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Analyses of costs and benefits in the pavement management systems

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Abstract

The role of the economic analyses in the road management systems consists of supplying quantified information of the possible work alternatives of the maintenance and management, on the basis of which decision can be made, about those which provide for the most efficient financial investment. This paper will present some models of economic analyses in the road management systems.

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1. Introduction

The purpose of the analysis is to increase benefit by decreasing the costs. In fact, each cost can be viewed as an investment into a capital project or an investment in road maintenance. Costs can be analysied from the aspect of

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benefit increase in reference in the accepted standards and duration of investment. Each decision in favour of investment is unique with its irreversible features. It is normal to estimate the costs that could incur within the period of non-investment and compare them with those resulting from investment [1-6].

2. Cost reduction analysis

2.1 Inflation

The first step is the analysis of the inflation effect in order to enable for comparison of cost and profit value on the same basis in time. In most cases, it can be presumed that inflation would struck both cost and profit in future, and its effect can be ignored. However, there can be exceptions and, in such cases, different prices and costs can be supposed depending on the period of analysis.

2.2 Discounts

Also, it is necessary to estimate the costs and benefit in order to calculate different economic benefits of investments made in different stages of the design. Commercially invested money usually entails payment of a complex interest on the capital amount. Interest includes inflation, risk and real price of deferred benefit. For example, money used on one investment can be used elsewhere, where such investment can bring dividend. Using the capital for investment in such type of projects the investor renounces dividend and this can be taken into account in the analysis. Therefore, all costs on future projects are transformed into present cost values (Present Values of Costs – PVC) by the following formula:

$$PVC = \frac{c_i}{\left(1+\left(\frac{r}{100}\right)\right)^i} \tag{1}$$

c_i – costs in the year and
r – discount rate
i – year of analysis (for the basic year i = 0)

3. Comparison of alternatives

Cost analysis deals with comparison of possible alternatives envisaged by the projects in relation to the referent present condition. Comparison refers to realization of the alternative a as related to do the minimum. Sometimes the selection is reduced to just one possible alternative which closes the possibility to classify the others. This is known as mutual exclusivity and is a situation mostly dealt with by cost analysis. In fact, this refers to the selection of the best investment method. Sometimes the alternatives do not exclude each other, and the process becomes one of classification and determination of priority.

3.1 Net Present Value – NPV

Profit analysis is necessary in order to estimate whether an investment could bring positive results. In the decision-making process, this is achieved by the net present value. This criterion can also be used to help the analysis about which investment option would be the most profitable one. The net present value (NET) is simply the difference between the discounted profits and costs in the course of the period of analysis.

$$NPV = \sum_{i=0}^{n-1} \frac{b_i - c_i}{\left(1 + \left(\frac{r}{100}\right)\right)^i} \tag{2}$$

n- period of analysis related to the number of years
i- current year, i = 0 in the basic year
b_i- sum of all profits in the year and
c_i- sum of all costs in the year and
r- discount rate expressed in percentages

NPV is a measure of the economic efficiency of an investment. Its positive value indicates that the investment is economically justifiable for the given discount rate and the pure net profit in higher by the increase of NPV. Thus the selection should be based on NPV, meaning that priority should be given to projects where NPV is higher.

3.2 Internal Rate of Return – IRR

In spite of the fact that NPV is a very good criterion for the estimation of the investment suitability, its use is sometimes impossible. Thus, an organization as World Bank estimates hundreds of projects from different sectors in different countries. The use of NPV is all projects, in order to determine the best choice, is impractical. Instead, World Bank uses, for example, a decision-making rule termed Internal Rate of Return – IRR.

IRR is a discount rate at which the current values of cost and profit are equal. In other words, it is a discount percentage at which NPV = 0. The IRR calculation is not a direct one, as is the estimation of NPV, and it is established by solving the following equation in relation to r:

$$\sum_{i=0}^{n-1} \frac{b_i - c_i}{\left(1 + \left(\frac{r}{100}\right)\right)^i} = 0 \Rightarrow \sum_{i=0}^{n-1} \frac{b_i}{\left(1 + \left(\frac{r}{100}\right)\right)^i} - \sum_{i=0}^{n-1} \frac{c_i}{\left(1 + \left(\frac{r}{100}\right)\right)^i} = 0 \tag{3}$$

IRR does not indicate the cost and profit of one investment, but is rather a guide to the determination of its profitability. By increasing the value of IRR results in a better investment. If the IRR is beyond the discount rate in a country, than the investment is economically justifiable.

3.3 NPV/costs relation

One of the most frequent problems in the application of NPV is that, when all other indices are equal, the higher investment shall have the higher value of NPV compared to the lower one. This can create difficulties when several potential investments are compared in the conditions of budged limitations. The problem can be solved by considering the NPV/costs relation. It indicates the amount of return assets expectable by unit of investment, and therefore, is a measure of the efficiency of an investment. The value of the relation increases in the following cases:

- By increasing the NPV scope
- By reducing the costs.

In case of a limited budget, the most efficient investment is the one with the higher relation of NVP/costs. That investment is to be effectuated first, followed by the investments with the lower relation between NVP and the costs, until the budget is spent. This offers the possibility of NVP maximation in limited budget conditions. This approach enables for the effectuation of several lower investments that, in total, have a higher NVP as compared to one smaller investment.

4. Life Cycle Cost Analyses

4.1 Choice of investment

It should be emphasized that the money spent on maintenance of a road should be considered as investment, identical to those on construction of new roads. Therefore, a cost analysis like this one is the appropriate tool in deciding on the amount of maintenance costs. Also, it is especially important to consider the influence on the life cycle of the projects and the future investment flows resulting from the activity of road maintenance.

A rational choice of a project should take into consideration the present-time investments compared to the appropriate future costs. Accepting higher road maintenance standards usually leads towards higher investment costs but also towards lower road administration costs in the sense of later costs on maintenance and renewal. Such life cycle cost concepts are justifiable if the current costs of the road users are taken into consideration, as are the costs on vehicle use, costs in travelling time and costs related to road accidents.

If the life cycle costs are not taken into account, the investment decisions become subjective and depend on the application of standards which are based on historical events, and not on objective estimations.

4.2 Models of cost determination depending on the life cycle of the road

The increase of the scope of damage increases the need of maintenance, and thereby increase of costs. In case of damage, roads become worse, and the driving costs are higher as well. The travelling time and the traffic accident rate can also increase. Thus, the road user costs will be influenced by the road surface condition, which changes in time under the influence of maintenance measures. The road surface condition is also influenced by the building technology and standards, the traffic load, maintenance standards and environment. The increase of the number of vehicles which use the road, the increase of the axe load degrades the road. Anyway, the influence of climate and environment cannot be neglected. Considering all these factors, which adversely affect the pavement condition, several models of cost determination depending on the life cycle of the road have been developed in the world. The model from the HDM/RTIM model series is surely the best known one. Most of these models function as demonstrated on Picture 1 and Picture 2.

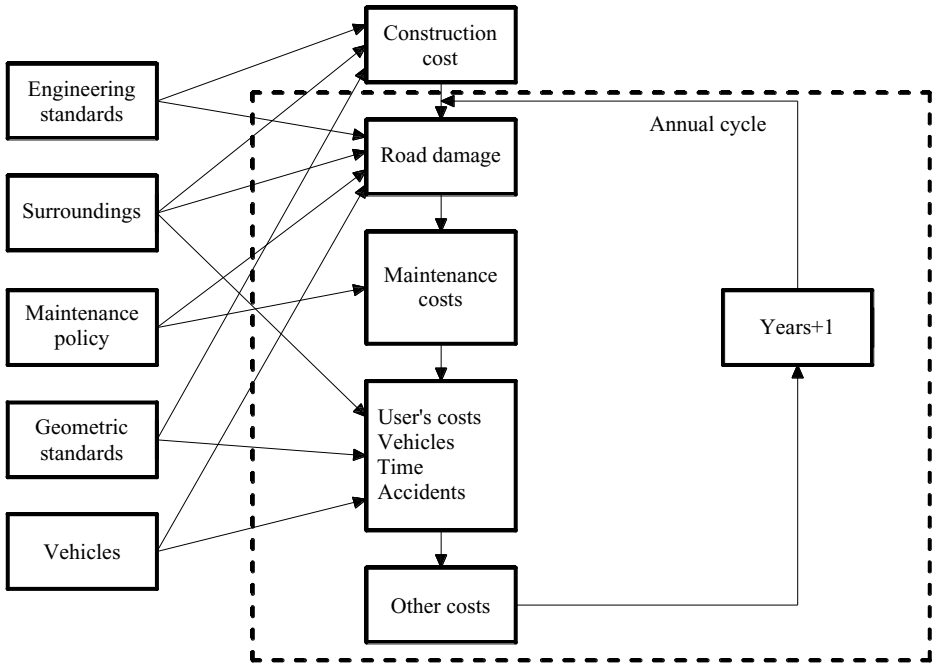

Fig. 1. Annual cost cycle.

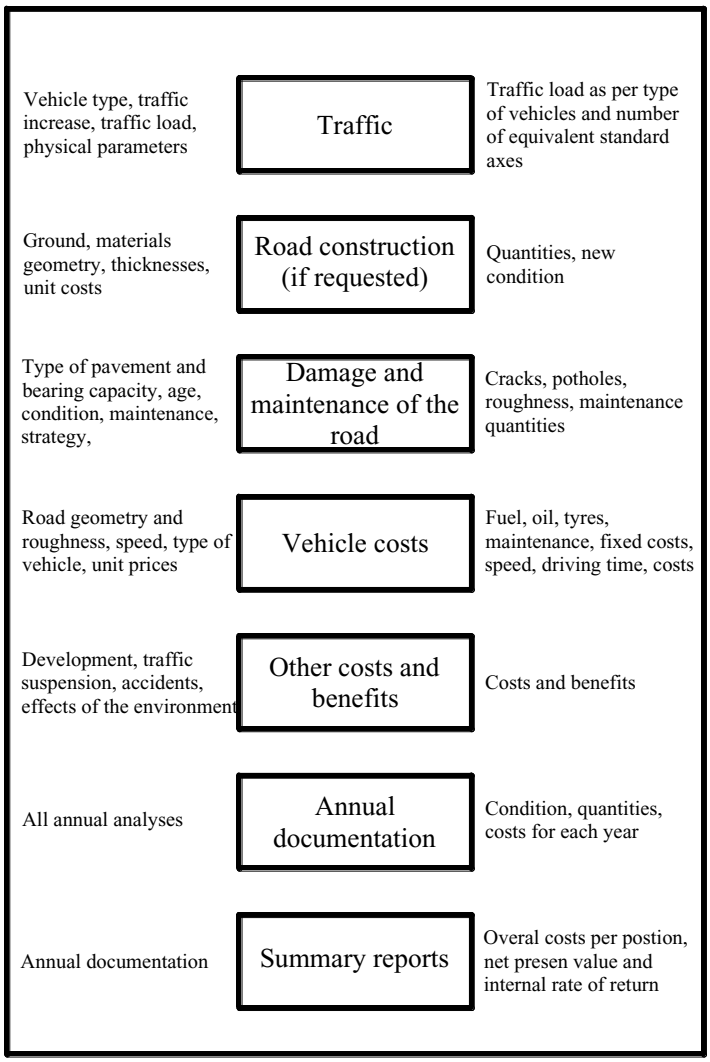

Fig. 2. Typical structure of the LCC model.

5. Conclusion

Economic analyses are essential from the viewpoint of planning of the sufficient funds for all activities envisaged within the management system and, ultimately, for making the correct decisions on the highest level of decision-making. As a whole, the management system cannot function without adequate cost-benefit analyses, that is, without Life Cycle Cost Analyses and appropriate comparisons of the invested funds and the profits.

The analyses conducted in Macedonia included 1500km of national and regional roads. As for the IRR value, the results demonstrated that regarding the traffic load and the level of road damage, the currently most cost-effective investments are the ones made in the maintenance of the existing roads. It can be concluded from Table 1 that the IRR of around 5.8km of national roads and approximately 395km of regional roads is lower than zero, and that the

length of the roads with IRR higher than zero is far overcoming, which contributes to the cost-effectiveness of maintenance investments.

Table 1. Lengths of the national and regional roads related to the IRR-value intervals.

IRR Intervals	National roads [km]	Regional roads [km]
<0	5.79	294.98
0-20	64.87	267.51
20-40	62.58	173.21
40-60	55.31	125.69
60-80	29.95	52.29
80-100	42.38	69.08
>100	13.75	31.38

References

[1] S. Ognjenović, Contribution to management of the sustainable quality condition of the pavement, Master thesis, Civil Engineering Faculty, Skopje. 6 (2007) 110-115.
[2] Project of the Regional Roads in Macedonia: Study of the Institutional Planning and Road Planning, BCEOM, 12 (2005) 65-87.
[3] Z. Radojković, Pavement Management System, Belgrade, 1990, pp. 256-290.
[4] R. Robinson, U. Danielson, M. Snaith, Road Maintenance Management (Concepts and Systems), The University of Birmingham and the Swedish National Road Administration. 234-244.
[5] E. Stannard, Getting Started with HDM-IV Version 2.0, The Highway Development and Managament Series. (2005) 35-62.
[6] M. Jocovic, B. Melovic, N. Vatin, V. Murgul, Modern business strategy customer relationship management in the area of civil engineering, Applied Mechanics and Materials, 678 (2014) 644-647