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SELECTION OF THE OPTIMAL TOLL COLLECTION SYSTEM FOR THE PURPOSES OF SUSTAINABLE DEVELOPMENT OF TRANSPORT IN THE REPUBLIC OF SRPSKA

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Abstract: *Transport system has multiple interactions and multidimensional effects on the environment, by way of, amongst other, land acquisition and urban pollution; on economic development with regard to the GDP growth; as well as on social equity in terms of access, quality of life and health of population. This paper considers the possibility of introducing toll collection in the Republic of Srpska. The goal of the developed model is to increase revenue, which could be directed to the sustainable development of transport in the Republic of Srpska. The selection of a toll collection system has been made taking account of: economic, traffic, technical, organizational and exploitation criteria. Multiple-criteria approach has been applied together with the Analytic Hierarchy Process.*

Keywords: *Toll collection systems, Multi-criteria approach, Analytic Hierarchy Process*

Introduction

The concept of sustainability, which is widely used in the field of planning, has been present since several decades ago. Sustainability has its general criteria and principles. As a rule, within a specific strategy or policy of sustainable development, several general and special principles and criteria are combined, the number of which depends on the level of decision-making and the specific problem to which they are applied. In order to make concrete decisions, it is necessary to define these criteria and principles, as well as to define the specific values and goals to which they refer. Development planning should be based on scientific knowledge and rationalism. It is logical that planning solutions must be sought through the examination of variants, which enables a wider offer in order to choose the best way of sustainable development for a certain geographical area, ie enables the choice between alternatives in order to achieve the desired goal.

Groups of people see the use of a certain space and the proposal of its development in different ways. Nevertheless, it is possible to form a set of values, which can be considered objective. The goal is to avoid decision-making according to intuition as much as possible, ie to rationalize the evaluation process as much as possible. This brings us to the idea of applying a popular approach to multi-criteria decision-making, the application of the Analytical Hierarchy Process (AHP) when considering the possibility of toll collection and choosing the optimal toll system for sustainable transport development in Republika Srpska.

Recently, highways, which represent a specific type of road transport, large capacity, intended exclusively for motor vehicle traffic, also form part of the Republika Srpska transport system. While highways as a creation, in the world, are present for a relatively short time (the first highway was built in 1924 in Italy), toll collection has been known since ancient

times and was widespread in the Roman Empire..

Decision making is often a complex problem due to the presence of competitive and conflicting criteria among the available alternatives. Analytical hierarchical process as an approach was developed by Thomas Saaty in the 1980s in order to solve multi-criteria decision-making problems.

The paper is conceived as follows. After the Introduction, the basic concept of the applied approach, Analytical Hierarchical Approach, is presented. Then, in the third chapter, the existing toll collection systems are defined. In the next chapter, a model for the selection of toll collection systems in the Republic of Srpska was developed. Also, part of this chapter are the results of the applied multi-criteria model, ie recommendations for the introduction of a certain toll collection system in the Republic of Srpska. Finally, the last chapter is devoted to concluding remarks.

1. Analytical hierarchical process - basic concept of approach

The AHP approach treats the problem of decision making as a hierarchy of elements important for decision making [5,6,7]. At the top is the goal, below are the criteria, at the bottom are the alternatives. If at least one of the criteria is decomposed into sub-criteria, a new hierarchical level is formed below the level of the criteria and above the level of alternatives.

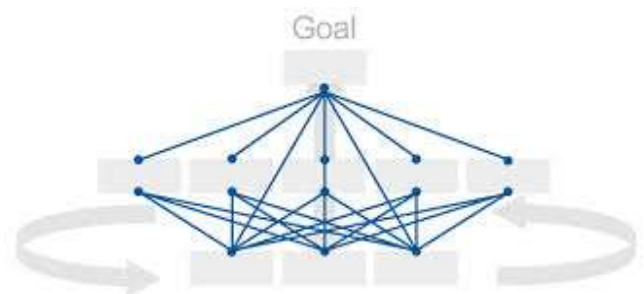


Photo 1. Scheme of the analytical-hierarchical process

The AHP requires that the criteria be compared first and that their relative weights be calculated in relation to the target. The alternatives are then compared in pairs with

respect to each criterion and their relative weights with respect to the criteria are determined by an analogous procedure. The result is vectors of relative weights of criteria and alternatives. Finally, the synthesis is performed and the final composite vector of the weight values of the alternative in relation to the target is determined. Apart from the hierarchical structuring of the problem, AHP differs methodologically from other methods in that the comparison is made in pairs of elements of the System, at a given level of hierarchy in relation to the elements of a higher level.

Analytical hierarchical approach has a number of advantages, such as: relative simplicity, intuitive approach, the possibility of using both qualitative and quantitative information in the decision-making process, matrices for comparing system elements by pairs, the possibility of group decision making, the possibility of calculating inconsistency index, the existence of user-oriented software, as well as a simple interpretation of the results. The biggest advantage of the AHP approach is its ability to identify and analyze the inconsistency of decision makers in the process of evaluating system elements. Of course, in addition to many advantages, this approach has some disadvantages, among which are the difficulties in applying this approach in the case of a large number of system elements (criteria and alternatives), due to the generation of a large number of comparison matrices by pairs.

2. Existing toll collection systems

Existing toll systems applied in European countries are heterogeneous and vary from country to country (Figure 2). The European Commission is trying to introduce more directives in this area with certain directives, both in terms of the type and system of collection, and in other non-harmonized issues. The main goal of the EU is interoperability, which is to be achieved by the policy "one market - one billing system"

through harmonized prices and vehicle categories.



Photo 2. Overview of highway tolls in Europe²⁷

It should be noted that the toll collection system at the national or regional level is analyzed, and not at the urban or separate infrastructure toll collection system. All these different systems are based on five basic characteristics, namely:

- Toll collection method (Multi-lane toll collection system with free flow of vehicles and Toll-based toll collection system)
- Billing Scheme (Distance Based and Time Based)
- System organization (Closed and Open billing system)
- Control (Control of collection based on ramps, Control of collection based on recognition of license plates and Control by authorized service - police)
- Billing technology (Manual billing and Electronic billing)

Model for selection of toll collection system in Republika Srpska

The highway is a public road specially built and intended exclusively for motor vehicle traffic, which is marked as a highway with the prescribed traffic sign, has two physically separate lanes for traffic from opposite directions with at least two lanes and a lane for forced stopping of vehicles, without intersection with transverse roads and railways or tram lines at the same level and in whose traffic can be included or excluded

²⁷ <http://www.vecernji.hr/naplata-autocestarina-u-europi-632250>

only by a certain and specially built connecting public road to the appropriate lane of the highway.

Highways are used to connect large cities and important economic areas of the country or region, are intended mainly for long-distance traffic, and are connected to the system of European highways. Highways meet the requirements related to the prescribed traffic-technical elements, or are being built in phases.

In Republika Srpska, the highway network consists of the following sections:

- Banja Luka - Gradiška (33 km);
- Banja Luka - Doboј (75 km), under construction.

Also, the plan for the development of the highway network for the next 20 years, the following sections are planned:

- Doboј - Modriča (47 km);
- Banja Luka - Mlinište (92 km);
- Modrica - Bijeljina - border with Serbia (91 km);
- Banja Luka - Prijedor - Novi Grad (72 km);
- Bijeljina - Zvornik - Foča - Trebinje (350 km);
- Pale - Rogatica - Visegrad - Vardiste (91 km);
- Ljubinje - Trebinje - border with Montenegro (71 km).

Elements of the developed model

When considering the criteria for the possibility of introducing toll collection in the Republic of Srpska and choosing the optimal toll system for the sustainable development of transport, the following groups of criteria should be taken into account: economic (total toll revenue, investment costs, operating costs), technical (toll system adaptability), interoperability of the billing system, modernity of the solution, possibility of control of the billing procedure, vulnerability of the billing system) and organizational criteria (organizational effort in exploitation and level of possible abuses).

From all the above, considering the possibility of introducing toll collection on the highway network in the Republic of Srpska, we come to a certain division of criteria in the process of multi-criteria decision-making, according to the following:

- K1 - implementation cost
- K2 - operating costs
- K3 - maintenance costs
- K4 - total income
- K5 - revenue dynamics (advance, continuous, cash-flow)
- K6 - risks (level of abuse, vulnerability)

Potentially, four different toll collection systems can be applied in the Republic of Srpska and they will be discussed below, and can be presented as follows:

- A1 - free system (current status)
- A2 - closed toll collection system
- A3 - open toll collection system
- A4 - vignette system

Model formation and results

The first hierarchical level contains only the goal, the second the criteria and the third the alternatives. In the Super Decisions program, the basic levels are formed first, with a description of the name. Then, we approach the creation of nodes in levels, their connection, or the creation of models. The next step is to compare the pairs of elements in the completed model.

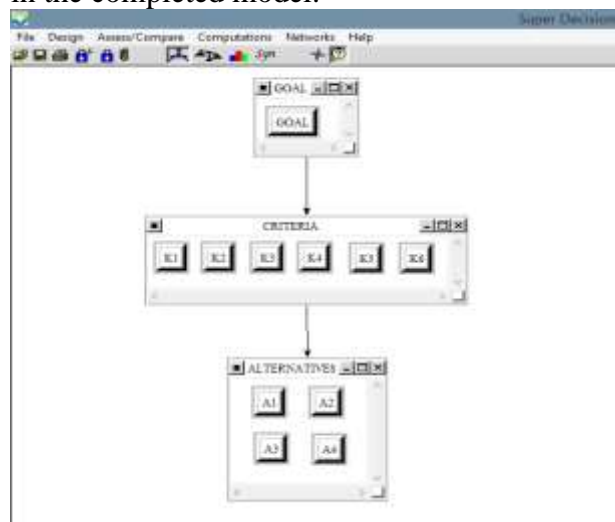


Photo 3. Model appearance

First, we compare the importance of individual criteria in relation to the set goal. The goal of the developed model is to

increase revenues that could be directed to the sustainable development of transport in the Republic of Srpska. The comparison of criteria, ie the definition of their relative importance, was performed on the basis of the fundamental Saaty scale [7], with grades from 1 to 9 (Table 1).

Table 1. Evaluation of criteria

	K1	K2	K3	K4	K5	K6
K1	1,00	0,20	3,00	0,14	5,00	5,00
K2		1,00	5,00	0,14	5,00	5,00
K3			1,00	0,11	1,00	3,00
K4				1,00	9,00	9,00
K5					1,00	3,00
K6						1,00

The final ranking of alternatives is presented in Table 2.

Table 2. Rank list

RANK	TOLL SYSTEMS	WEIGHT
1	A4 – VIGNETTE SYSTEM	0.321
2	A2 – CLOSED SYSTEM	0.270
3	A1 – CURRENT BALANCE FREE OF CHARGE	0.237
4	A3 – OPEN SYSTEM	0.172

Super Decision software for AHP analysis made it easy to obtain and verify results, as well as present it in a clear and legible way. In other words, it provides elements to support decision-making, by processing data in the process of multi-criteria evaluation of variant solutions.

Therefore, based on this analysis and simulations conducted by data processing, considering the possibility of introducing a toll collection system in the Republic of Srpska, a solution is imposed that it is necessary to introduce a toll collection system, and as an optimal solution offers alternative A4, which is a toll collection

system using the VIGNETTE. Also, by checking the consistency, it can be concluded that the obtained result is completely consistent.

3. Conclusion

The problem of choosing the toll collection system in the Republika Srpska was treated as a task of multi-criteria ranking of four alternatives, by considering six criteria, using the Analytical Hierarchical Process.

Each toll collection system is scored according to defined criteria, taking into account the importance of each of the different evaluation factors, in order to obtain a ranking of results that is least sensitive to changes in the weight of the criteria.

As a result of applying this method in considering the possibility of introducing toll collection in Republika Srpska and choosing the optimal toll system for sustainable transport development, ranking alternatives shows that the vignette is the best solution when taking into account economic, traffic, technical, organizational and operational criteria.

The vignette as a toll collection system is a very simple model, which is why they were introduced by almost all smaller European countries. Also, they have a certain advantage over other collection systems, first due to the simplicity of raising funds, which provides certain benefits for the budgets of each country through advance payments, then avoids possible congestion and delays due to collection, and achieves greater traffic safety.

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