



# 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 a few 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 they are applied to. In order to make complex specific decisions, it is necessary to define criteria and principles, as well as to differentiate the values and goals they relate to. Development planning must be based on scientific knowledge and rationalism. Therefore, planning solutions must be sought through the examination of variants, which enables consideration of the widest range of options in order to choose the best way of sustainable development for a specific geographical area, i.e. enables a choice between alternatives to achieve the desired goal.

Groups of people see the use of a certain space and the proposal of its development in different ways. However, in spite of that, it is possible to form a set of values, which can be considered objective. The goal is to avoid decision-making based on intuition as much as possible, i.e. to rationalize the evaluation process as much as possible. These premises provide opportunities for the application of a popular approach for multi-criteria decision-making, the Analytic Hierarchy Process (AHP), in

considering the possibilities of toll collection and choosing the optimal collection system for the purposes of sustainable development of transport in the Republic of Srpska.

Highways, which represent a specific type of road transport, of large capacity, intended exclusively for motor vehicle traffic, also form part of the Republic of Srpska transport system since recently.

And while highways as a creation have been present in the world for a relatively short time (the first highway was built in Italy in 1924), toll collection has been known since ancient times and was widespread as early as during the Roman Empire.

Decision making often represents a complex problem due to the presence of competitive and conflicting criteria among the available alternatives.

The paper is conceived in the following way. After the Introduction, the basic concept of the applied approach, Analytic Hierarchy Approach, is presented. After that, in the third chapter, the existing toll collection systems are defined. In the next chapter, a model for the selection of the toll collection system in the Republic of Srpska is developed. Moreover, one part of this chapter includes the results of the applied multi-criteria model, i.e. recommendations for the introduction of a specific toll collection system in the Republic of Srpska. Finally, the last chapters are devoted to concluding considerations.

## ANALYTIC HIERARCHY PROCESS - BASIC CONCEPT OF APPROACH

The AHP approach treats the problem of decision making as a hierarchy of elements important for decision making [7,8,9]. At the top is the goal, the criteria are at the next level, and alternatives at the bottom level. In case 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.

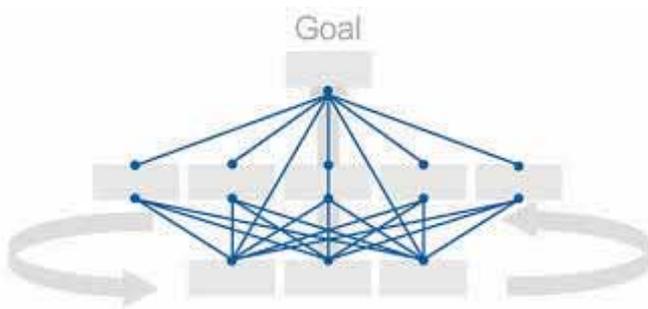


Figure 1: Analytic Hierarchy Process Scheme

AHP implies that the criteria are first compared with each other and that their relative weights in relation to the goal are calculated. The alternatives are then compared in pairs in relation to each criterion and their relative weights in respect to the criteria are determined through an analogous procedure. Vectors of relative weights of criteria and alternatives come out as a result. Finally, the synthesis is performed and the final composite vector of the weight values of an alternative in respect to the goal is determined. Apart from the hierarchical structuring of the problem, AHP also differs methodologically from other methods for the comparison is made in pairs of system elements, at a given level of hierarchy in relation to the elements of the higher level.

Analytic hierarchy approach has a number of advantages, such as: relative simplicity, intuitive approach, possibility of using both qualitative and quantitative information in the decision-making process, matrices, for comparing system elements by pairs, ability of group decision-making, simple calculation of inconsistency index, existence of user-oriented software just like simple interpretation of the results. The biggest advantage of the AHP approach is its ability to identify and analyse the inconsistency of decision makers in the process of evaluation of system elements. Of course, in addition to many advantages, this approach also has some disadvantages, among which, in particular, the difficulties in the application of 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.

## EXISTING TOLL COLLECTION SYSTEMS

The existing toll collection systems that are applied in European countries are heterogeneous and vary from country to country (Figure 2). The European Commission is trying, with certain directives, to bring more order to this field, both in terms of the collection type and system, as well as in terms of other non-harmonized issues. The main objective of the EU is *interoperability*, which is to be achieved by way of the "one market - one billing system" policy through harmonized prices and vehicle categories.



Figure 2. Overview of Highway Toll Collection in Europe

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

- Toll collection method (Multi-lane toll collection system with free flow of vehicles and the lane-based toll collection system)
- Toll collection scheme (Distance-Based and Time-Based)
- System organization (Closed and Open Toll Collection System)
- Control (Control of collection based on toll barriers, Control of collection based on license plate recognition and Control by authorized service - police)
- Toll collection technology (Manual toll collection and Electronic toll collection)

## MODEL FOR TOLL COLLECTION SYSTEM SELECTION IN THE REPUBLIC OF SRPSKA

A highway is a public road that is specially constructed and designed exclusively for motor vehicle traffic, which is marked as a highway with a prescribed traffic sign, has two physically separate carriageways for traffic from

opposite directions with at least two traffic lanes and an emergency lane, without any intersection with side roads and railway or tram lines at the same level, the traffic on which may be pulled into or pulled out of only through a specific and specially constructed public access road on the appropriate carriageway of the highway.

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

In the Republic of Srpska, the network of highways consists of the following sections:

- Banja Luka - Gradiška (33 km)
- Banja Luka - Doboj (75 km)
- Doboj - Modriča (47 km)
- Banja Luka - Mlinište (92 km)

Furthermore, the below-listed sections are planned under the strategy of development of the highway network for the next 20 years:

- Modriča - Bijeljina - border with Serbia (91 km)
- Banja Luka - Prijedor - Novi Grad (72 km)
- Bijeljina - Zvornik - Foča - Trebinje (350 km)
- Pale - Rogatica - Višegrad - Vardište (91 km)
- Ljubinje - Trebinje - border with Montenegro (71 km)

**Elements of the Developed Model**

In considering the criteria for the possibility of introduction of toll collection in the Republic of Srpska and selection of the optimal toll collection system for the purposes of sustainable development of transport, the following groups of criteria should be taken into account: economic (total toll revenue, investment costs, operating costs), technical (toll collection system adaptability, interoperability of the toll collection system, modern nature of the solution, possibility of control of the collection process, vulnerability of the collection system) and organizational criteria (organizational effort in exploitation and the level of possible abuses).

Based on the foregoing, in considering the possibility of introducing toll collection on the network of highways in the Republic of Srpska, the relevant criteria have been elaborated and differentiated and are presented below:

- K1 - implementation cost
- K2 - operating costs
- K3 - maintenance costs
- K4 - total revenue
- 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 that will be discussed further below, and they can be presented as follows:

- A1 - toll-free system
- A2 - closed toll collection system
- A3 - open toll collection system
- A4 - vignette system

**Forming of Model and Results**

The first hierarchical level contains only the objective, the second one contains the criteria and the third one contains the alternatives. In the *Super Decisions* program, the basic levels are formed first, with a description of the name. This is followed by the creation of nodes in the levels, their connectivity, i.e. the creation of a model. The next step is comparison of the pairs of elements in the completed model.

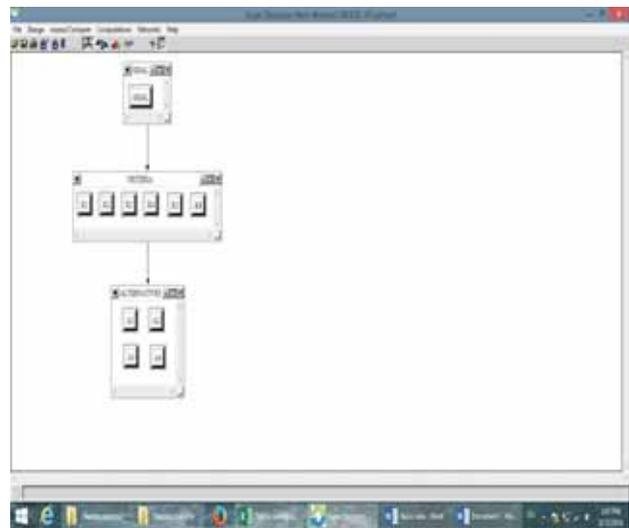


Figure 3. Appearance of the model

A comparison of the importance of specific criteria in relation to the set goal was made first. 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, i.e. the definition of their relative importance, was performed on the basis of the fundamental *Saaty scale* [9], with grades ranging from 1 to 9 (Table 1).

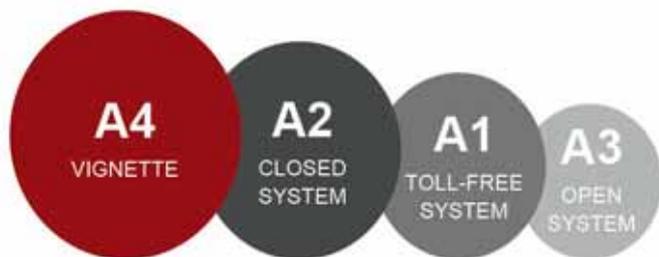
Table 1. Evaluation of Criteria

	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 provided in Table 2 and Figure 4.

**Table 2.** Ranking List

RANKING	TOLL COLLECTION SYSTEM	WEIGHT
1	A4 – VIGNETTE SYSTEM	0.321
2	A2 – CLOSED SYSTEM	0.270
3	A1 – TOLL-FREE SYSTEM	0.237
4	A3 – OPEN SYSTEM	0.172



**Figure 4.** Ranking view

*Super Decision* software for AHP analysis has made it easy to obtain and verify the results, just like to present it in a clear and elegant way. This approach provides elements to support decision-making, by adequate data processing in the process of multi-criteria evaluation of variant solutions.

Therefore, in considering the possibility of introducing a toll collection system in the Republic of Srpska, it has been shown, based on this analysis and the simulations conducted by data processing, that it is necessary to introduce a toll collection system, and the Alternative A4 is offered as an optimal solution, which is a toll collection system based on the use of vignette.

## CONCLUSION

The problem of selection of the toll collection system in the Republic of Srpska has been treated as a task of multi-criteria ranking of the four alternatives, by considering six criteria and using the Analytic Hierarchy Process.

Each toll collection system is scored according to the 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 the application of this method in considering the possibility of introduction of toll collection in the Republic of Srpska and the selection of the optimal toll system for the purpose of sustainable transport development, the ranking of alternatives shows that, taking into account economic, traffic, technical, organizational and exploitation criteria, the vignette system represents the best solution.

The vignette as a toll collection system represents a very simple model, which is why it has been introduced by almost all smaller European countries. Also, they have a certain advantage compared to other collection systems, first of all because of the simplicity of collection, which provides certain benefits for each country's budgets through advance payments, then avoiding of possible congestion and delays due to collection and, also, achieving of better traffic safety.

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## *IZBOR OPTIMALNOG NAČINA NAPLATE PUTARINE ZA POTREBE ODRŽIVOG RAZVOJA TRANSPORTA U REPUBLICI SRPSKOJ*

**Rezime:** Transportni sistem ima mnogostruke interakcije i multidimenzionalne efekte na okruženje, pored ostalog, zauzimanjem zemljišta i urbanim zagađenjem; na ekonomski razvoj, u pogledu rasta BDP-a; kao i na socijalnu jednakost, u smislu pristupačnosti, kvaliteta života i zdravlja stanovništva. U ovom radu se razmatra mogućnost uvođenja naplate putarine u Republici Srpskoj. Cilj razvijenog modela je povećanja prihoda koji bi se mogao usmeriti na održivi razvoj transporta u Republici Srpskoj. Izbor sistema za naplatu putarina izvršen je razmatranjem: ekonomskih, saobraćajnih, tehničkih, organizacionih i eksploatacionih kriterijuma. Primenjen je višekriterijumski pristup, Analitički hijerarhijski proces.

**Ključne reči:** Sistemi za naplatu putarine, Višekriterijumski pristup, Analitički hijerarhijski process