

Optimization of the toll collection system in the republic of srpska

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Abstract: Toll collection, as part of the source for financing the maintenance and reconstruction of existing and construction of new traffic infrastructure facilities, has an extremely significant place in the total costs of the mentioned processes. Therefore, it is extremely important to choose the optimal charging system and technology, which will satisfy the needs of users, as well as the needs of road managers and owners. The subject of this work are toll collection systems and technologies that are used in the world and in our country. The paper will analyze the open and closed tolling system, the zone or cordon system, the “HOV/HOT” system, and the network toll collection system, as well as the advantages and disadvantages of each of them. In addition, various toll collection technologies will be explored, including traditional, manual toll collection, electronic toll collection and vignettes, with a focus on more modern toll collection models and technologies. The main goal of the research is to compare the advantages and disadvantages of each of the toll collection systems and technologies in order to choose the optimal model of toll collection in the Republic of Srpska, which would satisfy all ecological, economic, traffic, security and sociological aspects.

Keywords: Toll, collection systems and technologies, collection optimization, toll collection in the Republic of Srpska

INTRODUCTION

The traditional way of paying tolls involves manual payment at toll booths. Although the payment of tolls can still be made in the traditional way, in cash, lately more and more people are switching to electronic toll collection systems. For this purpose, transponders are used, which are placed on the inside of the front windshield. Within the traditional method of toll payment, there are two basic systems for collection: open (the toll is collected only at one place on the highway, regardless of the section traveled) and closed (the user’s presence is registered at the entrance to the system, and the collection is performed at the exit from the highway). In the open and closed toll collection system, with traditional, manual toll collection, all vehicles stop at the toll ramps to pay the toll.

In contrast, with electronic tolling, the toll is collected without stopping the vehicle.

In addition, there are also the zone or cordon system, the “HOV/HOT” system and the network billing

system. Modern highways usually combine all types of toll collection systems.



Figure 1: Toll collection

Some countries have a sufficiently developed standard, and in addition, a high level of motorization and a huge number of vehicle kilometers, that is, a huge traffic

of oil and oil derivatives, from which they finance their highway networks, and they are not forced to charge tolls on them. Unlike them, less developed countries, including Bosnia and Herzegovina, that is, Republika Srpska, are forced to charge tolls, so that the entire system of highways in them is sustainable.

RESEARCH METHODOLOGY

Several scientific methods were used within the thematic research, primarily methods of analysis and synthesis of materials from relevant domestic and foreign texts in the field of the toll collection system. By processing the previous materials and sources, an outline list of literature was given. The optimal toll collection system was defined by the deductive method, which influenced the final considerations, in terms of the realized advantages of the electronic toll collection system, as well as the advantages of the introduction and development of new toll collection technologies.

The causal method is useful for establishing cause-and-effect relationships between the advantages and disadvantages of the toll collection system. The systemic and comparative method was used for the overall evaluation of the function of the electronic toll collection system. When comparing the existing system and the introduction of new electronic toll collection technologies, a comparative method was used.

RESEARCH RESULTS

Modern toll collection systems, in addition to being economical in the business of companies - highway managers, have the purpose of increasing the flow of vehicles, reducing congestion and obtaining higher financial indicators. Modern technologies of one type of transport are less and less a special feature today, and more and more a feature of the common technology of all types of transport. The technology of free flow of vehicles is a new type of technology that allows vehicles to pass through toll booths without reducing their speed. Users no longer need to own a transponder, because the system scans their registration plate with the help of implemented optical character recognition technology.

Toll collection systems

Toll collection theory and practice know open systems, closed systems, zone or cordon systems, HOV/HOT systems and network toll collection systems. There are countries that do not collect tolls, that is, using the highway is free. These are economically developed countries, with a high degree of motorization, which finance their highway networks from registrations, oil and oil derivatives traffic, and other sources.

Open toll collection system

An open toll collection system can save money because there is no need to build more toll ramps, because the toll ramp is located only at one end of the road, but this type of system can cause traffic congestion and crowds at the toll point. It is also possible for cars to enter the highway and exit before the toll booth, thus allowing them to use certain sections of the highway for free. Therefore, roads with an open toll collection system have certain loops or ramps with controlled access, in order to prevent the possibility of bypassing the toll booths.

Closed toll collection system

With a closed toll collection system, toll ramps are located at both ends of a certain section of the highway (entrance/exit), and also, all bends on the highway have toll ramps, in order to prevent the possibility of free use of some sections. In the closed system of toll collection, drivers take the card at the entrance to the highway, on the ramps adapted for that purpose. Users present this card at the exit ramps, where the toll amount is calculated based on the length of the section covered. If the user loses the card, he is usually charged the amount of toll he would have paid if he had driven on the longest section of that highway. Within both systems, there may be a combined variant of electronic toll collection. Electronic toll collection - ETC - allows the user to quickly and efficiently collect tolls, without the mediation of cashiers and waiting at toll booths.

Zone or cordon toll collection system

This toll collection system is used mainly to manage traffic flows in more urban areas. First of all, it is applied in the central parts and zones of the city or in areas that require greater environmental awareness (protected areas, national parks, etc.). Examples of the application of this system are in metropolises such as: Milan, London, Singapore, Stockholm... Cordons do not always have to function on the basis of paying to pass through the zone, but can allow certain users to pass or access the zone without paying. An example of this is the tenants of certain zones or the owners of business premises in those zones. The price of the toll in the zonal system is most often a function of achieving the appropriate environmental goal. Most of these systems usually use some of the non-stop billing technologies, in order to prevent queues, congestion, and all their negative effects.

"HOV/HOT" toll collection system

The "HOT" system ("High Occupancy Toll lane") is a charging system developed on the basis of "HOV" traffic lanes ("High Occupancy Vehicle lanes"), which include lanes intended for vehicles with more passengers. This system is mostly used in the United States of America. In addition, it is also used in Israel, while its use in the rest of the world is negligible. The difference

between the HOV and HOT lanes is that the HOV lane can only be used by vehicles with a higher number of passengers than prescribed for that lane, while the HOT lane can be used free of charge by vehicles with a higher number of passengers than prescribed for that lane, and vehicles with a lower number passengers pay a toll for using those lanes. These lanes are usually separated from the rest of the traffic.

Network toll collection system

The network toll collection system system allows for different pricing depending on the road rank or the congestion charging policy. It enables toll payment according to the volume and quality of the road network used by the driver. In Europe, there are several examples of its application, but it refers primarily to the network of highways and expressways. By applying this system, it is possible to introduce charging for entry into certain sections or charging for congestion on city roads. This type of system usage is still not sufficiently developed and has not yet been fully implemented anywhere.

Toll collection technologies

Toll collection is possible in cash, payment cards, and in lanes with electronic payment, payment is made cashless and without stopping using a TAG-device. In addition, there are modern toll payment technologies, such as toll machines, vignettes, "DSRC" with barriers, "MLFF" technology, "BAR-code" technology, "RFID" technology, "GNSS/CN" technology, "ANPR" " technology, "Infrared" technology, "Tachograph" technology, "Smart card" technology, "Smartphones" technology... Traditional methods of toll payment were used massively until the end of the last century. However, with the development of new technologies, the possibility has opened up for the development of new toll collection systems.

Manual toll collection

Experience so far has shown that with the traditional, manual, method of toll collection, traffic flows slow down significantly, crowds and traffic congestion increase. Therefore, since 2006, the introduction of payment systems based on wireless technology, i.e. the Electronic Toll Collection system, has started.

The transition from the traditional, conventional method of collection to electronic toll collection is becoming more and more intensive both in the whole world and in our country. Along with the existing open and closed tolling systems, at least one or more separate traffic lanes for electronic toll collection are being built. If there is no physical possibility to build an additional traffic lane for electronic tolling, the existing manual tolling lanes are used as combined lanes, in which there is a possibility for both manual and electronic toll collection.

Electronic toll collection

Electronic Toll Collection (ETC) systems support the collection and processing of toll transactions without requiring the driver to stop and pay manually, increasing operational efficiency and convenience for highway travelers. ETC systems operate either as an integrated multi-state system, such as the E-Zpass system, or as a stand-alone state toll system, such as the Oklahoma Turnpike System. ETC can reduce fuel consumption and emissions at toll booths by reducing delays, queuing, and idling. The transit toll system can provide greater convenience to customers and generate significant savings for transportation agencies by increasing the efficiency of handling processes and improving administrative control. Public transport users can choose different products, such as magnetic strips (read only or write and read), smart cards with different levels of memory and processing power, or use credit cards to pay for transport. Toll machines can read and write to different types of media and products, and regional processing centers can consolidate financial information and simplify the management of toll transactions for higher-level agencies. Billing systems can be used in the coordination of human services transportation, linking the reservation system to a payment system that tracks the billing of various mobility programs depending on the client's eligibility. (Drašković, 2017)

Electronic toll collection (ETC) is a collection method without the intervention of a cashier, and the toll collection process takes place using an ETC device located on the windshield of your vehicle and an antenna on the toll road. TAG-devices, with which the electronic toll collection service is used, can be downloaded by users at the "Jakupovci", "Čatrnja", "Prnjavor", "Kladari" and "Kostajnica" toll stations. (Highways of RS, 2019)

Electronic toll collection (ETC) is a wireless system for collecting fees for the use of highways, tunnels, bridges, and other traffic facilities. This way of paying the toll is much faster than the traditional way, where the vehicle has to stop and the driver manually pays the toll with cash or a payment card.

Electronic toll collection is a collection system where vehicles pass through the entry/toll lane without stopping. It is a contactless payment system. Between the radio device, which can be battery-powered, and which is most often placed on the inside of the front windshield, an automatic transaction is performed with the short-range communication system, whose antenna is installed on the canopy above the entrance/toll lane.

In most electronic toll collection systems, vehicles are equipped with an automated radio device, a transponder. When a vehicle with a transponder passes by a vehicle reading device, a radio signal from the vehicle registration antenna excites the transponder, which returns a signal with vehicle data, as well as data on the vehicle's movement path on the highway section in ques-

tion, and based on that, the electronic system charges it the toll by removing the appropriate number of pulses from the transponder, which is proportional to the length of the road section traveled.

The main advantage of this method of toll payment is that there is no stopping of the vehicle, which reduces the loss of time and minimizes traffic delays, and in addition, it greatly contributes to the increase of traffic safety, because traffic congestion is reduced, and the possibility of traffic accidents is also reduced.

Electronic toll collection is cheaper than toll collection, because the use of electronic tolling reduces the transaction costs of road owners. This system requires users to top up their account with the desired amount of money in advance, so that the appropriate amount of toll is deducted from that account, every time the vehicle passes through the toll booth, and in accordance with the length of the highway section traveled.

Electronic toll collection is an increasingly popular way of collecting fees for the use of traffic infrastructure facilities, because it, among other things, reduces traffic bottlenecks caused by the slowing down and stopping of vehicles that pay the toll manually. There are also electronic payment systems that function on the principle of automatic recognition of vehicle license plates, and based on the data recorded at the entrance and exit of the highway, the amount of toll that the user needs to pay is calculated, and the bill arrives at his home address, or the bill can be paid online or by phone.

Combined toll collection technology

In addition to the previously mentioned technologies, there is also a combined method of toll collection, which involves a combination of the previously mentioned technologies, and which is very often used in practice.

Electronic toll collection can be combined with traditional, manual toll collection, so that drivers who do not have a transponder, or who have a transponder but do not have enough credit on it, can pay the toll (Figure 2).



Figure 2: Symbols of electronic and manual toll collection

DISCUSSIONS

So far, about 112 kilometers of highways have been built in the Republic of Srpska. First, the section from Banja Luka to Gradiška was built, with a length of 33.7 kilometers, which was put into traffic in 2011. The section from Prnjavor to Doboj, 36.91 kilometers long, was put into traffic at the beginning of 2017, so that the complete highway "9. Januar", as the highway connecting Banja Luka and Doboj is called, and whose length is 72 kilometers, and part of which is the section from Prnjavor to Doboj, opened for traffic at the end of 2018. The last to open to traffic was the section Johovac-Rudanka, with a length of about 8 km, which is part of the international corridor "5c".

In March 2015, the Public Company " Republic of Srpska Motorways" started collecting tolls on the section of the highway from Banja Luka to Gradiška. The system was conceived as open, with one front toll station in the town of Jakupovci (Laktaši municipality), within which there was also the possibility of electronic toll collection. The toll was charged in accordance with the Rulebook on toll collection, which provided for the division of all vehicles into four categories, depending on the number of axles and the height above the front axle of the vehicle. Along with the collection in Jakupovci, with the completion of the construction of the highway section "9. January", from Prnjavor to Doboj, in December 2016, tolling on the mentioned section began. The toll stations in Kladari (Doboj) and Prnjavor were organized as open system toll stations, with the possibility of electronic payment. This system was maintained until November 2018, i.e. until the completion of the section of the highway from Banja Luka to Prnjavor, which completed the complete highway "9. January", when it was switched to a combination of open and closed tolling system, on the highway network of Republika Srpska. The open system was maintained on the section from Banja Luka to Gradiška, while on highway "9. January" payment was made in a closed system.

Experience has shown that the open tolling system was not fully effective, because users could enter the highway in Čatrnja (Gradiška), use more than 20 kilometers of the highway, and bypass the Jakupovci toll station, by turning off the highway via the Mahovljanska loop, or via one of the previous two exits from the highway (Nova Topola and Aleksandrovac), then via Laktaš to return to the Banja Luka Gradiška highway, and to use the aforementioned sections of the highway for free.

In November 2019, the collection system was closed on all sections of the Republika Srpska Highways, which is still in effect today, and into which the collection of tolls on the section of the "5c" corridor, from Johovac to Rudanka, was integrated, after it was put into traffic. Payment is made per kilometer of the highway, according to the valid toll price list, adopted by the Government of the Republic of Srpska.

Toll collection in Republika Srpska is carried out by kilometers traveled, that is, it is based on the “distance-based (DB)” approach. The price of tolls in the Republic of Srpska is generally cheaper compared to the price of tolls in the countries of the region, and for the first toll category of vehicles, which includes passenger cars (PA), the toll price per kilometer is 0.10 KM.

Multi-criteria tariff model

The problem of choosing a toll collection system in the Republic of Srpska was treated as a task of multi-criteria ranking of four alternatives, considering six criteria, using the Analytical Hierarchy process. Each toll collection system is scored according to defined criteria, taking into consideration the importance of each of the different evaluation factors, in order to obtain a ranking of results that is the least sensitive in relation to the change in the weight of the criteria. As a result of the application of this method in the consideration of the possibility of introducing toll collection in the Republic of Srpska and the selection of the optimal collection system for the purpose of sustainable development of transport, by ranking the alternatives it is obtained that the vignette system represents the best solution when economic, traffic, technical, organizational and operational factors are taken into account eligibility criteria. The vignette as a toll collection system is a very simple model, which is why they have been introduced by almost all smaller European countries. They also have certain advantages over other billing systems, first of all due to the simplicity of collecting funds, which provides certain benefits for the budgets of each country through advance payments, then avoids possible crowds and delays due to billing, and achieves greater traffic safety. (Injac, Macura, & Bojović, 2014)



Figure 3: Vignettes

Vignettes (Figure 3) are applied in the countries of Central and Southeastern Europe, namely: Bulgaria, Hungary, Moldova, Romania, Slovakia, Slovenia, Austria, the Czech Republic and Switzerland. European directives provide for the abolition of vignettes and the transition to the single EETS electronic toll market. A vignette implies that occasional users have to stop, park their car, get out and buy a vignette, which is then stuck on the windshield, which takes a lot of time, and drivers are often forced to turn off the road to buy a vignette,

which creates an additional road. Also, drivers are subject to stops during the journey to check the correctness and validity of the vignette. (Glavić, 2016)

Hybrid tariff model

The hybrid tariff model is a combination of payment based on time and mileage, adapted to specific groups of highway users. By introducing a defined hybrid tariff system, the so-called “win-win” situation both for the highway user, as well as for the driver and society as a whole. In other words, by applying the hybrid tariff model of toll collection, all interest groups would have certain benefits. Although the highway provides users with a higher level of service, greater safety and shorter travel time for the same distances, previous research indicates that a significant number of users prefer free, alternative routes, which are not their primary choice for the “additional costs” of toll collection. Implementation of the trip. Avoiding the use of toll highways has a significant impact on users, road managers and society as a whole. The road manager aims to achieve as much revenue as possible from toll collection by increasing the number of highway users. Also, it is in the interest of the road manager that there are as few users as possible on the alternative secondary network, especially users of commercial vehicles, so that the damage to this infrastructure is as small as possible, and thus the costs of reflecting the road are lower. Accordingly, the main goal of the road manager is to retain existing users, with a constant effort to attract users who would naturally use the highway due to their requirements, but do not do so because of the toll collection. From the user’s point of view, the economic dimension implies the costs incurred by users when using certain road infrastructure. In the case of using the highway, the user’s costs are first of all reflected in the costs of the toll and the costs of travel time and the exploitation of motor vehicles. Users of the secondary alternative road network do not have toll costs, but due to the inferior technical exploitation characteristics of the road, the costs of travel time and exploitation of motor vehicles of these users are often higher, compared to the costs of highway users. In addition to the road manager and the users themselves, certain costs are borne by society as a whole. Namely, the use of an alternative secondary network, due to the worse technical exploitation characteristics of the road, entails higher costs of traffic accidents, emissions of pollutants, noise, etc. A hybrid tariff model would entail a combination of toll payments based on time/mileage and adapted to specific groups of highway users. From the user’s point of view, toll collection on a monthly and annual basis at more favorable prices is an adequate solution for everyday users. In this way, this group of users is enabled to use toll roads, and thus avoid local roads of poor quality, which reduces the deterioration of local roads, reduces vehicle operating costs and pollut-

ant emissions. On the other hand, the road manager will increase his income, which can be used to improve the level of service and traffic safety. Having this in mind, the road manager must take these findings into account and offer the group of users who avoid using the highway a specific compensation scheme through a hybrid model. Such a hybrid model would imply a combination of toll collection based on time and kilometers traveled as an optimal solution for both road managers and users. This hybrid model of tolling represents the potential for a successful compromise between road managers who aim to minimize the number of users who avoid using the toll highway and thereby maximize toll revenue, and users whose goal is to maximize the use of the highway at an acceptable cost. (University of Belgrade, 2022)

CONCLUSION

The choice of the toll collection system (which should be optimal at a given moment) is extremely important, in order to avoid possible economic, traffic, environmental, security and social problems. An appropriate balance must be found when choosing a tolling system, because the chosen system must adequately meet the needs of both road managers and road users.

In this paper, the advantages and disadvantages of individual toll collection systems are analyzed, with reference to newer technologies applied in this area, and some systems are proposed that would lead to the optimization of the toll collection system in the Republic of Srpska. With the introduction of electronic toll collection technology, all the disadvantages of traditional, manual collection have been largely reduced, if not completely eliminated. It can be said that the electronic toll collection system has as its primary goal the avoidance of vehicle waiting in toll queues, increasing the flow of vehicles, simplifying collection, reducing environmental pollution and reducing the number of traffic accidents. The introduction of the electronic toll collection system has in practice shown a reduced efficiency of the system in unfavorable weather conditions (fog, moisture). The paper also shows the advantages of introducing vignettes, which greatly improved toll collection compared to previously used systems, but even this system is not ideal, so European directives foresee the abolition of vignettes and the transition to a single market of electronic toll collection with the most modern technologies.

There is a tendency to introduce new, more modern technologies, which have much greater efficiency, and which would remove all the shortcomings of electronic tolling and vignettes and improve the entire toll collection system. An example is the technology of free flow of vehicles, but it has not yet taken root in wide application, both in the world and in our country.

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