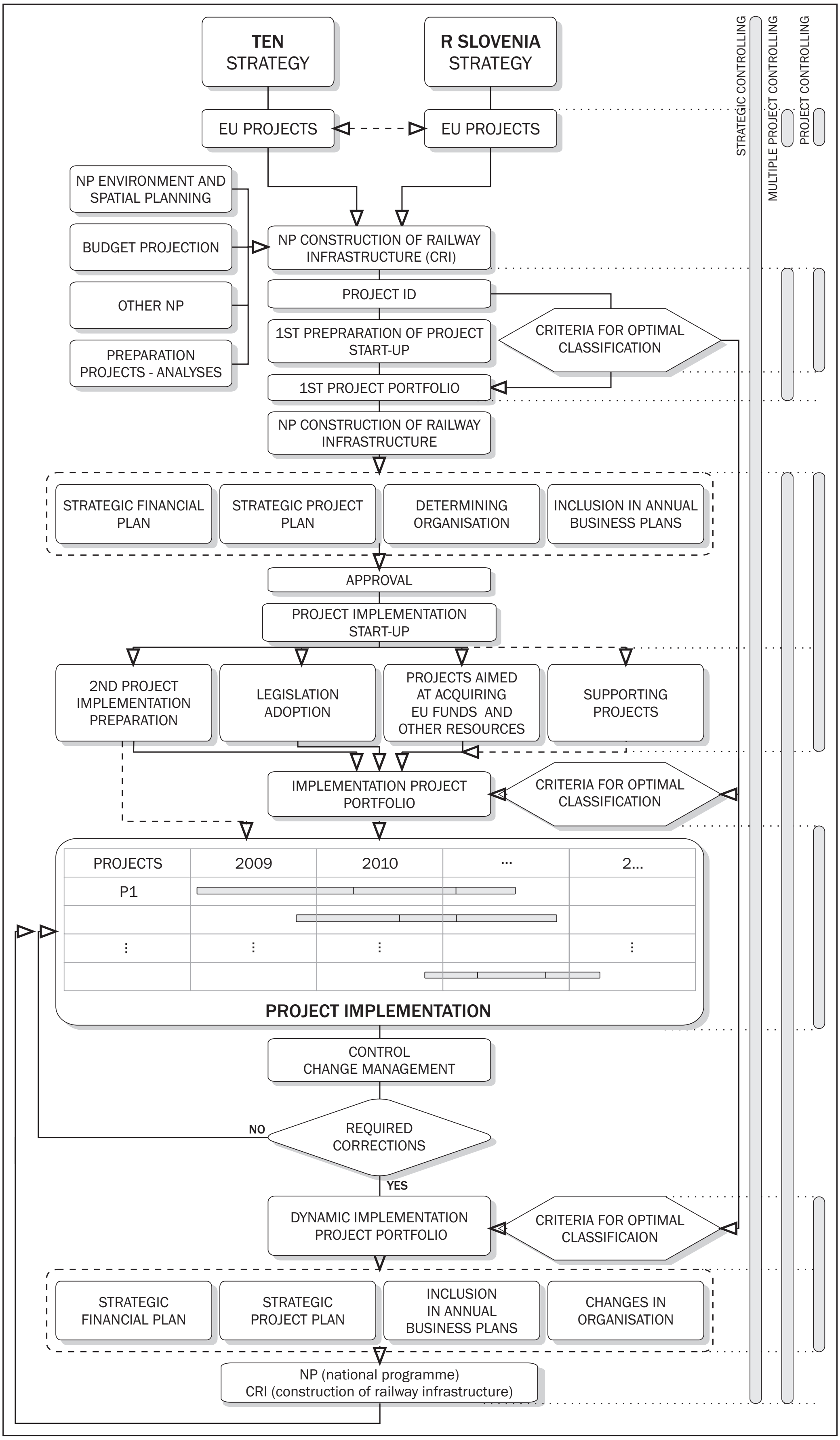

Figure 2 - Process of project implementation of railway infrastructure construction

implementation, with the aim to insure the improvement of the economic operation of SŽ and the fulfilment of EU directive.

4. PREPARATION OF THE PROJECT PORTFOLIO FOR CORRIDORS V AND X IN THE REPUBLIC OF SLOVENIA

4.1 Pan-European traffic Corridor V and X projects

Data from the first project identification in the national programme for the construction of railway infrastructure are shown in *Table 1*. By taking into account the European and national legislation referring to the implementation of RI construction projects, the projects can be divided into specific phases—namely, for the preparation of studies and the national spatial plan (DPN), the preparation of project documentation for obtaining building permits (PGD), and the building of railway lines and initiation of service via the lines (G-O). The duration of project phases are estimates, supported by the analysis of the complexity of project implementation according to established sections and by comparisons made with similar projects previously implemented. The cost assessment was determined according to prior project documentation and comparisons with similar projects. The construction of both corridors should be completed by the end of December 2026 in light of the initial presumption that financial resources have been ensured and that all projects can be implemented simultaneously according to the determined phases (*Figure 2*).

4.2 Project portfolio for the construction of corridors

The preparation of the first project portfolio for the construction of Corridors V and X should take into account the deadlines, technical and other requirements, strategic goals of TEN, TEN-T, strategic goals of the Republic of Slovenia, and financial possibilities. It should be carried out in the following steps:

- project identification and evaluation of the costs and duration;
- classification of projects according to their contribution towards the achievement of strategic goals;
- portfolio preparation.

4.2.1 Project identification

The construction of Corridors V and X in the Republic of Slovenia will be implemented through ten projects, as shown in *Figure 1* and presented in *Table 1*. The costs and duration of each project phase have been evaluated based on the assumption that the required financial funds are ensured; in other words, this discussion speaks of the "ideal" project portfolio. *Figure 3* presents the Gantt chart for this "ideal" project portfolio. According to the schedule, if all projects started on January 1, 2009, both corridors would be finished by December 31, 2026. Project P(V,X)4 lies on a critical path.

Total project portfolio costs amount to 8,380 million euro. The project portfolio costs in year t were calculated as follows:

$$S_t = \sum_{j=1}^{n} s_{jt} \quad t = 1, \ldots, k \qquad (4.1)$$

where S_t represents project portfolio cost in year t and s_{jt} is the cost of project j in year t. Funds provided for the construction of corridors by the EU, in the amount of 50 percent of the planned or real costs for the implementation of individual projects, are realised a year after each phase ends. EU funds received during the project implementation are successively used for subsequent project financing. According to the schedule provided in *Figure 3*, DNP phases of seven projects will be finished within the first three years. Thus, the initial EU funds of 49.2 million EUR will be transferred to Slovenia in the fourth year (2012). As evident in *Table 2*, relatively substantial financial assets are needed between 2015 and 2019, indicating that it will not be possible to carry out the "ideal" project portfolio.

Table 2 - Annual cost plans for the "ideal" project portfolio (in mio EUR)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Cost	34.2	42	42.2	187	215	410.6	735	878	1068	1240
EU funds	0	0	0	49.2	6	116.2	123.1	25.5	25.5	50
Necessary funds	34.2	42	42.2	137.8	209	294.4	611.9	852.5	1042.5	1.190

	2019	2020	2021	2022	2023	2024	2025	2026	2027
Cost	1145	546	586	344	225	225	267	190	0
EU funds	91	1338	0	820	637	0	0	318.5	929.795
Necessary funds	1.054	0	0	0	0	0	0	0	0

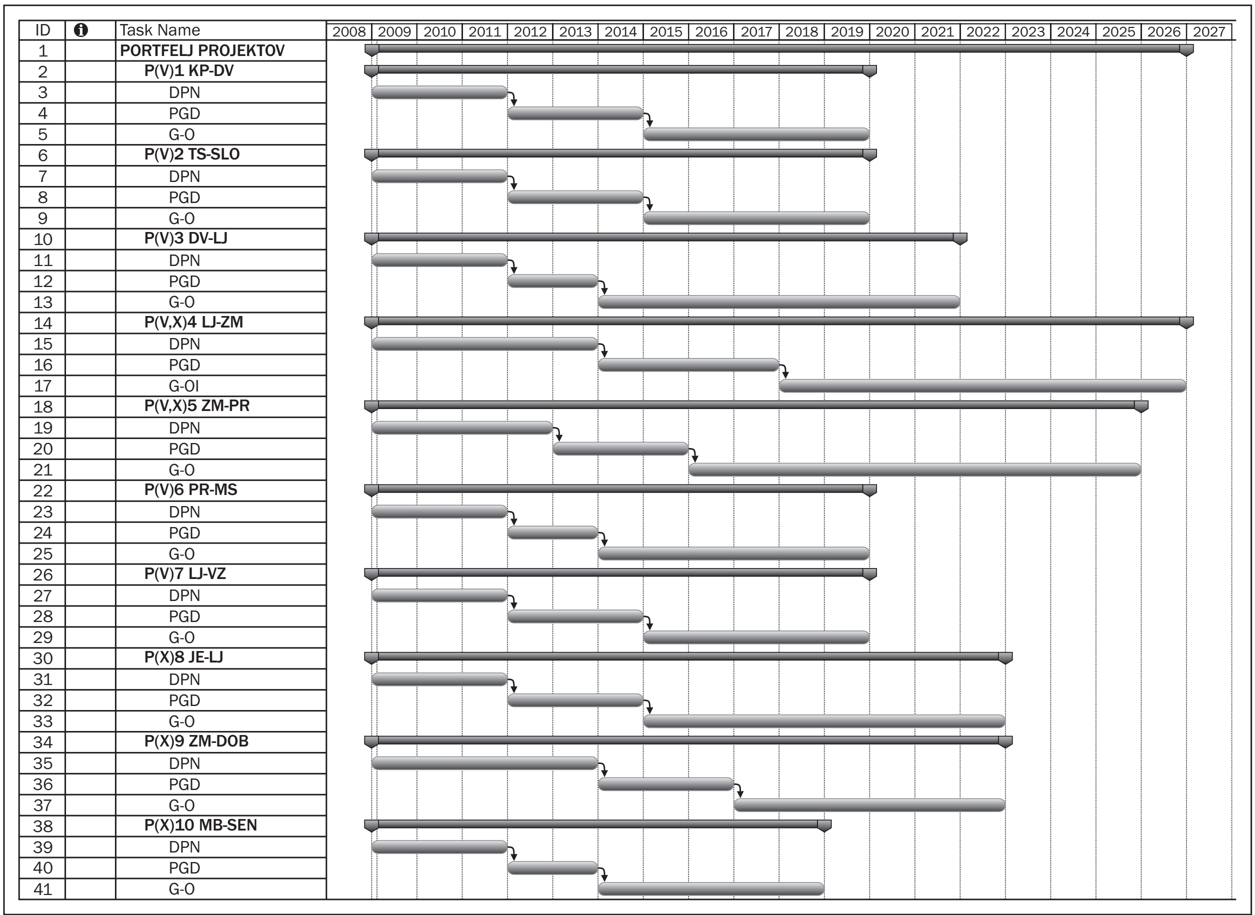

Figure 3 - Gantt chart of the "ideal" project portfolio

4.2.2 Project prioritisation

Decision-making often involves multiple—sometimes conflicting—objectives and/or criteria, creating a situation called multi-criteria decision-making (MCDM) [6]. Various multi-criteria decision analyses (MCDA) have evolved in response to the inability of people to analyse multiple streams of dissimilar information in a structured way. MCDA involves choosing from a number of alternatives based on how well those alternatives rate against a chosen set of objectives as well as subjective criteria.

The simple multi-attribute rating technique (SMART) and analytical hierarchy process (AHP) are two major types of MCDM techniques, differing primarily in the way in which data are gathered from the decision makers. Developed by Saaty [7], AHP provides a flexible and easily understood method for analysing complicated problems. Meanwhile, SMART is a multi-criteria decision-making tool in which ratings of alternatives are assigned directly, using natural scales of criteria. In order to keep the weighting of criteria and the rating of alternatives as separate as possible, different scales of criteria need to be converted to a common interval scale, which the decision maker does mathematically by means of "value function". The simplest choice of a value function is a linear function, which is sufficient in most cases [8]. AHP has several drawbacks - it is, namely, much more time consuming than SMART method and involves "rank reversal" [8]. Judgments in AHP are relative by nature; changing the set of alternatives may change the decision scores of all the alternatives. The SMART model, however, is independent of the alternatives. Since the ratings of alternatives are not relative, changing the number of alternatives considered will not in itself change the decision scores of the original alternatives, which is particularly useful when new alternatives or features are added to the existing comparison [9].

Goodwin and Wright [10] suggested the following steps in MCDA (*Table 3*):

Table 3 - Steps in MCDA

Model structuring	Data collection
identification of alternatives	preference elicitation
determination of relevant criteria for the decision problem	synthesis sensitivity analysis

Model structuring

The first step in MCDA is the formulation of a decision problem in the form of a hierarchical structure.

Table 4 - Description of criteria and attributes

Criterion	Attribute	Description
Macroeconomic criterion		Includes attributes that have a decisive influence on reaching strategic and implementation requirements for the construction of TEN-T network and represent the priority in determining the strategic project plan for the construction of corridors and for making decisions regarding optimal project ranking by taking into account the deadlines for the construction of TEN-T and financial possibilities of the Republic of Slovenia.
	Freight	Corridors should meet the needs of increased freight in TEN-T network, which have been assessed in a number of studies and forecasts. This is especially true if freight services will be directed to railways.
	Speed	Corridors must ensure a minimal speed of 160 km/h for cargo and passengers.
	Safety	High level of security should be ensured according to all normative documents of TEN-T network, emphasising ensuring level crossings of road and railway infrastructure.
	Costs	Project costs (cots of studies, research, spatial and project investment documentation, and construction) serve as the basis for the preparation of strategic financial plans and have an important influence on ensuring financial resources of the Republic of Slovenia and EU funds.
	Length	Projects ensure the construction of certain corridor sections differing in length with regard to the entire corridor length. Geographical characteristics and construction complexity are also taken into account.
Infrastructural criterion		Includes attributes such as input requirements for individual projects and represents the basis for efficient achievement of objectives in constructing TEN-T network through the Republic of Slovenia.
	Double track	The construction of TEN-T network envisages short transportation time and safety, which can only be reached through the construction of double tracks.
	Corridors	Only some projects or both are part of Corridors V and X, ensuring rationalisation and impacting costs.
	Electrification	TEN-T network seeks to promote electrification, which should be taken into account when constructing corridors in the Republic of Slovenia.
	Documentation	The start-up and implementation documentation for certain projects has already been prepared, which thereby contribute towards meeting deadlines.

The procedure is initiated with the identification of alternatives - in the current case, the identification of projects of construction railway connections on Corridors V and X. The next step involves identifying criteria relevant to the decision problem. A group of engineering experts in RI construction identified two criteria - macroeconomic and infrastructural (*Table 4*).

The group of experts from the Ministry of Transport and of the external experts and project organisations have prepared the study Reconstruction and the new construction of railway lines in direction of Corridors V and X in the Republic of Slovenia, 2006 [11] and on this base they have identified five macroeconomic attributes:

- expected increase of transported freight (abbreviated as Freight);
- increase of speed (Speed);
- safety improvements (Safety);
- construction costs (Costs);
- length of railway connection (Length).

The infrastructure criteria proceed from the goals of the construction of TEN-T and the goals defined by the national programme by solving actual bottlenecks, which result from technical characteristics of the line as are the radii of curves, cross and longitudinal inclines of the line which today do not allow higher speeds than 70-80 km/h, further on the bottlenecks of level crossings of road and railway traffic and inadequate axle loads. Between the infrastructure goals also the use of the existing railway line alignments for the needs of both corridors have to be included as well as the capacity of the line for the load of up to 225kN/axle for the average speed of 160km/h. The attribute, regarding the documentation for the starting of the projects is very important, mostly because of the lack of time, which is the result of the previous delays after the time schedule of TEN-T.

From among the infrastructural attributes, the experts chose four for prioritisation (a detailed explanation is given in *Table 4*):

- Double track (Double track);
- Corridor (Corridor);
- Cost of electrification (Electrification);

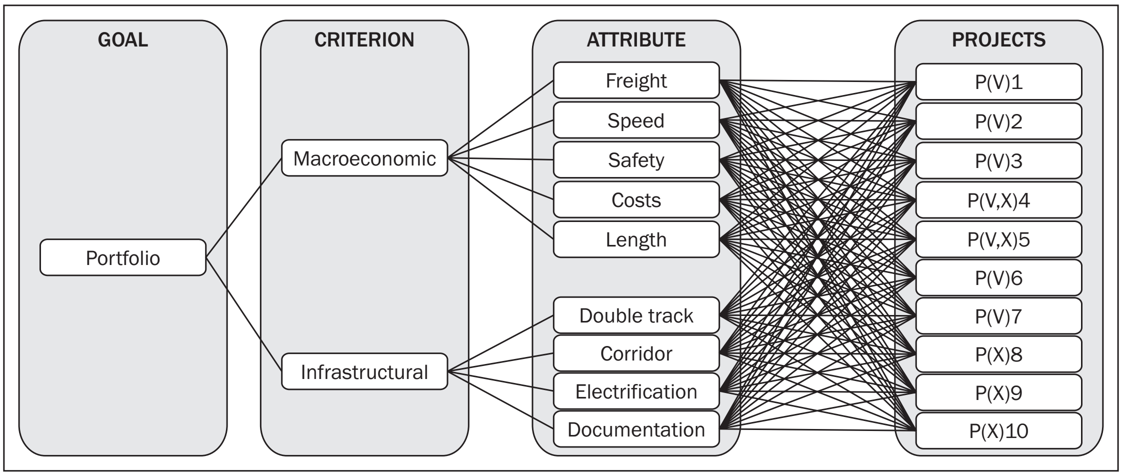

Figure 4 - Hierarchical tree for the decision problem related to the optimal project portfolio

– The level of documentation elaboration (Documentation).

Based on the identified criteria, attributes, and alternatives, a hierarchical tree can be constructed. In a typical hierarchy, the tree root reflects the overall objective related to the decision problem. The elements affecting the decision are presented at intermediate levels. The criteria are shown on the first intermediate level, whereas attributes are shown on the second intermediate level. Alternatives are shown on the lowest level. The hierarchy tree for the decision problem in searching for the optimal project portfolio is presented in *Figure 4*.

Preference elicitation

This step focuses on eliciting the relative importance of the criteria and attributes shown on the hierarchy tree. Various methods exist to support the elicitation of preferences, such as those developed by von Winterfeldt and Edwards [12] and Weber and Borcherding [13]. This study used the SMART method along with the SWING technique. A group of experts first assessed the importance of macroeconomic and infrastructural criteria with respect to the main goal as well as the importance of macroeconomic and infrastructural attributes with respect to macroeconomic and infrastructural criteria, respectively. The experts introduced an interval scale from 0 to 100, where 100 points are first given to the most important criterion and then less than 100 points are given to other criteria with respect to the most important ones. The same procedure is applied for the assessment of the importance of attributes. The value scores are provided in *Table 5*.

As the importance of the criteria was assessed using a direct method, the weights were calculated by dividing the individual criterion's value score by the sum of value scores for all criteria. The weight of the macroeconomic criterion is 0.588 (100/170); for the infrastructural criterion, it is 0.412 (70/170). In the same way the weights of attributes (i.e., local weights) were calculated. The local weight of the attribute 'freight' was 0.2 (80/400). The sum of local weights of macroeconomic attributes equalled 1. The global weights were also calculated for attributes, which were obtained by multiplying the local weight by the parent criterion's weight. The global weight of the attribute 'freight' was 0.118 (0.2*0.588). The sum of the global weights of all attributes equalled 1. *Tables 5* identify the values of the local and global weights.

Table 5 - Relative importance and local and global weights for criteria and attributes

Criterion	Attribute	Value score	Local weights	Global weights
Macroeconomic criteria		100	0.588	0.588
	Freight	80	0.200	0.118
	Speed	100	0.250	0.147
	Safety	70	0.175	0.103
	Costs	100	0.250	0.147
	Length	50	0.125	0.074
Infrastructural criteria		70	0.412	0.412
	Double track	100	0.345	0.142
	Corridor	80	0.276	0.114
	Electrification	60	0.207	0.085
	Documentation	50	0.172	0.071

The values of the projects, with respect to the macroeconomic attributes, were measured on a ratio scale. The decision makers often find it difficult to assess the importance of alternatives' values according to the ratio scale. In such cases, a value function with the lowest and highest values can be applied to convert the ratio scale to a common interval scale from 0 to 100. The lowest and highest function values are usually determined using the lowest and highest attribute value. A decreasing linear function was applied to rank projects' values against the macroeconomic attribute 'construction costs' and an

Table 6 - Results of decision analysis and ranking of projects

Rank	Project (alternative)	Overall performance	Performance	
			Macroeconomic attributes	Infrastructural attributes
1	P(V)6	0.741	0.395	0.346
2	P(X)8	0.516	0.302	0.214
3	P(V)1	0.507	0.246	0.261
4	P(X)10	0.492	0.282	0.210
5	P(V,X)5	0.378	0.264	0.114
6	P(V)2	0.365	0.260	0.105
7	P(V)7	0.330	0.209	0.121
8	P(V)3	0.325	0.234	0.091
9	P(V,X)4	0.310	0.196	0.114
10	P(X)9	0.309	0.241	0.068

increasing linear function for the remaining macroeconomic attributes. The importance of projects' values with respect to the infrastructural attributes was assessed using the SWING technique on the interval scale from 0 to 100.

Synthesis

The synthesis step involves obtaining the overall performance score of the project (alternative). It is usually evaluated as:

$$v(a) = \sum_{j=1}^{n} w_j v_j (s_j(a)) \tag{4.2}$$

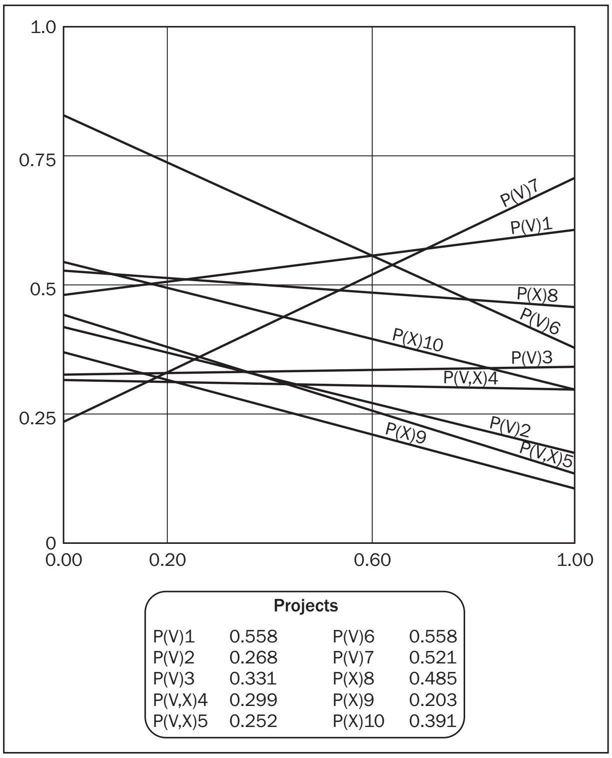

Figure 5 - Sensitivity analysis for the weight of the attribute 'freight'

where $1 \leq j \leq n$ and n is the number of considered attributes, $s_j(a)$ denotes the score of alternative a with respect to attribute j, $w = (w_1,...w_n)$,

$$(\sum_{j=1}^{n} w_j = l, w_j \geq 0 \text{ for all j})$$

is the weighting vector, and $v_j(x)$ $(z\ x = s_j(a))$ is the value function used to evaluate the performance of alternative a with respect to attribute j. The MCDA tool Web-HIPRE was applied to obtain the projects overall performance score. Web-HIPRE provides methods for structuring and analysing decision problems by means of attribute trees and eliciting the relative importance of criteria attributes in such a tree [14].

Table 6 defines the rank order of the Slovenian projects for Corridors V and X with respect to the projects overall performance. In addition to the overall performance, the projects performance with respect to the macroeconomic and infrastructural attributes is also identified. The results indicate that project P(V)6 ranked first according to its highest overall performance (0.741), followed by projects P(X)8 and P(V)1. Project P(V)6 also had the highest performance with respect to macroeconomic and infrastructural objectives.

4.2.3 Sensitivity analysis

It is also important to analyse the robustness of the overall priority rating according to the overall performance of the ten ranked projects, which also sets the order of project implementation. If the sensitivity analysis indicates that the ranking of alternatives is very sensitive to changes in weight, the decision makers should carefully check if the weighting accurately reflects their preferences [6]

The sensitivity analysis indicates that ten projects can be classified into three homogenous groups regarding their ranking sensitivity. The first group consists of only one project - project P(V)6, with an overall performance of 0.741 - although its first place is sen-

Table 7 - Annual cost plans of the project portfolio for the construction of corridors (in mio EUR)

	2009	2010	2011	2012	2013	2014	2015	2016
Cost	13.2	14.2	13.8	68.01	74.8	131.2	286.99	419
EU funds	0	0	0	20.6	0	15.2	82.3	6
Budget	13.2	14.2	13.8	47.41	74.8	116	204.69	413

	2017	2018	2019	2020	2021	2022	2023	2024	2025
Cost	422.8	695	786.86	570.14	707	648	306.84	386.16	466
EU funds	0	54.4	131.5	651	101	0	1005.5	25.5	50
Budget	422.8	640.6	653.36	0	525.14	648	0	0	78

	2026	2027	2028	2029	2030	2031	2032	2033	2034
Cost	481	480.8	523.2	207	150	150	190	190	0
EU funds	0	0	0	1138.5	318.5	0	0	0	590
Budget	481	480.8	523.2	0	0	0	0	0	0

sitive only to the change of the attribute's weight 'expected increase of transported freight'. Increasing this weight by more than three times would push project P(V)6 to the second place (see *Figure 5*).

Projects P(X)8, P(V)1, and P(X)10 are included in the second group as small changes in the attributes' weights would change their rankings. For the same reason, the remaining six projects are classified in the third group.

4.2.4 Implementation of the project portfolio for corridor construction

By considering the project prioritisations in three homogenous groups as well as the necessary financial

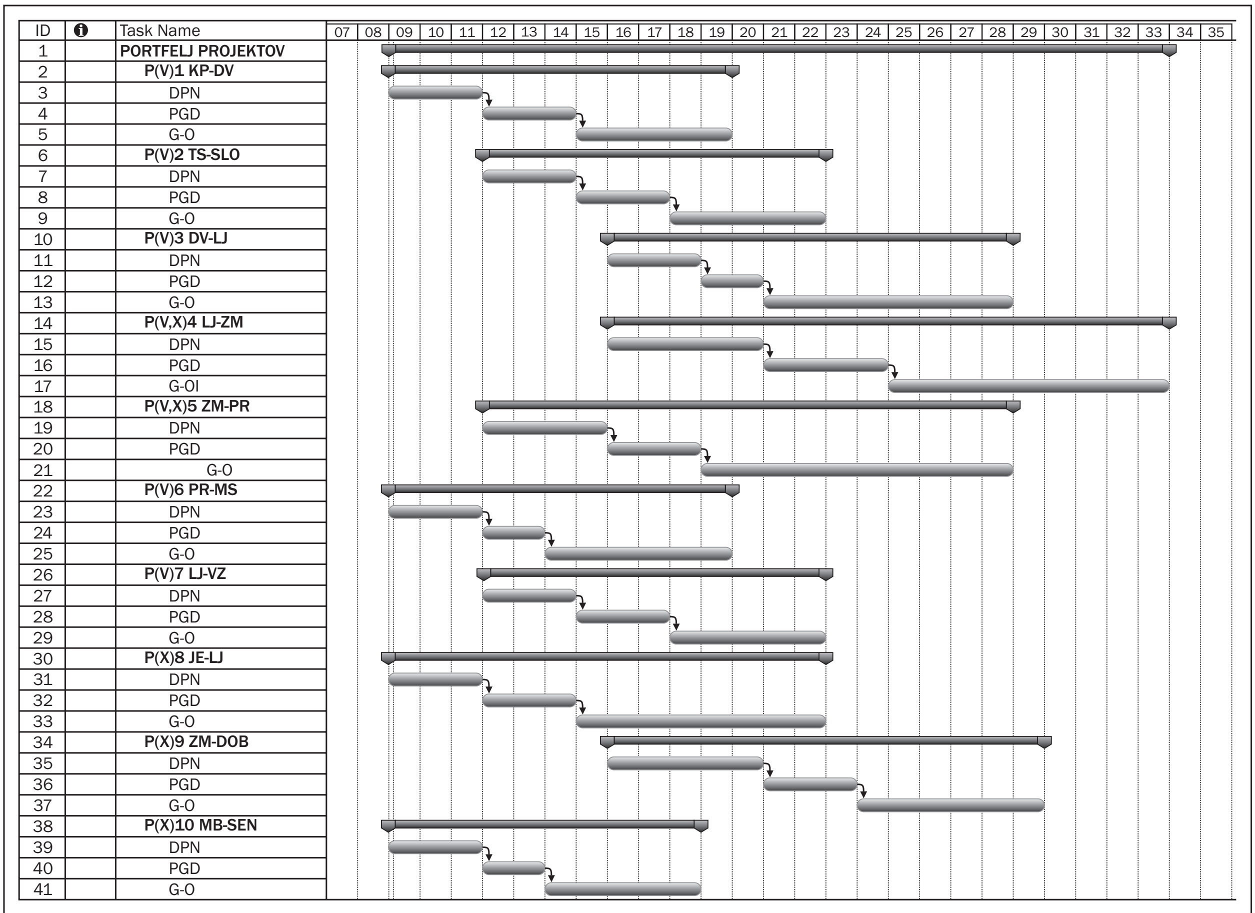

Figure 6 - Gantt chart of project portfolio

assets for financing the portfolio and its deadline, the project portfolio implementation for the construction of Corridors V and X in the Republic of Slovenia can be planned in three stages:

– Stage I includes projects P(V)6, P(X)8, P(V)1, and P(X)10.
– Stage II includes projects P(V,X)5, P(V)2, and P(V)7.
– Stage III includes projects P(V)3, P(V,X)4, and P(X)9.

Due to the deadline for the completion of the portfolio set by the EU - namely, 2024 - the first stage includes projects from the first and second groups. As the available financial assets will be limited, the second stage includes only the first half of the projects from the third group, whereas the other three projects are included in the third stage.

The implementation of projects from the first stage started on January 1, 2009. The second stage will start after the completion of the DPN phase of the projects from the first stage; the third stage will start after the completion of DPN of the projects started during the second stage. Considering the described interdependencies among the projects and their phases, both corridors should be completed by the end of 2033 (*Figure 6*). The annual cost plans are presented in *Table 7*.

As the financial plan indicates, a surplus of funds occurs at the end of the last project implementation in 2034 due to the payment arrangements for assets acquired from the EU funds. This surplus can have an important effect on the Republic of Slovenia financial plan, especially in its efforts to secure loans and prepare the national budget to ensure the financial resources needed. The project portfolio in the implementation plan and financial plan is in the process of project implementation of railway infrastructure construction (*Figure 2*), denoted as "first project portfolio".

5. CONCLUSION

The research has established that the construction of Corridors V and X represents a complex investment cycle for the Republic of Slovenia as it requires the preparation of project implementation by taking into account the strategies of TEN, the macroeconomic and infrastructural goals, the limited financial assets, the deadlines for the construction of TEN-T, the rules of EU co-financing and standard processes of project implementation. The existing experience and results in infrastructural development in the Republic of Slovenia show that previously the country had not developed an integral approach that would include, from its initial stage, the portfolio for further decision-making in the process of project implementation of infrastructure construction. The result of the research is a model for optimal project portfolio for the construction of railway infrastructure on Corridors V and X in the Republic of Slovenia. It includes:

– the process of project implementation of railway infrastructure construction,
– the classification of projects according to their initial strategic, macroeconomic and infrastructural goals,
– the preparation of financial plans which include EU co-financing.

The described methods applied in designing the portfolio of projects allow planning of the project costs and scheduling also for new alternatives needed in case of delays and increase in costs during the project implementation and even in case of changes of the input construction strategy, which results in the changes of the criteria, attributes and/or their values. Thus the presented portfolio of projects for the construction of Corridors V and X is the base for preparing revised national programmes for the construction of railway infrastructure of the Republic of Slovenia. It is also the base for insuring the EU financing. The method for defining the project portfolio can be used for risk management of the complete process of the construction of the railway infrastructure.

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POVZETEK

MODEL OPTIMALNEGA PORTFELJA PROJEKTOV IZGRADNJE ŽELEZNIŠKE INFRASTRUKTURE NA V. IN X. KORIDORJU

Izgradnjo železniške infrastrukture je potrebno obravnavati kot nacionalni strateški razvojni program, ki se zaradi tehničnih, geografskih, logističnih in drugih zahtev izvaja z več projekti in pomeni za investitorje, izvajalce in druge vplivne dejavnike kompleksno multiprojektno poslovanje. Nacionalni strateški razvojni program izgradnje železniške infrastrukture se navezuje na programe sosednjih držav in v primeru držav, ki so članice EU, na Trans-evropsko transportno omrežje (TEN), ki strateško ureja to izgradnjo v okviru te skupnosti. V R Sloveniji se izgradnja železniške infrastrukture v okviru TEN izvaja na V. in X. pan-evropskima prometnima koridorjema s posameznimi projekti izgradnje odsekov in vrsto podpirajočih projektov. Tehnične, rokovne in druge zahteve TEN, nacionalne strateške zahteve ter finančne možnosti države so osrednji kriteriji, ki se morajo upoštevati pri pripravi strateškega projektnega plana z optimalnim razvrščanjem projektov, kar daje izvedbeni protfelj

projektov. Za oblikovanje portfelja je bila uporabljena metoda večkriterijskega razvrščanja, kjer so bili upoštevani makroekonomski in infrastrukturni kriteriji, hkrati pa je osnova za izdelavo finančnega plana, ki je optimalen glede na možnosti financiranja s strani R Slovenije in EU. Članek podaja tudi izsledke raziskave oblikovanja procesa projektnega izvajanja izgradnje TEN-T omrežja v R Sloveniji.

KLJUČNE BESEDE

nacionalni strateški razvojni program, izgradnja železniške infrastrukture, V. in X. koridor, portfelj projektov, večkriterijska odločitvena analiza, Republika Slovenija

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