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**ЭФФЕКТИВНОСТЬ ДОРОЖНЫХ ПРОЕКТОВ: МЕТОДИКА РАСЧЕТА  
ПОКАЗАТЕЛЕЙ И АЛГОРИТМ ОЦЕНКИ**

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**Аннотация.** Данная статья посвящена методологии оценки эффективности эксплуатации автомобильных дорог и дорожного строительства. Представлены основные виды эффективности дорожных проектов: общественная, коммерческая и бюджетная. Описана методика расчета основных показателей эффективности проектов строительства и эксплуатации дорог: интегрального эффекта или чистого дисконтируемого дохода, индекса доходности инвестиций, внутренней нормы доходности, срока окупаемости. Раскрыто содержание показателей результатов и затрат в зависимости от вида рассчитываемой эффективности дорожного проекта. Определена суть экономического окружения, имеющего значение при оценке коммерческой и бюджетной эффективности дорожного проекта. Выявлены основные технико-экономические параметры транспортно-эксплуатационного состояния дорожной сети или ее элементов. Представлен алгоритм оценки экономической эффективности содержания автомобильных дорог общего пользования.

**Ключевые слова:** методология, расчет, параметры, автомобильная дорога, оценка, эффективность, эксплуатация, дорожное строительство, интегральный эффект, чистый дисконтируемый доход, индекс доходности инвестиций, внутренняя норма доходности, срок окупаемости

**THE EFFECTIVENESS OF ROAD PROJECTS: A METHODOLOGY FOR CALCULATING  
INDICATORS AND AN EVALUATION ALGORITHM**

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**Abstract.** The paper covers issues of methodology of efficiency evaluation of road operation and construction. It describes main types of efficiency of road projects: public, commercial and budget. Also, the work contains methods of calculation main metrics of efficiency of road operation and construction projects (integral effect or net present value, investments returns index, IRR, payback period) and reveals metrics of results and costs in terms of calculated efficiency of a road project. The paper determines the essence of economic environment which matters in valuation of commercial and budget efficiency of a road project. It discovers main technical and economic parameters of operational status of a road network or its elements and provides algorithm of cost-benefit analysis of a public road.

**Keywords:** methodology, calculation, parameters, road, assessment, efficiency, operation, road construction, integral effect, net present value, investment return index, internal rate of return, payback period.

**INTRODUCTION**

Nowadays, issues of cost-benefit analysis of road operations and construction are becoming more and more relevant. They are of urgent relevance in calculation of public, commercial and budget efficiency of road programs and projects, in evaluation of financial feasibility of commercial road projects, in comparison of design options in construction, reconstruction, roadways or road buildings repair or replacement, in analysis of social and economic effects of road programs and projects, in expert evaluation and preparing expert report concerning relevance of government support for road projects etc. [1] There are 3 types of evaluation of efficiency of investments: public, commercial and budget [2]. Public evaluation puts emphasis on social and economic impact of a project for a public in general, commercial – on financial impact for its participants (investors), budget – on financial impact for federal, regional and local budgets. Public evaluation of efficiency is calculated for largescale projects, which have significant impact on economic, social and ecological situation in a country or on individual regions or industries (projects for public roads construction, reconstruction, capital and current repair). Commercial efficiency of roads construction and operation is calculated when funding source other than the public purse are used or toll road is planned [3]. Budget efficiency of roads construction and operation (in terms of revenues or expenses of budgets of corresponding level) is calculated when in case of government participation is needed.

*Analysis of recent studies and publications, which*

*considered aspects of this problem and on which the author is justified; identification of previously unresolved parts of the General problem.* The article is based on the works of domestic and foreign scientists and experts in the field of road construction and operation (Bernardo Villarreal, Jose Arturo Garza-Reyes, Vikas Kumar & Ming K. Lim [1]; Chengpeng Wan, Zaili Yang, Di Zhang, Xinping Yan & Shiqi Fan [3]; Merzlikin VG, Ilushin Ya.A., Olenin, AL, Sidorov OV, Tovstonog, VA [16] and others); involved industry regulatory [11; 12; 17] and methodological documentation [2; 4; 9; 12; 14; etc.].

**METHODOLOGY**

*Formation of the objectives of the article (setting the task).*

The purpose of the article is to develop a methodology for evaluating the efficiency of road operation and construction.

*Methods, techniques and technologies used in the research.* In the course of the study, general scientific methods and techniques were used: methods of micro- and macro-analysis, a combination of qualitative and quantitative approaches, comparative and system analysis.

**RESULTS**

*Presentation of the main research material with full justification of the obtained scientific results.*

*1. Calculation of key efficiency indicators for road construction and operations projects*

For evaluation of efficiency of road construction and operation projects, the following key indicators are used, based on the comparison of the costs and the results of their implementation: integral effect or net present value (NPV); investment return index (IRI); internal rate of return (IRR);

payback period [4].

Net present value (NPV) – is a sum of discounted net benefits flows, defined as the difference between results and costs over the entire payback period:

$$NPV = \sum_{t=0}^T (R_t - 3_t)(1+E)^{-t}, \quad (1)$$

where  $R_t$  – results from a project implementation on step  $t$  of a calculation;  $3_t$  – project costs on the same step;  $E$  – discount rate;  $T$  – time horizon (payback period for comparison of the options);  $T$  – number of a stage;  $(1+E)^{-t}$  – discount factor.

If NPV is positive, then a project is efficient (at the given discount rate) and it may be implemented [5]. If NPV is negative, then financial rate of return is lower compared with given discounted rate (rate of return). So, a project should be abandoned.

In practice, modified NPV formula is widely used [6]. It excludes discounted capital expenditures ( $K$ ), which are calculated in the following way:

$$K = \sum_{t=0}^T K_t(1+E)^{-t}, \quad (2)$$

where  $K_t$  – capital expenditures for step  $t$  of calculations. So, the NPV formula becomes the following:

$$NPV = \sum_{t=0}^T (R_t - 3^*_t)(1+E)^{-t} - K, \quad (3)$$

where  $3^*_t$  – costs for step  $t$  capital expenditures.

Investment return index (IRI) is a ratio of a sum of discounted effects to the value discounted capital expenditures

$$IRI = \frac{1}{K} \sum_{t=0}^T (R_t - 3^*_t)(1+E)^{-t} K \quad (4)$$

Value of IRI always exceeds 1 for the projects with positive NPV.

IRR is the interest rate for an investment project at which the net present value of all discounted effects equals discounted expenses [7]. The formula is the following:

$$\sum_{t=0}^T \frac{R_t - 3_t}{(1+IRR)^t} = 0. \quad (5)$$

IRR shows actual level of total investments costs. If  $IRR > E$ , then integral effect is positive and, thus, a project has sufficient level of efficiency. If  $IRR < E$ , then integral effect is negative and, thus, a project is not efficient. Payback period of investments ( $T_0$ ) is a minimal time period (since the beginning of a project), after that NPV remains nonnegative. Also, besides above mentioned main criteria of efficiency, for comparison of road projects the following indicators may be used: discounted costs (when their operational results are the same) and discounted effects (if the project costs are equal).

NPV is the most important indicator to measure the efficiency of a project. It takes into account all the revenues and expenses [8]. Other efficiency metrics are less representational as they do not have sufficient quantitative relations with all the conditions of an investment project (net present effects or expenses) or they do not provide clear economic interpretation of potential impacts of changes in the conditions (IRR, return index, payback period). Performance indicators of above mentioned formulas, expenses and discount rates depend on the type of efficiency evaluation [9] (Table 1).

In calculation of public efficiency, a discount rate is set in a centralized way, in calculation of budget efficiency – by a budget of a corresponding level, in calculation of commercial efficiency – by each actor (investor) itself.

Performance indicators of a road project and the conditions of its financial feasibility are determined on the base of

cashflow, elements of which depend on the type of efficiency evaluation.

Table 1 - Performance and costs metrics depending on a type of an evaluation of a road project efficiency

Result	Costs
Public efficiency	
Economic effects on transport and in the social sphere from their full or partial reproduction	Social costs of road works, calculated on the basis of so-called «economic» prices (net of taxes and other transfer payments)
Commercial efficiency	
Revenues of each project participant (a company, shareholders, bank etc.) from the invested capital	Real financial costs of road works, calculated on the basis of either market or administratively set prices
Budget efficiency	
Ratio of tax revenues of the budget of the corresponding level to direct budget allocations for a project implementation	The costs of road works are determined on the basis of real terms

Evaluation of commercial and budget efficiency of a road project must include its economic environment, including: forecasts for general inflation index and price change indexes for the whole payback period of a project; current tax system [10]. Calculation of predictive value indicators of a road project is made sequentially in accordance with the steps of the payback period given general price index (in case of homogeneous inflation) and price indexes for production and services (in case of inhomogeneous inflation).

General inflation index for step  $t = m$  is calculated in the following way:

$$I_{total} = I_0 I_1 \dots I_t \dots I_m, \quad (6)$$

where  $I_0$  – base inflation index (equals to 1, if zero tick is a start point);  $I_t = (1 + i_t / 100)$  – chain inflation index for step  $t$ , defining ratio of average prices levels at the end of the current and previous steps;  $i_t$  – inflation rate (%) at step  $t$ .

Price index for product (service) A is calculated in the following way:

$$PI_A = \prod_{t=1}^m (1 + k_{At} i_t / 100), \quad (7)$$

where  $k_{At}$  – ratio of heterogeneity of the growth rate of product A prices in relative terms of measurement for the step  $t$  of the calculation period.

Information about current tax system must contain full list of federal, regional and local taxes, related to activity of each actor of an investment project. For each tax the following parameters must be shown: tax base, tax rate, payment deadline, tax relief, tax allocation between the corresponding budgets.

2. Evaluation of a road network condition with respect to use for traffic

Main aim of road projects is to improve condition of a road network or its elements in terms of traffic and operations [11-15]. It can be measured by the following indicators: intensity and composition of traffic flows, average speed. These indicators are calculated for all the options of road projects, including 'zero option' (no project), given road conditions of motor traffic under options under consideration.

Indicators of general intensity and traffic composition of traffic flows are set for each time step of the comparison period. They may be calculated by various methods depending on available data and implementation conditions of project options: time serie forecasting (extrapolation), multifactor forecasting, forecasting based on gravity models, forecasting based on expert evaluation [16].

Regardless of selected method of forecasting of intensity and composition of traffic flows, their values at each step of payback period must be in certain range. Upper limit of the range should mean favorable conditions (optimistic scenario)

of a project implementation, and lower limit – the most unfavorable conditions (pessimistic scenario). Additional growth of motor traffic intensity caused by construction of a new road installation should be calculated similarly to actual increase of motor traffic intensity for comparable road projects, which were already built, or it should be defined by method of expert evaluation (if there are no comparable road projects available). While forecasting of shipping volumes and motor traffic intensity, the principle of comparability of options of location and capacity of motor roads should be followed – equality for all the options of passenger traffic and freight in the limits of load area of a road project [17].

### 3. Evaluation of commercial efficiency of road construction and operations projects

Commercial efficiency evaluation of a project is conducted in two stages. The first stage evaluates a project efficiency in general in order to assess potential attractiveness for potential participants and for search of funding sources. The second stage determines list of participants, financing structure, financial feasibility and efficiency level of participation for each participant. Commercial efficiency evaluation takes into account the following revenues from operations of road project on a fee basis: road toll, advertising, motor and roadside services.

Road toll is the most significant source of revenue. It should take into account improved comfort of a trip and users benefits arising from decrease of traffic handling costs due to shortened distance between destination points, cutting journey and driving time, fallen fuel consumption. Calculation of road toll may take into consideration higher requirements to features and conditions of toll roads in terms of motor traffic, decreased depreciation of a vehicle and tires due to improved road conditions, enhanced road safety and reduced risk of road accidents.

Evaluation of commercial efficiency of a road project includes not only the indicators, used for evaluation of public efficiency (based on projected market prices), but also one-time and current costs for organization of a toll road, and other commercial costs given all kinds of taxes as stipulated by current legislation. While evaluating commercial efficiency, break-up of a payback billing period should be done with the consideration of the following requirements: coincidence of the time periods of completion of construction of road structures or their individual structural elements with the end of the corresponding steps, which makes it possible to check the financial feasibility of a project at certain stages of its implementation; coincidence of periodicity of a project financing with start or end of the corresponding steps; matching step duration to a period of relatively stable prices (changes of prices should be not more than 5-10%). In general, evaluation of commercial efficiency is based only on calculation of two kinds of cashflows: operating and investing (Table 2).

Table 2 - Structure of cash inflows and outflows under evaluation of commercial efficiency of a road project

Inflows	Outflows
<b>Operating cashflow</b>	
Toll revenues; Advertising revenues; Revenues from road and motor service companies; Other revenues.	Costs of organization of commercial use of road installation; Operational maintenance and repair costs; Other costs
<b>Investing cashflow</b>	
Revenues from asset sales (including intangible assets) of a company, which provides commercial use of a road object; Decrease in working capital during all the steps of a payback period	Investments in the construction (reconstruction) of a road object; Increase working capital during all the steps of a payback period

Evaluation of efficiency of a road project must take into account its financing structure. So, it should also calculate financing cashflow. Loan proceed are calculated as inflows, while repayments on loans are calculated as outflows. All calculations are made in projected prices. Before calculating

efficiency indicators investing cashflow is adjusted (if necessary) in a way that provides financial feasibility of a road project (so, at each calculation step common balance of total cashflow should be non-negative). Adjustment is made by the addition of additional funds into investing cashflows, which are required to achieve positive balance of total flow.

Calculation of participation efficiency in a road project is made in the same way as evaluation of commercial efficiency in general. But the following features should be taken into account: investing cash outflows includes liabilities due to maintenance (working capital investments) and investments in additional funds; deflation of total cash flow from operating and investment activities. It is recommended to perform evaluation of commercial efficiency of a road project in general and for each of its participants via computer modelling. Algorithm of evaluation of economic efficiency of maintenance of public roads is presented in Figure 1.

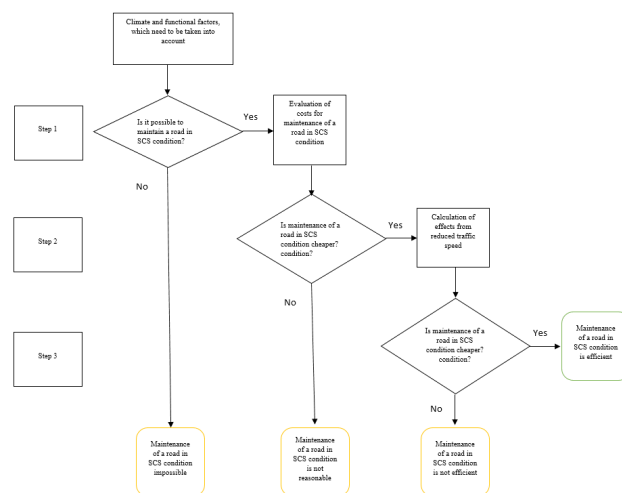


Figure 1 - Algorithm of evaluation of economic efficiency of maintenance of public roads

Climatic and functional ability to operate a road under compacted snow cover (CSC) is determined from the condition of availability of appropriate climatic factors, traffic intensity and traffic load level [18].

In evaluating economic feasibility of maintaining a particular road under compacted snow cover, calculation and comparison of the costs of winter maintenance is made.

For evaluation of efficiency of road maintenance under CSC economy of costs for maintenance under CSC should be compared with public losses, arising from reduced safe driving speed, in relation to keeping the road clean [19].

### SUMMARY

*Conclusions of the study. The findings of the study and prospects for further research in this direction.* All calculations for evaluating the effectiveness of road projects are greatly simplified by using computer models of the conditions for implementation of such projects [20]. As experience of developing feasibility studies and business plans for road projects demonstrates, Microsoft Excel is the most convenient tool to perform such evaluation.

Order of developing a computer model does not depend on the type of project efficiency being considered, nor on degree of detail of conditions for its implementation. It is unified for all types of road projects: new construction, reconstruction, major and current repairs.

*Prospects for further research in this direction.* Development of a computer model to evaluate efficiency of a road project allows to solve the following tasks: to define the degree of influence of individual parameters of a road project on resulting indicators of its efficiency; to evaluate the feasibility of taking into account various socio-economic consequences of its implementation; to determine the degree of influence of risk factors and uncertainties on conditions and results of road projects.



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