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ECONOMIC FUNCTIONS PROPOSAL OF URGENCY PRIORITIZATION OF INVESTMENT PROJECTS OF OPERATED RAILWAY BRIDGES

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Abstract

The main objective of the article is to describe the proposals of economic functions within the prioritization of urgency investments of operated railway bridges within a comprehensive evaluation of existing bridges. The purpose of the paper is a comprehensive assessment of existing bridges and to define determinants and determinants of decision-making and designing a mechanism of decision-making procedures of prioritized infrastructure measures in the form of repairs and reconstructions of bridges resulting from the records of supervising activities based not only on technical but also economic aspects to the railway infrastructure manager.

Keywords:

Economic function;
Railways bridges;
Prioritization of urgency;
Investments.

1. Introduction

From a global perspective, the decision on the final order of importance, repairs, or technically demanding reconstructions and investments-assessed bridges supposed to be based on two-levels. The first level is to prioritize the basis of technical condition of structures, which represents the two functional parameters and load capacity determined by the level of reliability of the various structural elements of bridges and volatility traffic load. The second level supposed to represent a ranking order based on the values of utility function based on indicators of economic efficiency. Assessing the economic return can be understood in two ways. The first is to create indicators of economic efficiency of technology used in repair or reconstruction of the dimensions of technical, economic and time-consuming, and also of the relevant life-cycle, for which the bridge structure will require additional investment, other than routine maintenance. The second level consists of efficiency from the users' point of view and their economic benefits expressed in monetary units on the one hand and from the carriers' point of view in freight transport and time benefits in passenger transport expressed in monetary units and financial benefits resulting from the payments for traffic road utilization on the other hand. In this case, the absolute value of the financial and economic benefits represents the starting point, i.e. the zero state, which is in the timeframe of contemplated life of the investment activity compared with the state of current or expected limited life of bridges in traffic road, causing the influence of operational performance and throughput of the track section.

2. Possible function for representing the prioritization of railway bridges

Methodology function for prioritizing investment projects should exclude bridges whose technical condition was evaluated as good, while requiring only routine maintenance procedures. Methodology objective supposed to conclude only bridges whose technical condition was evaluated as 2nd grade, or more precisely, 3rd grade.

In the view of the currently achieved level of sophistication and complexity of the assessment system for the structural condition of bridges, there is indicative range of other evaluation factors needed to align their mutual data, computing and time consuming. The need to maintain the adequacy of the results of the prioritization decision-making function, that is the level of the simplification, does not affect the credibility of the selection process measures, but also provides a sufficient degree of simplification purpose.

In general, decision-making role *Rp* could be written as:

$$f(R_p) = W_i\, f_i\{Z_i, P_i, E_i\}, \tag{1}$$

where:
- $f(R_p)$ is a function of the decision-making procedure on prioritization of investment projects to the proposed collection of railway bridges;
- W_i are weighting factors are defined for a finite number of parameters determining decision;
- $f_i\{Z_i\}$ the carrying capacity is a function of the respective bridge building resulting from $\Delta Z_{LM_{71}}$;
- $f_i\{P_i\}$ the continuity is a function of traffic load under consideration of a bridge resulting from the current class of the track carrying capacity;
- $f_i\{E_i\}$ is a function of the resulting economic efficiency of each technology repairs and reconstructions, as well as loss of function of user benefits and economic downturn financial benefits resulting from infrastructure manager with transport and traffic limited to the railway line.

2.1 Cost efficiency factor

In the view of the urgency of prioritizing investment projects of operated railway bridges on the railway lines, economic efficiency should be seen in two ways. The first is composed of financial efficiency indicators of technology used in repairs or reconstructions, taking into account the investment demands of life and action, during which the bridge structure will require additional investment, but only routine maintenance.

The second level of efficiency, which is important in terms of selection and prioritization of bridges in terms of the urgency of the implementation of investment projects, is based on socio-economic and financial losses of relevant stakeholders, i. e. passenger and infrastructure manager. In the case of passengers, the factor of economic efficiency level of loss of time, expressed in monetary terms, of the carriers are aspects of economic efficiency of defined financial terms of delays in freight transport. Infrastructure manager must follow the criterion of economic efficiency of potential losses from payments for the use of road transport.

2.1.1 The functions of the economic efficiency in collecting technology investment shares

For purposes of evaluation and selection of investment activity at the individual elements of the transport infrastructure, I e. micro level, it is important to take into account the aspect of life element of transport infrastructure in the application of technologies being compared. Mathematical expression of this relationship can be defined as follows:

$$IN_r = IN \times \frac{1}{n}, \tag{2}$$

where:
- IN_r are the relative investment costs over the life of the infrastructure element;
- IN are investment costs, in monetary units (e.g. EUR);
- n is the lifetime of a structural element of a bridge, if necessary, bridge building after the implementation of the investment project, expressed in years.

Elements of transport infrastructure, depending on the investment project, mean a structural element of a bridge, (e. g. beam, crossbeam) the repair, reconstruction, if the entire bridge building is concerning to the whole bridge structure.

If available, reliable and objective data should be counted in the calculation of the operating costs necessary for the operation of a bridge under consideration after the realization of the investment project during its whole life because of the potential variability in operating costs due to the implementation of the selected technology investment action. After counting of the operating costs, we can't talk about relative investment costs anymore, but about the relative total costs for the realization of selected investment project:

$$CN_r = (IN + \sum_1^n PN) \times \frac{1}{n}, \tag{3}$$

where: CN_r is the relative total cost of investment activity for the life- cycle of the element / elements of transport infrastructure;
IN are investment costs, in monetary units (e.g. EUR);
PN are operating costs, in monetary units (e.g. EUR);
n is the life of the element of transport infrastructure after the implementation of the investment project, expressed in years.

2.1.2 Cost efficiency function in prioritization of bridges

Socio-economic and financial impacts are assessed in terms of three major stakeholders - passengers, carriers, infrastructure manager. In the case of passengers, it is necessary to evaluate the level of costs on running time expressed in monetary terms. In the case of carriers, there are aspects of economic efficiency defined in financial terms of the additional costs for driving time in freight transport. In the case of infrastructure manager, it is necessary to consider the implications of using alternative routes and to quantify the potential financial losses resulting from the difference in payments for the original route usage.

2.1.2.1 Determining the increase of socio-economic costs of passengers on the journey time

In order to calculate the cost of driving time, it is necessary to know the average transit time for passenger services prior to the implementation of the investment project (variant 0) and after implementation of the measure (variant I). Driving time within each option should be set based on the estimated average speed of passenger trains each category, taking into account variations of operating conditions and the length of the track section in which the investment action is carried out. In the case of total exclusion of transport on the track section due to investment action, it is necessary to know the average speed of the alternative (diversionary) route and its length. Starting and end point of compared track sections must be the same in both scenarios. The average time loss of one train should be established for each category of passenger trains as follows:

$$\Delta t_{vod} = \frac{l_0}{v_0} - \frac{l_1}{v_1}, \tag{4}$$

where: Δt_{vod} is a waste of time one passenger train runs due to the current operational constraints, railway clock;
l_0 length is considered, where appropriate, as an alternative track section before implementing measures in km;
v_0 is the average speed on a specific or alternate track section before implementing measures in km.h^{-1};
l_1 is considered as the length of track section after the implementation of measures in km;
v_1 is the average speed on a specific track section after the implementation of measures in km·h^{-1}.

Another important input required for the determination of total losses for running time is the total number of passengers transported by passenger trains on the track section evaluated for one year. Indication of the number of passengers on the route section can be obtained from the carrier (s), or it is possible to determine the average value per train (any category) from other performance indicators of passenger railway transport, for example, share of the transport performance in passenger-kilometres and transport capacity in train kilometres. The resulting equation for determining the total loss for journey time of passengers can thus be defined as follows:

$$\Delta T_{OD} = \left[\left(\Delta t_{vi} \times n_c \times \frac{r_i}{100}\right) \times 365 \times 24\right] + \left[\left(\Delta t_{vj} \times n_c \times \frac{r_j}{100}\right) \times 365 \times 24\right], \tag{5}$$

where: ΔT is the total loss of driving time of all passengers carried per year and considered section, man-hours;

Δt_{vi} is a waste of time one passenger train runs in passenger transport category and in the given field, railway clock;

Δt_{vj} is a waste of time one passenger train runs in transport category "j" in the given field, railway clock;

n_c is the number of passengers on a specific track section in one day;

r_i is the proportion of passenger trains categories and the total number of trains in percentage terms;

r_j is the proportion of passenger trains in category "j" in the total number of trains in percentage terms.

The resulting equation for the determination of total losses running time passengers can be defined as follows:

$$C_{OD} = \left(\Delta T_p * c_p\right) + (\Delta T_s * c_s), \tag{6}$$

where: C_{OD} are the total annual socio-economic costs (losses) on driving time for passenger evaluated for the track section, the monetary unit;

ΔT_p is the total annual loss of journey time of all passengers with a working purpose of the journey, man-hours;

ΔT_s is the total annual loss of driving time all passengers with the private purpose of the journey, man-hours;

c_p is the rate for the valuation of the running time for working purpose of the journey, the monetary unit for man-hours;

c_s is the rate for the valuation of the running time for the private purpose of the journey, the monetary unit for person per hour.

Equation for determining the total loss journey time of passengers during the period of the implementation of the investment project is therefore possible to define the following:

$$\Delta T_{ODI} = \left[\left(\Delta t_{vi} \times n_c \times \tfrac{r_i}{100}\right) \times (t_1 \times 24)\right] + \left[\left(\Delta t_{vj} \times n_c \times \tfrac{r_j}{100}\right) \times (t_1 \times 24)\right], \tag{7}$$

where: ΔT_{ODI} is the total loss of driving time all passengers carried for the period under consideration of stretch performance of investment activities, man-hours;

Δt_{vi} is a waste of time running one train in the passenger transport category and in the given field, railway clock;

Δt_{vj} is a waste of time running one train in the passenger transport category is given section, railway clock;

n_c is the number of passengers on a specific track section in one day;

r_i is the proportion of passenger trains categories and the total number of trains in percentage terms;

r_j is the proportion of passenger trains in category "j" in the total number of trains in percentage terms;

t_I is the duration of the performance of investment activities on bridges, expressed in days.

Equation for determining the total loss of journey time of passengers during the period of implementation of the measure will be almost the same as the annual indicator:

$$C_{ODI} = \left(\Delta T_p * c_p\right) + (\Delta T_s * c_s), \tag{8}$$

where: C_{ODI} are the overall socio-economic costs (losses) on driving time passengers on the assessed track section during the period of implementation of the investment project, the monetary unit;

ΔT_p is the total loss of driving time of all passengers with a business purpose roads during the period of implementation of the investment project, man-hours;

ΔT_s is the total loss of driving time of all passengers with the private purpose of the journey during the period of implementation of the investment project, man-hours;
c_p is the rate for the valuation of the running time for working purpose of the journey, the monetary unit for person per hour;
c_s is the rate for the valuation of the running time for the private purpose of the journey, the monetary unit for person per hour.

2.1.2.2 Determining the increase in socio-economic costs of the journey time in freight

As in the case of passenger transport, the limitation of the operation on given track sections or partial complete immobilization due to the worsening of the technical condition of bridges or its structural elements also occur in freight transport. In passenger transport, the increased socio-economic costs on driving time have impact on passengers, so carriers and consequently, shippers, whose goods are transported, bear the increased socio-economic costs on travel time.

Calculation of the high cost of driving time in freight transport is critical methodological approach almost the same as when calculating driving time for passenger services. Firstly, it is necessary to determine the average transit time for freight services prior to the implementation of the investment project (variant 0) and after implementation of the measure (variant I). Driving time within each option should be set based on the estimated average speed of freight trains in each category, taking into account variations of operating conditions and the length of the track section. In the case of total exclusion of transport on the track section due to investment action, it is necessary to know the average speed of the alternative (diversionary) route and its length. Starting and end point of compared track sections must be the same in both scenarios. Useful source of information can be timetables, or Route Book. The average time loss of one train should be established for each category of freight trains as follows:

$$\Delta t_{vnd} = \frac{l_0}{v_0} - \frac{l_1}{v_1}, \tag{9}$$

where: Δt_{vnd} is a waste of time one freight train runs due to the current operational constraints, railway clock;
l_0 length is considered, where appropriate, as an alternative track section before implementing measures in km;
v_0 is the average speed on a specific or alternate track section before implementing measures in km·h^{-1};
l_1 considered the length of track section after the implementation of measures in km;
v_1 is the average speed on a specific track section after the implementation of measures in km·h^{-1}.

Important input for the calculation of the loss of running time in freight transport is the volume of goods transported by trains in freight traffic on the route section, and was evaluated over a period of one year. Indication of the volume of goods transported over the track section can be obtained from carriers, it is also possible to determine the average value per train (any category) of the output performance indicators of rail freight, for example, share of the transport performance in tonne-kilometres of clean power and transportation in train kilometres.

Mathematical relationship to determine the total loss of driving time in freight transport can therefore be defined as follows:

$$\Delta T_{ND} = \left[\left(\Delta t_{vi} \times V_c \times \frac{r_i}{100}\right) \times 365 \times 24\right] + \left[\left(t_{vj} \times V_c \times \frac{r_j}{100}\right) \times 365 \times 24\right], \tag{10}$$

where: ΔT is the total loss of time driving around the volume of goods transported on a specific section for the year, tons per hour;
Δt_{vi} is a waste of time one freight train runs in category and in the given field, railway clock;
Δt_{vj} is a waste of time one freight train runs in category “j” in the given field, train hours (in the case of identification of another category of freight trains, it needs to be added to the calculation formula similarly as already defined categories “i” and “j”);

V_c is the total volume of goods in considered track section in one day;
r_i is the proportion of freight trains categories and the total number of trains in percentage terms;
r_j is the proportion of freight trains in category "j" in the total number of trains expressed in percentage terms (in the case of identification of another category of freight trains needs to be added to the calculation formula similarly as previously defined categories "i" and "j").

Unlike passenger transport, freight transport routes are all considered as business trips.

The resulting equation for determining the total driving time losses in freight transport can be defined as follows:

$$C_{ND} = (\Delta T_{ND} * c_{ND}), \tag{11}$$

where: C_{ND} are the total annual socio-economic costs (losses) on driving time in freight transport for the evaluation section, in monetary units;
ΔT_{ND} is the total annual loss of driving time in freight transport on a specific section tons per hour;
c_{ND} is the rate for the valuation of driving time for rail freight transport, the monetary unit for tons per hour.

It is true that the higher value of costs (losses) on driving time in freight transport is evaluated by track sections and the urgency of the performance of investment activities on bridges is higher. The indicator can be evaluated separately, or a summary indicator of the cost of driving time in passenger traffic and driving time in freight transport can be given.

After calculating of total annual socio-economic costs on driving time in freight transport, it is necessary to calculate the cost of driving time during the implementation of the investment project. This indicator should be used as an additional parameter for prioritizing bridges to the urgency of the implementation of the investment project.

Relationship for determining of the cost on driving time in freight transport during the period of implementation of the investment project is similar to the determining of the annual cost on driving time:

$$\Delta T_{NDI} = \left[\left(\Delta t_{vi} \times V_c \times \frac{r_i}{100}\right) \times (t_I \times 24)\right] + \left[\left(\Delta t_{vj} \times V_c \times\right) \frac{r_j}{100} \times (t_I \times 24)\right], \tag{12}$$

where: ΔT_{NDI} is the total loss of time driving around the volume of goods transported on a specific section during the period of performance of investment activities on bridges, tons per hour;
Δt_{vi} is a waste of time running one train freight category and the given field, railway clock;
Δt_{vj} is a waste of time running one train freight category "j" in the given field, train hours (in the case of identification of another category of freight trains needs to be added to the calculation formula similarly as already defined categories "i" and "j");
V_c is the total volume of goods considered track section in one day;
r_i is the proportion of freight trains categories and the total number of trains in percentage terms;
r_j is the proportion of freight trains category "j" in the total number of trains in percentage terms (in the case of identification of another category of freight trains needs to be added to the calculation formula similarly as previously defined categories "i" and "j");
t_I is the duration of the performance of investment activities on bridges, expressed in days.

Equation for determining the total loss of journey time of passengers during the period of the implementation of investment project, arises from the relationship of the annual indicators as the follows:

$$C_{NDI} = (\Delta T_{ND} * c_{ND}), \tag{13}$$

where: C_{NDI} are the overall socio-economic costs (losses) on driving time in freight transport for the evaluation section during the period of implementation of the investment project, the monetary unit;

ΔT_{ND} is the total loss of driving time in freight transport on a specific segment during the period of implementation of the investment project, tons per hour;

c_{ND} is the rate for the valuation of driving time for rail freight transport, the monetary unit for tons per hour.

5. Conclusions

Outcome of the proposal of decision-making process should be designed and set up for three definitional features, the load capacity and traffic load which consist of volatility component reliability and efficiency of decision-making functions , or more precisely, returns of the economic benefits. The technical part of the assessment is in determining current carrying capacity very sensitive to the accuracy of the input data, which depend both on the results of supervising activities regularly carried out by the infrastructure manager on a series of bridges under consideration and on outcomes of numerically more accurate diagnostic tests of materials, tests of the resistance against the effects of stress, as well as on direct tests executed by load models.

An economic efficiency function that reflects the summary of corrective measures or a complex reconstruction, follows the urgency of interventions from the viewpoint of proposed measures, both at the level of objects whose current state of technical characteristics does not meet the minimally required values, e. g. for maintaining the design class of track load, dynamic effects due to running speed, etc., and at the level of objects whose current situation dangerously approaches the stage, when it is necessary to accept certain operational restrictions, or, in some cases, to completely eliminate the traffic. Economic efficiency is perceived in two basic levels. The first level consists of costs, or rather losses of users (passengers, freight transport carrier, or shipper). The second level consists of benefits of the infrastructure manager.

The main purpose of the proposed decision algorithm conceived by triplet partial decision-making functions about the implementation of interventions ensuring interoperability of bridges is, more effectively and adequately, allocate the resources in the field of complex investment projects of railway infrastructure manager, in the terms of actual needs of infrastructure.

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