

# **Economic ways of increasing efficiency of road-building planning**

## **Raman Ivuts**

Bialystok University of Technology, Faculty of Management,  
Department of Marketing and Entrepreneurship, Poland  
e-mail: r.ivuts@pb.edu.pl

## **Irene Tsarenkova**

Belarusian State University of Transport, Faculty of Process Management Traffic, Belarus  
e-mail: tsar\_irina@mail.ru

## **Marta Jarocka**

Bialystok University of Technology, Faculty of Management,  
Department of Business Informatics and Logistics, Poland  
e-mail: m.jarocka@pb.edu.pl

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## **Abstract**

The formation of the road-building program with the use of traffic flows logistics can achieve rational use of the limited financial resources and to provide current and long-term interests of the road users. In order to evaluate the effectiveness of conducting the road repair and reconstruction, the factors reflecting their importance for the national economy are used: road organizations, which are the main subjects of the implementation of the formed program; enterprises of motor transport complex, which are the main consumers of the road facilities and the state, who is the main investor in the road branch. The integral criterion characterizing the efficiency of using the logistical approach to the formation of the optimal scheme of repairing and reconstructing the road network, both for the users and for the contractors, is calculated. Its size makes it possible to assess the effectiveness of fulfilling the overhaul and reconstruction on a definite site and at the formed optimal scheme of distributing the overhaul and reconstruction of the road network. The article presents the methodological fundamentals of the economic evaluation logistical systems of roads facilities.

## Keywords

roads, road facilities, repair, reconstruction, logistical system

## Introduction

Nowadays, improving the socio-economic relations, increasing the competitiveness of the national economy, the growth of freight traffic volumes in the national and international communication require that the road industry should provide reliable transport links, and also the integration into the transport system of the European international roads and the unified motor-road network of the international motorways. Due to the limited financing there is under repair of roads that leads to the deterioration of their transportation and operational condition. Every year it will require significant investments. The rational distribution of the available financial resources for the maintenance, repair, reconstruction and construction of roads is one of the main problems of the road sector.

At the present stage there is a necessity in comparing possible variants of solutions satisfying the same requirements, but which are different in organizational and technical nature and economic effectiveness. For this purpose, the systems of controlling the pavement state are being developed. They are designed in many countries: Poland, Finland, Denmark, UK, Norway, Canada, France, Lithuania. Much attention to the problem of maintenance and repair of roads is paid by the international financial institutions. With the support of the World Bank engineering and economic system called Highway Development and Management System (HDM) has been developed (Archondo-Callao, 1995; Morosiuk *et al.*, 2004). Many countries use it for controlling the national roads network (Hutnik, Obara, 2009; Sen *et al.*, 2014).

### 1. The system of controlling the transport operating condition of the roads

One of the system of controlling the transport operating condition of the roads is "Repair". It collects the necessary information (evenness of the pavement, road holding capacity, carrier capacity of the road coating, traffic volume and the composition of the transport flow) and sends it to the automated data bank. Then using the data analysis it makes the estimation and prediction of the road condition, allows to ground the choice of the repair strategy and also to calculate the economical efficiency and to optimize the cost of repairs.

As a criterion for assessing the economic effect in the system "Repair" total transport costs (TTC) are used, including transport operation costs (TOC) and carrying out the repair work of the road network (N). While calculating TOC, the data of the actual evenness and smoothness of the pavement and the evenness in the future are used, which is determined by the method of prediction. When choosing a repair strategy such a variant is accepted which provides the reduction of the total transport expenses after the repair activities as compared with the case when the repair was not made. Next, to compare the effectiveness of different variants of repair work the indicators or indexes of the investment projects efficiency are calculated: the pure current cost, the internal rate of profitability, relation of profit and expenditure, the rate of profit for the first year. By optimization of the annual expenses for repair of the road sections in the road network, within the allocated funds various methods of economic analysis are used: a heuristic optimization, the concept of an area under the curve.

Analysis has shown that the modern systems of controlling the roads condition work for the purpose of the repair measures. These systems do not take into consideration the construction and reconstruction of the roads. The selection of sites for repair implementation is fulfilled only on the basis of the analysis of the road surface condition and the efficiency of investments in their restoration. When choosing a repair strategy one of the main indicators is to minimize the cost of road repairs. Although the current method of determining the investment efficiency in the construction, reconstruction, repair and maintenance of roads, envisages the calculation of the transport and operating costs connected with the road operation in a certain condition, but only for determining the efficiency level, confirming the appropriateness of fulfilling a specific kind of work on the investigated section of the road. The systems of controlling the transport maintenance condition of roads, which are used, do not take into account a feedback mechanism and do not consider the results of the road facilities work in cooperation with the other branches, as the most important aspect of its operation. In addition, there are no methods for the selection of the priority for fulfilling the reconstruction of the road sections which allow to maximize the speed of the cars with the allotted amount of financing.

The main objective of the logistics in the road facilities is the formation of the logistical systems providing the minimization of the total costs connected with the production and consumption of the road traffic output. Investments and capital investments into the maintenance, repair, reconstruction and construction of roads are associated with the analysis of the logistical phases, which give the possibility to implement strategies of their optimal planning in the road facilities as streaming processes (Tsarenkova, 2007a). Logistical unit integrates the organization of production

with the processes of the work planning and by the coordinated interaction of different types of flows operating in road construction.

The actuality of the investigation is caused by the fact that in the market conditions the road facilities are guided by the demands of the consumers of its production. It requires the constant improvement of the planning process of road construction works in order to reduce the losses that occur with the road users due to the unfavorable conditions, while making optimal use of limited financial resources.

## 2. Methodological fundamentals of the economic evaluation logistical systems of roads facilities

Functioning and effective development of the road network directly depends on those market instruments with the help of which the realization of the investment projects is being implemented. Taking into account the peculiarities of the road facilities, the logistical approach is the most efficient in controlling the investment business, which includes the complex representation of the flow processes on the basis of constructing the logistical systems which are characterized by a number of specific signs caused by the branch accessory in order to optimize them (Chemov-  
alov, 2008).

The economic mechanism of developing the logistical systems in the road facilities is formed as a system of interaction of material, informational, financial logistical flows and also economic, informational and organizational and social measures, whose implementation allows to improve the organization of the road facilities with the aim of the optimal use of the investments into the maintenance, repair, reconstruction and construction of automobile roads. The stages of the economic mechanism of developing the logistical systems in the road facilities shows Fig. 1.

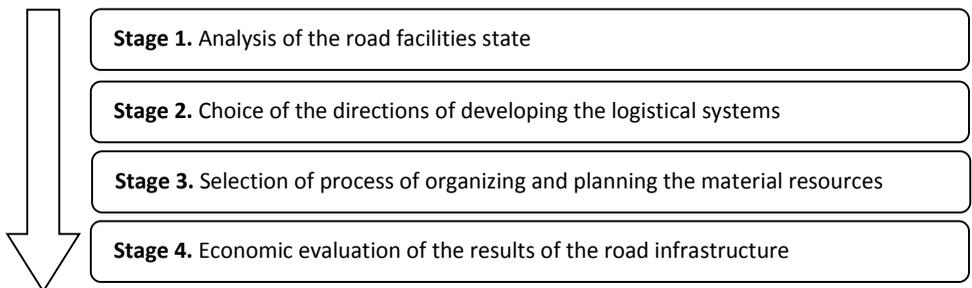


Fig. 1. The stages of the economic mechanism of developing the logistical systems in the road facilities

Source: own study.

At the first stage, in order to determine the factors influencing the development of logistical systems, the analysis of the road facilities state is made.

At the second and the third stages controlling the logistical systems is performed under the implementation of the planned directions of their development in the road facilities.

At the second stage, at the macro-level, on the road network scale, the main directions of developing the logistical systems in the road facilities are chosen. These directions are connected with the planning and organization of production. The program of road works is formed by finding a rational variant of making the overhaul and reconstruction of automobile roads, that provides reducing the losses of the users connected with the unfavorable road conditions (Tsarenkova, 2007b).

At the third stage, at the micro level, in the process of organizing the road building operation the contractor organizations, which selected on a competitive basis, form adequate logistical systems of promoting the logistical flow. When calculating the forecasts and planning the material resources such factors as the raw material for the road construction, its storage, transportation are taken into account; record and control of the material resources movement is made; measures for their economy are taken; the analysis of the rational use of the material resources is made. In order to monitor the progress of the road construction the technical supervision over the quality of the work performed is carried out. On the basis of the taken decisions controlling the development of logistical systems in the road facilities is performed. At the final stage, the economic evaluation of the results of the road infrastructure, based on the analysis of many factors affecting the level of efficiency is done (Tsarenkova, 2007c).

The road facilities are represented as a logistical system with feedback, in which the planning of road building works is being carried out continuously. In addition to the traditional production and economic services the specially trained staff (logisticians) should take part in the developing of the road building work. They will perform the analysis of coming information about the state of the roads, not only in terms of their owner, but also with regard to the requirements imposed on them by the consumers, comparing the actual condition of the road pavement with that it would be desirable to have. The roads are the traffic arteries of the country, so the nature of their operation is significantly affected by the external factors. The information about external influences comes to logisticians so the reverse relationship is made.

The purpose of functioning the system of planning road building works on the basis of traffic flows logistics is to make an optimal work program which will provide the achievement of the following objectives:

- maintenance of the road network in the state meeting the normative requirements;
- the development of the road network in accordance with the requirements of the national economy;
- ensuring minimal expenses for users at the road network functioning.

Due to the limited financial resources different variants of achieving this goal are modeled.

The actual state of the planning process is compared with the logistical one, which should correspond to the qualitative performance of the tasks set not only at present, but also throughout the entire accounting period. At the exit in this and in another case a work program is formed, but each variant will be corresponded by its own level of efficiency.

In this case we are dealing with the multi-criteria problem of estimating the effectiveness. The effectiveness of the developed plan can be estimated according to different criteria, every of which may be the main one, but one can not say exactly which is that criteria. There are different ways of solving multi-criteria problems of estimating the effectiveness, but all of them can be summarized in three basic ones.

The first variant of finding the optimal solution according to several criteria of efficiency is the ranking criteria. After ranking the criteria, it is necessary to proceed to searching an optimal solution for the most important of them. Then, setting to the admissible magnitude of changing the first criterion, one must look for a solution to the second criterion - the best one in the area thus obtained. It is obvious that the order of the importance and admissible ranges of their variation are chosen arbitrarily (Semenenko, 2003). Therefore, this method is not devoid of subjectivism and requires that the executor should have deep knowledge and experience of work with the solution of such problems.

The second variant of solving multi-criteria problems is to transform all objective functions, except one, into the limits (Semenenko, 2003). In the mathematical treatment the problem is to find a function of the main criteria, limited by the various systems of inequalities. However, while solving this problem, just as in the previous case, there is a question of choosing the main criterion. It is clear that when assessing the level of efficiency only by one criterion it is not possible to achieve an objective evaluation of the measures investigated. The most promising in this case is the third variant envisaging the reduction of a multi-criterion problem to a single-criterion one.

The third variant is to construct a single (integral) efficiency criterion by means of summing the products of the existing criteria into some "weight" coefficients (coefficients of the criteria importance). The greatest complexity of realization of this

variant is associated with the appointment of weight factors that determine the relative importance of private efficiency criteria (Maltsev, 2010).

The first component of the integral indicator of the efficiency can be examined by comparing the economic effectiveness of alternative variants, by means of calculating the absolute value of the income increase of the road facilities logistical system and determining the relative effectiveness of investing means into the overhauls and reconstruction of automobile roads, which characterizes the relative "projects return" on the investment in them.

$$K_{av} = \sum_{j=1}^m K_{1j} - \sum_{j=1}^m K_{2j}, \quad (1)$$

where:

- $K_{av}$  – the absolute value of income increase of the logistical system;
- $K_{1j}$  – the value of the pure discounted income received in the performance of repairs and reconstruction on the automobile road sections in accordance with the plan, based on the logistics of traffic flows;
- $K_{2j}$  – the pure discounted value of the income received in the performance of road works on the other alternative schemes.

Pure discounted value of different projects is summarized as this indicator is additive in the space-time aspect. This feature allows to use this figure as the principal one in evaluating the effectiveness of the road building work program. The expenses of many branches of national economy depend on the technical and operational state of the automobile roads, which are the social objects.

Therefore, an important aspect of the effectiveness of the road repair and reconstruction in the logistical systems of road facilities is their positive influence on the expenses mentioned above. In turn, this leads to the profitability increase of motor transport enterprises. The profitability index characterizes the efficiency of investment return into the transportation process. But since it is not possible for a particular section of the automobile road to determine the motor transport of whose organizations is moving along the road, then the other criteria for determining the effectiveness of planning road building works were taken. The most important criteria are the transport and logistics costs of motor transport organizations connected with the implementation of trucking, and the costs of the other industries associated with unfavorable road conditions.

In the result of comparing the two variants the biggest savings of the total transport and logistical costs is determined, achieved in the case of forming the optimal scheme of fulfilling the road network repairs and their reconstruction.

$$E_{pt} = \sum_{j=1}^m V_{c1j} - \sum_{j=1}^m V_{c2j}, \quad (2)$$

where:

- $E_{pt}$  – the effect produced on the transport in the formation of road building works program using the logistics of traffic flows;
- $V_{c1j}$  – the value of the transport and logistical costs of the transport enterprises complex, obtained in the performance of overhaul and reconstruction with traditional planning;
- $V_{c2j}$  – the value of the transport and logistical costs of the transport enterprises complex, obtained when performing repairs and reconstruction on the automobile road sections in accordance with the plan, formed on the basis of logistics of traffic flows.

$$E_{br} = \sum_{j=1}^m V_{e1j} - \sum_{j=1}^m V_{e2j}, \quad (3)$$

where:

- $E_{br}$  – the effect produced by the other branches of the national economy in the formation of the road building works program with the logistics of traffic flows;
- $V_{e1j}$  – the value of the expenses of other branches of the national economy, depending on the automobile road state;
- $V_{e2j}$  – the value of the expenses of the other sectors of the national economy, obtained when fulfilling the overhaul and reconstruction according to the program formed with the logistics of traffic flows.

The diversity of the given indicators shows the lack of the clearly defined criteria and scientifically grounded approach that would define the forming of the objective set of indicators and their hierarchical importance for assessing the effectiveness of repairs and reconstruction of automobile roads in the logistical systems of road facilities. In this case, there is a need for new methods of the analysis of the social and economic phenomena with a large number of characteristics.

Let's use the method of cluster analysis (Abonyi, Feil, 2007) which allows to understand under the multidimensional object – the logistics system, and under a set of indication values - financial indexes reflecting the effectiveness of the system of road repair and reconstruction. Let's form the observation matrix where the elements  $F_{ij}$  are the values of the financial indexes of the road facilities logistics system for a certain period

$$\begin{bmatrix} F_{11} & F_{12} & \dots & F_{1n} \\ F_{21} & F_{22} & \dots & F_{2n} \\ \dots & \dots & \dots & \dots \\ F_{m1} & F_{m2} & \dots & F_{mn} \end{bmatrix}. \quad (4)$$

This technique provides a 100-point rating scale, where the best value of the index is always equal to 101 points, and the worst – 1 point.

$$K_j = \frac{\sum_{i=1}^m L_{ij}}{n}, \quad (5)$$

where:

- $K_j$  – the individual integral performance index of the effectiveness on a particular  $j$  object,  $j = 1, \dots, m$ ,  $m$  – the number of the objects;
- $L_{ij}$  – the point of the  $i$  index on the  $j$  object,  $i = 1, \dots, n$ ,  $n$  – the number of the analyzed indexes.

In turn, the value  $L_{ij}$  is calculated as follows:

$$L_{ij} = \frac{k_{ij} - k_{i \min}}{V_{i \text{ var}}} 100 + 1, \quad (6)$$

where:

- $k_{ij}$  – the value of the  $i$  index on the  $j$  object;
- $k_{i \min}$  – the worst value of the  $i$  index;
- $k_{i \max}$  – the best value of  $i$  index;
- $V_{i \text{ var}} = k_{i \max} - k_{i \min}$  – the range of the variation of  $i$  index.

As the indexes characterizing the efficiency of using logistical approach to the optimization of carrying out the overhauls and reconstruction of the roads the following criteria are taken: the pure discounted income increase, the absolute change of the profitableness index, the economy of the transport and logistical expenses for the transport complex enterprises and the cost savings of the other sectors of the national economy, connected with the unfavorable road conditions.

In the result of the calculation of the point values for each index they are led to the comparable form by eliminating the individual peculiarities of the characteristics of the investigated areas. However, at the given stage the degree of the influence of each of them on the total characteristics of the effectiveness of the optimal road building work system is not taken into account.

Therefore, the ranking of the effectiveness indexes is performed, using the method of the standard quadratic deviation for each criterion. The standard deviation

characterizes the measure of the oscillation of the series. As the efficiency of conducting the logistical measures in the planning of overhauls and reconstruction on different sites compared with the traditional planning methods is determined, the greatest impact on the amount of effect will be rendered by the index which provides maximum deviation from the original version.

The calculation of the hierarchy is as follows. First, the standard deviations for each index using the "biased" or "n" method are determined.

$$S_o = \sqrt{\frac{n \sum k_{ij}^2 - (\sum kf_{ij})^2}{n^2}}, \quad (7)$$

where:

-  $n$  – the number of the numerical arguments corresponding to the general totality.

The maximum standard deviation is recorded as a divisor and is correlated with the others, which serve as a dividend. The obtained coefficients of the hierarchy for each index, calculated in terms of points, are multiplied by the point value of the corresponding index. Thus, the ranking of the indexes is performed on the hierarchy.

Then the integral index ( $K_0$ ) in all parameters is calculated characterizing the efficiency of using logistical approach to the formation of the optimal scheme of the repairs and reconstruction of the road network, both for their users and for contractors.

$$K_o = \sum_{j=1}^m \alpha_j K_{1j} + \sum_{j=1}^m \alpha_j \frac{1}{E_{trj}} + \sum_{j=1}^m \alpha_j \frac{1}{E_{brj}} \rightarrow \max, \quad (8)$$

where:

-  $\alpha_j$  – the coefficient of the criterion value.

This index provides an opportunity to assess the effectiveness of the overhauls and reconstruction at a specific site and on the formed optimal of scheme of allocating the overhauls and reconstruction of the road network.

## Conclusion

To improve the efficiency of the repair and reconstruction of automobile road network in the conditions of the limited financing it is necessary to consider the logistics of traffic flows, allowing to coordinate the interests of road and transport organizations, enterprises of the other branches of the national economy and the state at the stage of planning road building works.

Elaborated methodical fundamentals of the economic evaluation of the effectiveness of repairs and reconstruction of roads in the road facilities logistics systems, that lie in the formation of the integral criterion, allow to use the allocated investments rationally, guaranteeing the needs of the road users in the safe and all year-round transportation with the minimal transport and logistics expenditures. Unlike the existing methods, the synergetic effect of joint planning of repairs and reconstruction as on the separate sites of the road, as in general on the entire road network of the definite region is provided.

The methods of forming the repair system of automobile roads network and choosing the rational variant of their reconstruction, developed by the author, allow to consider the interests of the road and transport organizations, enterprises of the other branches of the national economy and the state. Using the developed methods makes it possible to assess the processes of the overhaul and reconstruction of automobile roads on any parts of the road network comprehensively. The universality of the methods allows to determine the number of important indicators such as the effect of reducing the travelling time of the passengers that is achieved while removing speed limits, the amount of the necessary capital investments required for performing work on the roads, the amount of the possible travel reduction time, the effect of reducing the level of the transport and logistics expenses of motor transport organizations, as a result of selecting the optimal sequence of operations.

The methods of forming the system of repairs and reconstruction of the road network on the basis of the logistics of traffic flows, using the calculation of the efficiency indicators of the investment projects, allow to take into account the interests of road organizations by comparing the economical efficiency of the alternative variants, by the definition of the increase value of the economic potential of the logistics system in the case of implementing the logistical approach to the formation of the repair and reconstruction optimal scheme of the road network and the motor transport enterprises, determining the economy of the total transport and logistics costs.

On the basis of the synthesis of the given methods the integral indicator or index of evaluating the efficiency of the performance of the organizational and economic mechanism of developing logistical systems in the road facilities was elaborated and it allows to take into account the interests of all-interested sides: the road facilities, the transport complex, other industries of the national economy and the state.

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## Ekonomiczne sposoby zwiększenie efektywności planowania budowy dróg

### Streszczenie

Powstawanie programu budowy dróg z wykorzystaniem informacji na temat natężenia ruchu drogowego może przyczynić się do racjonalnego wykorzystania ograniczonych często zasobów finansowych. Do oceny skuteczności przebudowy i remontu dróg angażuje się organizacje zajmujące się implementacją programu budowy dróg, przedsiębiorstwa trans-

portu drogowego, będące głównym konsumentem infrastruktury drogowej, jak również państwo, które jest głównym inwestorem takiego przedsięwzięcia. Zaleca się wykorzystanie wskaźnika, określającego skuteczność wykorzystania logistycznego podejścia w procesie tworzenia programu naprawy i odbudowy sieci drogowej, zarówno dla jej użytkowników, jak i wykonawców.

## **Słowa kluczowe**

drogi, remont, przebudowa, system logistyczny

## **Author information**

### **Raman Ivuts**

Białystok University of Technology  
Wiejska 45a, 15-351 Białystok, Poland  
e-mail: r.ivuts@pb.edu.pl

### **Irene Tsarenkova**

Belarusian State University of Transport  
Kirowa 34, 246653 Gomel, Belarus  
e-mail: tsar\_irina@mail.ru

### **Marta Jarocka**

Białystok University of Technology  
Wiejska 45a, 15-351 Białystok, Poland  
e-mail: m.jarocka@pb.edu.pl