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THE PROS AND CONS OF THE INTELLIGENT TRANSPORTATION SYSTEM IMPLEMENTATION AT TOLL PLAZAS IN RUSSIA

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THE PROS AND CONS OF THE INTELLIGENT TRANSPORTATION SYSTEM IMPLEMENTATION AT TOLL PLAZAS IN RUSSIA[6]

The implementation of Intelligent Transportation System elements into the toll plaza system is an actual topic nowadays and its positive effect is the subject of wide speculations. It is considered that the toll plaza Intelligent Transportation System can play a significant role in construction and operating costs reduction and improve the traffic safety. Also, the implementation of the Intelligent Transportation System elements provides the CO_2 emissions reduction and increases the level of toll road user satisfaction. However, the usage of these elements at toll plazas has some disadvantages. While the usage of the old-school (manual) toll collection technology provides 100% toll collection rate, the implementation of the Intelligent Transportation System elements at toll roads entails toll payment deficiency. Discussion as whether to use the old technology or to implement the Intelligent Transportation System elements is the right way to operate toll roads and toll plazas forms a point of departure for this paper.

This article focuses on the economic, social and environmental effects of the implementation of the Intelligent Transportation System elements at toll roads. Almost all kinds of positive and negative effects of the Intelligent Transportation System elements implementation are evaluated in money terms and made on the basis of author's calculations and sociological researches data.

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Keywords: toll road, Intelligent transportation system, toll collection, Russia, environmental effect.

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Introduction

Toll roads in Russia: current situation and the proposals on implementation of the Intelligent Transportation System elements

Nowadays all the toll roads in Russia are operated both manually and electronically. Payments are collected at the charging points which are situated at the entrance to the toll road. In order to increase the traffic capacity there are usually more traffic lanes on the charging points than on the usual road sector. Payments could be made manually to the cashiers-operators or electronically using transponders-cards. Currently only 8% of payments are made electronically[8]. Thus, the most common toll collection technology in Russia is the manual charging by the cashier-operator.

This toll collection method entails a number of negative effects:

- High toll plaza construction costs, including additional land costs, construction costs, infrastructure engineering costs, etc.
- High operational costs, including salaries for the cashiers-operators etc.
- The vehicles have to stop at each toll plaza, leading to a traffic congestion and time losses.

Summarizing the characteristics of the current toll collection technology, we are able to conclude, that its main advantage is the provision of 100% toll collection rate. At the same time the main disadvantage of the current technology is the high costs for the state (high construction and operational costs) and time losses for society as well as for road users.

Nevertheless, there is an alternative toll collection technology, which includes the elements of Intelligent Transportation System. This technology provides free traffic flow and non-stop passage through the toll plaza because of the usage of automatic vehicle number recognition system through cameras and electronic toll collection systems such as transponders, electronic smart cards, payment via Internet, SMS etc. Since this type of technology provides more freedom in case of the toll payment rules violation, the administrative penalty for unpaid trips should be implemented to ensure the payment.

Apparently, both toll collection technologies have its advantages and disadvantages. This paper focuses on the analysis of positive and negative effects of Intelligent Transportation System elements implementation in toll collection activity. The purpose of this article is to evaluate costs and benefits of Intelligent Transportation System elements implementation and to provide a conclusion about its expediency.

Section 1 describes the foreign experience and presents the research methodology. In Sections 2-4 the research results are presented: Section 2 is devoted to the economic effects, Section

[8] Here and further the data is provided by the toll road operator in Russia "Avtodor"

3 – to the social effects and Section 4 – to the environmental effects. Almost all effects have been evaluated in money terms.

Background and research methodology.

The Intelligent Transportation System elements at the toll plazas are actively implemented worldwide. For example free flow technologies are used in Norway (Hensher, 1989), Taiwan (Chen, Fan, Farn, 2006; Tseng, Lin, Chien, 2014), South Korea, Spain (Perez-Martınez, Ming, Dell'Asin, Monzon, 2011), England and Italy (Lee, Tseng, Wang, 2008). Electronic Road Pricing System based on a free flow principle is also used in road congestion managament in Singapore: motorists are charged when they use toll roads during peak hours (Santos, 2005). Also, in Melbourne all tolled motorways have electronic tolling as well (Athanassiou, Bagchi and Bates, Steer Davies Gleave, 2005). Melbourne hasn't had the old fashion 'stop and pay' tolling since the 70's. Lots of scientists have investigated the effects of the Intelligent Transportation System elements implementation for toll collection. Among the positive effects foreign researchers mention the following:

- reduction of construction and operational costs of the toll collection system (Hensher, 1989) including the salary expenses (Lee, Tseng, Wang, 2008; Saffarzadeh, Rezaee-Arjroody, 2006)
- increase of traffic capacity (Hensher, 1989)
- time losses reduction for drivers (Tseng, Lin, Chien, 2014; Saffarzadeh, Rezaee-Arjroody, 2006)
- reduction of traffic congestion (Chen, Fan, Farn, 2006) (Vats, Vats, Vaish, Kumar, 2013)
- reduction of service time (Diaz, Mappala, Sigua, Madrigal, Palmiano, 2005)
- increase of traffic safety (Chen, Fan, Farn, 2006)
- additional opportunities for e-commerce (Golob, Regan, 2001)
- reduction of fuel consumption (Kenworthy, Rainford, Newman and Lyons, 1986; Tseng, Lin, Chien, 2014; Saffarzadeh, Rezaee-Arjroody, 2006)
- reduction of carbon dioxide emissions (Newman and Kenworthy, 1984; Tseng, Lin, Chien, 2014; Coelho, Farias, Rouphail, 2005; Bartin, Mudigonda, Ozbay, 2011; Perez-Mart, Ming, Dell 'Asin, Monzon, 2011; Bartin, Mudigonda, Ozbay, 2006) and other substances emissions (Bartin, Mudigonda, Ozbay, 2011)
- user satisfaction growth (Saffarzadeh, Rezaee-Arjroody, 2006).

This paper contains the evaluation of the economic, social and environmental effects of the Intelligent Transportation System elements implementation at toll plazas.

To evaluate the economic impacts the construction and operational costs, time losses and toll collection rates have been analyzed. The impact on traffic safety and user satisfaction was examined to evaluate social effects. Finally, the emissions of carbon dioxide and other emission substances were calculated to assess the environmental impact.

Following methods were used to conduct the analysis of the effects:

- Calculations based on toll plaza data provided by the toll road operator “Avtodor”. Using this data, the economic, environmental and social effects of the Intelligent Transportation System elements implementation at toll plaza have been calculated.
- Sociological research, i.e. quantitative survey via Internet using programmed formalized questionnaire. Target groups consisted of the residents from Moscow, the Moscow region, Voronezh, Lipetsk and Rostov-on-Don, who have used highway M4 "Don" toll plazas within the last 12 months. The sample size was 1 305 respondents. Using this data the Intelligent Transportation System implementation impact on the toll roads has been calculated.

The effects were examined for one toll plaza at first and then extrapolated for all toll plazas. The data for toll plaza 48-71 at the toll section of M-4 "Don" highway, which consists of 29 toll collection lanes, was used, since the data about this toll plaza is the most complete and correct due to this toll plaza is the largest one in Russia nowadays.

The economic effects evaluation

Capital and operating costs

Currently, nevertheless, the toll plazas are operated manually by cashiers-operators, or electronically using transponder-cards. The cost structure for the manually operated toll plaza is the following:

1. Toll plaza construction costs

The construction costs of the toll plaza is about 44.6 million rubles (0.6 million Euro) per one traffic lane. For example, the construction costs of the toll plaza 48-71, which has 29 traffic lanes is approximately 1 293.3 million rubles (17.5 million Euro).

2. Land allocation costs for the toll plaza

The current toll plaza design requires the additional land. The costs of the additional land (compared to the main roadway) for the toll plaza 48-71 construction is 17.5 million rubles (0.24 million Euro) total or 0.6 million rubles (0.008 million Euro) per one traffic lane.

3. Toll plaza annual operating costs

Toll plaza annual operating costs, including toll plaza operator salaries and other expenses, are about 13.4 million rubles (0.18 million Euro) per one traffic lane.

Thus, using the current manual technology the expenses per toll plaza are the next:

- Capital costs (formed by the costs on land and toll plaza construction itself) are 45.2 million rubles (0.6 million Euro) per one traffic lane

- Toll plaza annual operating costs - 13.4 million rubles (0.18 million Euro) per one traffic lane

The calculations above were based on the data related to a single toll plaza. To define a complete summary about the total quantity of toll plazas the data extrapolation was executed.

The total quantity of the toll plazas is presented in Table 1.

Tab. 1. The toll plazas quantity and the number of the traffic lanes

(counts)

Year of construction	Quantity of toll plazas	Quantity of traffic lanes
2011	2	31
2012	2	24
2013	0	0
2014	7	73
Totally constructed in 2011-2014	11	128
2015	2	62
2016	15	221
Totally planned in 2015-2016	17	283

The extrapolation is carried out: a) for all already constructed toll plazas (retro-analysis) and b) for all toll plazas, scheduled for construction in 2015-2016 (forecast). The calculation of the capital and operational costs is presented in Table 2.

Tab. 2. The calculation of the capital and operating costs

(million rubles/million euro[9])

	Capital costs	Operating costs
Retro-analysis (up to 2014)	5 785.6 / 78.2	3 604.6 / 48.7
Forecast for 2 years (2015-2016)	12 791.6 / 172.9	8 053.4 / 108.8

Thus, while using the manual approach, the toll plaza construction and operation costs since 2011 are close to 9 390.2 million rubles (126.9 million Euro). The costs of the toll plaza construction and operation for the next 2 years could reach 20 845 million rubles (281.7 million Euro).

At the same time, the expenses structure on the Intelligent Transportation System elements implementation at toll-plaza consists of the data center equipment costs, costs on cameras and its set up, and the information campaign costs.

1) The data center equipment costs are estimated to 362 million rubles (4.9 million Euro).

Therefore, the data center costs per one toll plaza (where total toll plaza number is 28) is 12.9 million rubles (0.17 million Euro).

2) Cameras setting costs is 75.2 million rubles (1 million Euro) per year.

3) The Intelligent Transportation System implementation at toll plazas in Russia should be introduced to the citizens through the information campaign to make people aware about the new payment procedures. This information campaign should also include the boards and signs installation. The annual costs of the campaign is estimated at 2-3 million rubles (0.03-0.04 million Euro) per one toll plaza (averaged over the first 2-3 years).

Thus, the financial expenses of the state for the necessary organizational measures related to the Intelligent Transportation System elements implementation at toll plazas include the data center costs (12.9 million rubles / 0.17 million Euro per toll plaza), cameras setting (75.2 million rubles / 1 million Euro per toll plaza annually), as well as an information campaign (3 million rubles / 0.04 million Euro per toll plaza annually). The capital and operating costs of the Intelligent Transportation System elements implementation at toll plazas are presented in Table 3.

[9] 1 Euro = 74 rubles on 04.12.2015

Tab. 3. The capital and operating costs of the Intelligent Transportation System elements implementation at toll plazas

(million rubles / million Euro)

	Capital costs	Operating costs
Retro-analysis (up to 2014)	141.9 / 1.9	860.2 / 11.6
Forecast for 2 years (2015-2016).	219.3 / 3	3 206.2 / 43.3

Thus, the cost of the Intelligent Transportation System elements implementation at toll plazas is 4 427.6 million rubles (59.8 million Euro) in the next 2 years.

The required funding is 45% less than planned operating costs of the toll plazas, which had already been constructed using old technology, and 65% less than planned expenses for the toll plazas construction using old technology in the next two years.

Motorists time cost evaluation in terms of money

In this section we will consider the motorists time costs when passing through the toll roads. Currently (without the free flow technology), when driving through the toll plaza, motorists face the following situations:

- toll plaza carrying capacity (the number of cars that can be served by toll plaza cashiers-operators) is exceeded (the loading factor is greater than 1), the amount of the arriving cars is not decreasing but increasing, causing a traffic congestion;

- toll plaza carrying capacity is not exceeded (the loading factor is less than 1), but there is traffic congestion (the loading factor greater than 0.8)

- free passage, there is no traffic congestion (the loading factor is less than 0.8)

The motorists bear certain costs in each of these situations. Let's consider all of these situations in turn.

1) Congestion waiting time (toll plaza loading factor is more than 1)

To conduct the calculations we estimate the loss of time on 30th of April 2014, i.e. the first day of the year when toll plaza usage demand exceeded carrying capacity.

On that date the toll plaza usage demand was 81 010 vehicles while the carrying capacity is 72 000 vehicles. Thus the difference between demand and carrying capacity was 9 010 vehicles.

Let's calculate the "time deficit" (in hours) required for the passage of the "excessive" number of vehicles. The toll plaza carrying capacity is 72 000 cars in 24 hours. Thus for the passage of 9 010 vehicles the additional 3.03 hours (9 010 * 24/72 000) are required. That means that it took 27 hours for all vehicles to pass through the toll plaza. It turns out that the vehicle arrived on 30th of

April 2014 at the toll plaza was waiting in the congestion for additional 3 hours on average. In other words, the traffic congestion time loss reached 81 010 vehicles x 3 hours = 243 030 vehicle-hours.

Similarly, the calculation for other days of the year when the toll plaza usage demand exceeded the carrying capacity can be conducted. In 2014 total time loss while waiting for payment at the toll plaza constructed using old technology amounts to 7 990 thousand vehicle-hours.

It is important to draw attention to the fact that the traffic congestion has an additional negative effect - toll collection revenue loss, because of the potential users choose alternative free route.

2) The queue waiting time (the situation when loading factor is 0.8-1.0)

The limited toll plaza traffic capacity results in the queue, which can be calculated using Silbertal theorem and Poliaček-Khinchin formula (Blinkin, 2008). Figure 1 shows the average waiting time in minutes (y-axis) as a function of the toll plaza loading factor (x-axis).

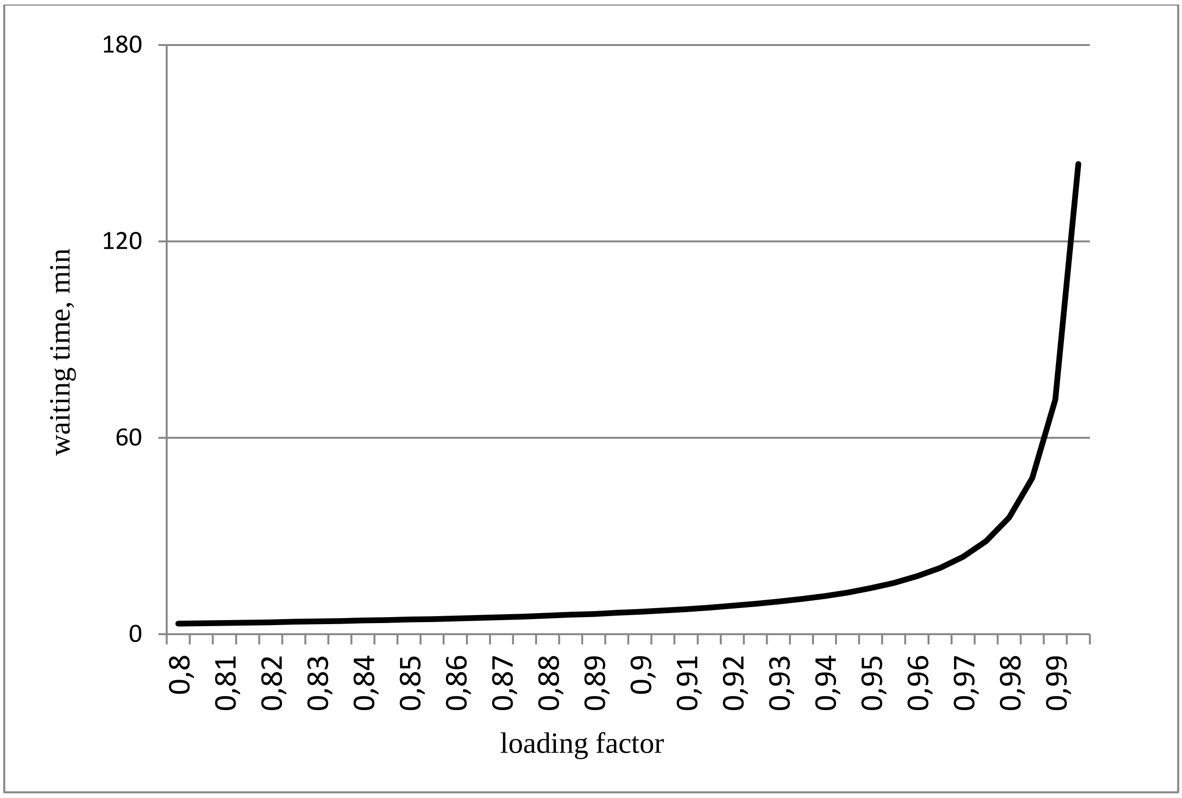

Fig. 1. The average waiting time depending on the toll plaza loading factor

According to the toll collection intensity analysis based on toll plaza 48-71 data for the year 2014, the passage waiting time was 685.6 thousand vehicle-hours.

3) A free passage time loss (toll plaza loading factor is less than 0.8)

Even if motorists do not waste time in the traffic congestion, they have to loose time to stop the vehicle and pay the passage through the toll plaza. That means that the motorists have to reduce their speed from 110 km/h to 0 km/h. The loss of time for the braking and acceleration of the vehicle is 34.7 seconds. (17.9 * 2-1.18).

The total amount of vehicles passed through the toll plaza without queuing and waiting in the congestion was 10 790 600. Therefore, the braking and acceleration total time loss is 10 790 600 * 34.7 sec / 3600 = 104 010 vehicle-hours.

Thus, in the current situation of old technology usage the motorists time loss amounts to 685 600 vehicle-hours of waiting in the queue, 7 990 000 vehicle-hours of waiting in the congestion and 104 010 vehicle-hours for braking / acceleration at the free road, that totally amounts to 8 779 610 vehicle-hours per year.

Since the load factor of vehicles is 1.3 persons on average (Artamonov, Datiev, Zhulin, Kondrashov, Lavrentiev, Muleev, Plaksin, Styrin, Yastrebova, 2015), the total annual time loss is equal to 11 413 493 man-hours (8 779 610 x 1.3).

For economic evaluation of the time loss calculated above there is a basic postulate that in the equilibrium state of the economy the marginal utility of an additional unit of time for the person will be the same in all possible areas of its application - work, education or leisure. Despite the fact that the nature of these activities and their impact on the economy are different, utility identity at the equilibrium point allows to carry a reasonably accurate evaluation of the lost benefit. The monthly income in Russia per capita (Rosstat, 2014) is 25 928 rubles (350.2 Euro), that is equal to average income of 157.9 rubles (2.1 Euro) per hour in a 40-hour working week. Thus, the economic effect of time loss is equal to 1 802 190 545 rubles (24 353 926 Euro).

This index is underestimated, since it includes only the driver's time loss in case of commercial freight transport passage, but do not take into account the multiplier effect that arises in connection with delivery time reduction.

The time loss evaluation in terms of money in the current situation using the old technology is presented in Table 4.

Tab. 4. The time loss evaluation in terms of money in the current situation using the old technology

(million rubles / million Euro)

	Motorists time loss
Retro-analysis	16 716.9 / 225.9
Forecast for 2 years (15-16 years)	37 348.8 / 504.7

Thus, in the current situation using the old technology, the motorists time loss in terms of money since 2011 is 16 716.9 million rubles (226 million Euro). In the next 2 year time loss would amount to 37 348.8 million rubles (504.7 million Euro).

The Intelligent Transportation System elements implementation at toll plaza involves free flow non-stop travel that prevents the time losses listed above. In this case the absence of time losses which amount to 37 348.8 million rubles (504.7 million Euro) in money terms in the next two years can be considered as a profit for the society.

When we eliminate the traffic jams at the toll plazas and vehicles can pass through with high speed, there could be system feedback effect that will encourage more vehicles onto the road as people find the new situation more attractive. But in this case the extra traffic that might be attracted on a toll road is limited by road capacity. When there is congestion on a toll road, users prefer free route to a toll one. In addition the operator of a toll road is interested in absence of congestion in order to avoid social displeasure. The most common measure to avoid congestion on the toll road is a fare size regulation. When the traffic density is too high and causes congestion, the operator simply increases fares, and vice versa when the traffic density is low, fares are reduced. Thus, the fare regulation is an efficient approach to control user demand.

Additional fuel consumption costs evaluation

This section describes the additional fuel consumption costs using the old technology.

In the current situation of the old technology usage, considering fuel consumption as up to 2 liters per hour (Artamonov, Datiev, Zhulin, Kondrashov, Lavrentiev, Muleev, Plaksin, Styrin, Yastrebova, 2015) and the average fuel price as 33 rubles (0.4 Euro) per liter, the additional fuel consumption costs are 2 liters per hour x 33 rubles per liter x 8 779 610 vehicle-hours per year, i.e. 579 454 260 rubles (7 830 463 Euro). However, these costs are at the same time provide the income for the fuel companies.

Thus, the additional fuel consumption costs is close to 579.5 million rubles (7.8 million Euro) per year.

Retro-analysis and forecast for the 2 years of additional fuel consumption costs in the current situation are shown in Table 5.

Tab. 5. Additional fuel consumption costs in the current situation of the old technology usage

(million rubles / million Euro)

	Additional fuel consumption costs in the current situation of the old technology usage
Retro-analysis	5 374.9 / 72.6
Forecast for 2 years (15-16 years).	12 008.8 / 162.3

The Intelligent Transportation System elements implementation at toll plaza, that involves non-stop passage, prevent additional fuel costs mentioned above. In this case the absence of additional fuel consumption costs can be considered to be a benefit for society.

Fare collection rate evaluation

The old technology provides 100% toll collection rate. At the same time, the Intelligent Transportation System elements implementation at toll plaza does not guarantee 100% toll collection rate. As it was indicated before, in case of Intelligent Transportation System elements implementation at toll plaza the administrative penalty for unpaid tolls is proposed to ensure the toll payment. Thus it is quite reasonable to suggest that in case of Intelligent Transportation System elements implementation some motorists would not pay the toll, that would result in a shortfall in income for the toll road operator.

Consider the number of toll payment rules violations. A similar case of the legal regulation is the administrative liability for unpaid chargeable public parking service, which is ratified in the Administrative Violations Code of Moscow. According to the survey about parking enforcement conducted by the Higher School of Economics in Moscow, approximately 3% of parked vehicles have serial numbers hidden (Kondrashov, Yastrebova, 2015). It is assumed that the number of toll roads payment rules offenders also would be not less than 3%.

For example, in 2014 17 513 879 vehicles passed the toll plaza 48-71. The potential number of violations is 17 513 879 x 3% = 525 416 violations. Since the toll plaza revenue in 2014 was 2 500 million rubles (33.8 million Euro), a drop-down payment of 75 million rubles (1 million Euro) can be expected.

Thus, in case of the Intelligent Transportation System elements implementation at toll plaza, the toll payment offenders share would be about 3% and the toll collection deficit in 2014 would be close to 75 million rubles (1 million Euro).

Social effects

The evaluation of the impact on road safety

The data shows that in the current situation when the old technology is used a significant number of accidents occur near toll plazas. Moreover, the accidents number at toll plazas is higher than on usual highway sections, which is a result of current toll plazas design (there are more traffic lanes at toll plaza than before and after it) that provokes the growth of the traffic density.

When calculating the accident number, especially for a long period of time, it should be noted that the number of accidents depends not only on traffic, but also on the toll plaza operation period (first there is so-called rump-up period, after a while there is a habituation effect to the toll road). In this context the statistics for southern section of toll road "Western High-Speed Diameter” in St. Petersburg is used to calculate the accident reduction index more accurate. The data for "Western High-Speed Diameter” is more detailed and available for a longer period of time.

For all the time of "Western High-Speed Diameter” operating 424 accidents were registered at the toll plaza and 220 - on the usual highway sections. Nowadays, accidents at the toll plazas occur mostly due to congestions. Consequently, the Intelligent Transportation System elements implementation at toll plaza would increase the speed at toll plazas that in fact could reduce the accident rate from 424 to 220 traffic accidents in a period of 3 years, i.e. 1.93 times.

There were 424 accidents registered at the toll plaza "Western High-Speed Diameter” in the last 3 years while the traffic volume is 74.1 million vehicles for the whole period, i.e. 5.72. accidents occur per one million journeys.

As the traffic lane number at the toll plaza 48-71 is comparable with the "Western High-Speed Diameter”, it can be assumed that in the current situation of the old technology use the accident rate at the toll plaza 48-71 is 100.1 (there are 17.5 million passages through toll plaza 48-71 annually). Accordingly, when implementing Intelligent Transportation System elements at toll plaza the number of accidents would be reduced 1.93 times, i.e. 48.2 accidents.

Thus, extrapolating the results obtained, it can be argued that in case of Intelligent Transportation System elements implementation at toll plaza 1 060 accidents could have been avoided since 2011, and the possible effect in the next 2 years is evaluated as the accident number decreased by 1 976 accidents.

User satisfaction evaluation

According to the conducted sociological research, only 10% of respondents evaluated the existing toll plaza technology as a very user-friendly; another 47% called it quite user-friendly (see Figure 2). At the same time 42% of respondents were dissatisfied with the current toll collection technology. Dissatisfaction with the current toll collection technology is higher among Muscovites (43% in Moscow vs. 36% of in the regions).

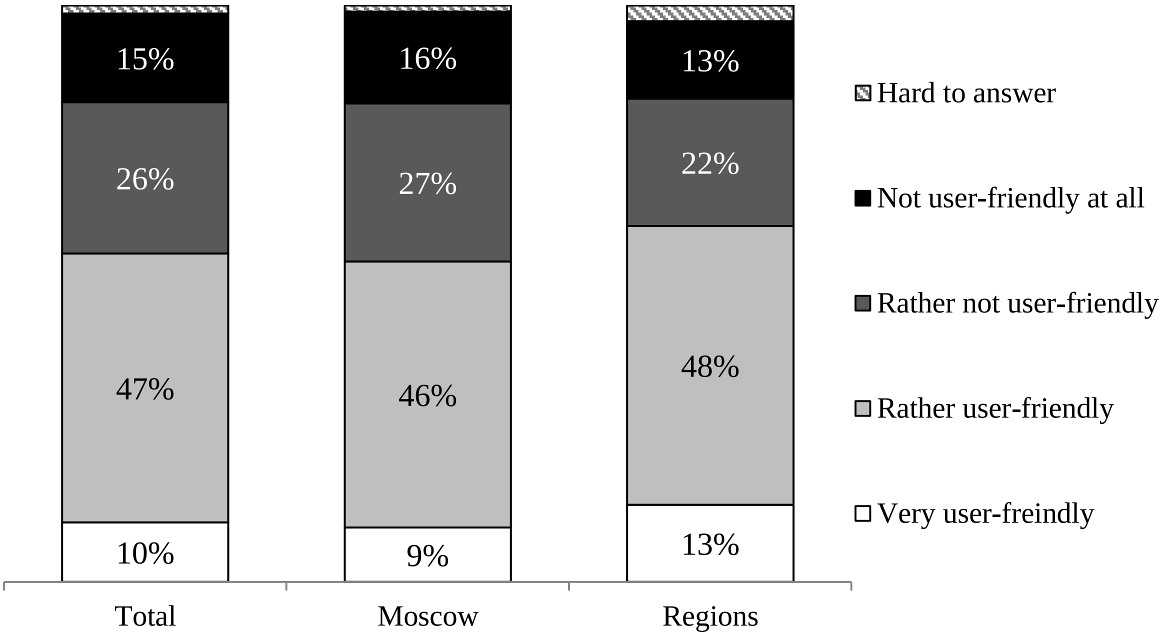

Fig. 2. Existing toll plaza technology convenience evaluation

As for the Intelligent Transportation System elements implementation at toll plaza, this idea is particularly positive perceived by the toll plaza users who were facing traffic congestion (there are 67% of motorists of that type). 65% of toll plaza users, who were facing the traffic congestion at the toll plaza, think of the idea the Intelligent Transportation System elements implementation positively. For comparison, the current toll plaza technology is evaluated positively only by 46% of drivers. Thus, in case of the Intelligent Transportation System elements implementation at toll plaza the satisfaction with toll plaza service will increase by 38% among motorists facing traffic congestion at toll plaza.

However, toll plaza users who have never been facing the traffic congestion problem at toll plaza do not see any sense in the Intelligent Transportation System elements implementation. Only 41% of these drivers reacted to the Intelligent Transportation System elements usage positively; for comparison - 76% of these motorists are positive about the current toll plaza technology.

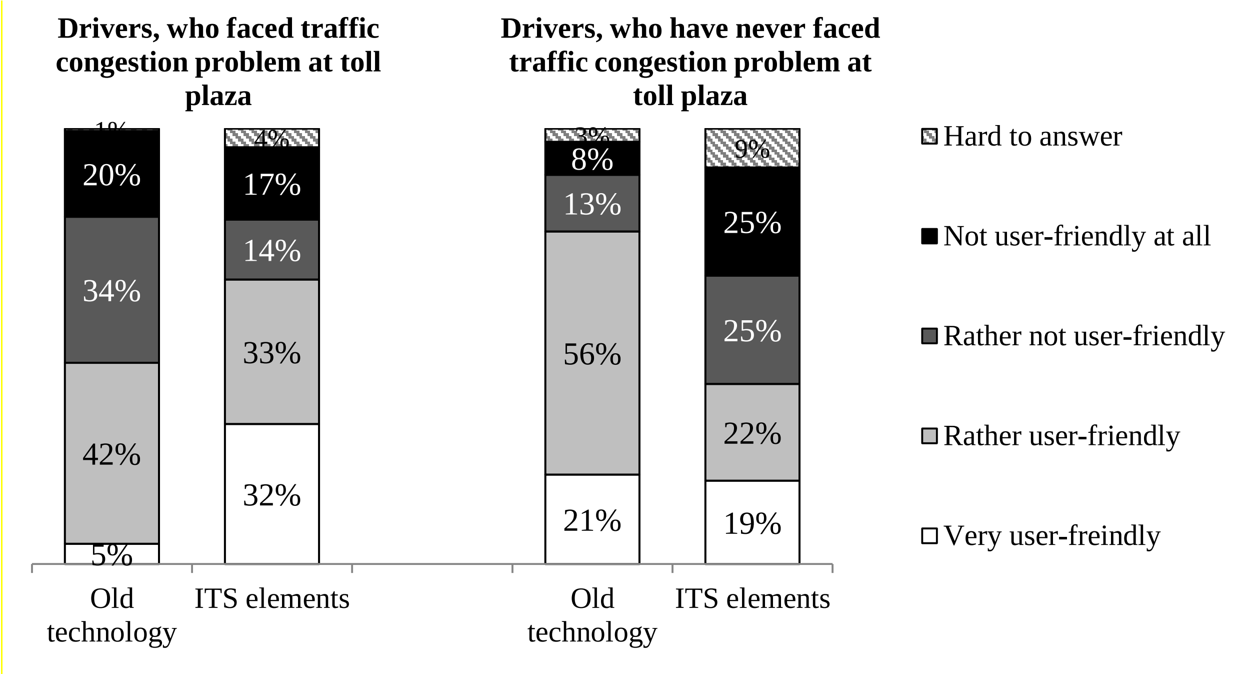

Fig. 3. Old-school toll plaza technology vs. Intelligent Transportation System elements adoption

Thus, in case of the Intelligent Transportation System elements implementation at toll plaza a significant user satisfaction increase can be expected. The expected satisfaction increase among motorists facing traffic congestion problem at toll plaza in case of the Intelligent Transportation System elements implementation is 38% (the satisfaction level among this group will grow from 47% to 65%).

Environmental effects

Emissions into the atmosphere estimation

In addition to the economic and social effects environmental effects of the Intelligent Transportation System elements implementation at toll plaza can be estimated.

The emissions from one kilogram fuel combustion are: (Trofimenko, Vorontsov, Trofimenko, 2011):

- CO, g / kg fuel 21.5
- VOC, g / kg fuel 2,4
- NOx, g / kg fuel 5,8
- SO2, g / kg fuel 0.5

At fuel density of 750 kg per cubic meter (Cars in Russia, 2006), the number of liters per kilogram is 1.333. In the current situation when old technology is used the additional fuel consumption per year are 2 liters per hour x 8 779 610 machine hours = 17 559 220 liters, which is 13 172 708 kg.

Thus, annual emissions in the current situation per one toll plaza are:

- CO 283 213 kg
- VOC, 31 614 kg
- NOx, 76 402 kg
- SO2, 7113 kg

The environmental effect of the current toll plaza technology usage is presented in Table 6.

Tab. 6. Environmental effects of the current toll plaza technology usage

(tons)

	Emissions since 2011	Emissions in the next 2 years
CO 2	76184.3	170211.0
VOC	8504.2	19000.0
NOx	20552.1	45917.6
SO 2	1913.4	4274.9

All these emissions can be eliminated in the case of Intelligent Transportation System elements implementation at toll plaza.

Land use change

Land use change ahead of new freeways was a key reason why many US freeways were clogged more or less at opening decades ago. (Newman, Kenworthy,1984). A free-flowing and faster freeway/highway system encouraged land use change by way of new residential or commercial and industrial development finding location near the systems more attractive.

In Russia the situation differs from the US. It can be stated that suburbs of most major cities had already been densely built up with housing before building the road. In fact, not a new road is a key reason for new residential or commercial and industrial development, but the residential, commercial and industrial development itself encourages a new road construction.

What is more interesting, not the higher travel speeds but the construction of a new road itself could affect more on the land use change in Russia. From this point of view there is no reason to believe that the change to ITS handling of road charges will induce land use change.

In any way user growth on toll roads, as well as increasing the attractiveness of regions may be true after some period of time. An analysis of these effects could be the subject of our future research as it needs carrying out additional studies and thorough researches.

Conclusion

In this paper the economic, social and environmental effects of the Intelligent Transportation System elements implementation at toll roads were analyzed. The retro-analysis (2011 - 2014) and forecast for the next two years (2015 - 2016) of the evaluated effects were performed.

As a result of the analysis following conclusions were presented:

- The old technology usage at toll plaza results in higher capital and operating costs compared with the Intelligent Transportation System elements implementation. The required funding of Intelligent Transportation System elements implementation at toll plaza is 45% less than planned operating costs of the toll plazas, which were already constructed using current technology, and 65% less than planned expenses for the toll plazas construction in the next two years using current technology.
- The current-technology usage results in higher time costs for toll plaza users compared to the situation of the Intelligent Transportation System elements implementation. Considering time costs in terms of money, it can be argued that the Intelligent Transportation System elements implementation at toll plaza will reduce the time costs by 37 348.8 million rubles (504.7 million Euro) in the next 2 years.
- The Intelligent Transportation System elements implementation at toll plaza has positive social effects. The Intelligent Transportation System elements implementation at toll plaza would result in the traffic accidents decrease by 1 976 accidents in the next 2 years.
- The Intelligent Transportation System elements implementation at toll plaza provides higher user satisfaction level than old technology usage.
- The Intelligent Transportation System elements implementation at toll plaza has a positive impact on the ecological situation. In case of Intelligent Transportation System elements implementation the emissions will decrease by 239 thousand tons.
- The old technology usage provides one hundred percent toll collection rate. At the same time the Intelligent Transportation System elements implementation at toll plaza entails toll payment deficiency. In case of the Intelligent Transportation System elements implementation at toll plaza the toll payment offenders share would be 3% and the toll collection deficit in 2014 would amount to 75 million rubles (1 million Euro).

To summarize, while the old technology usage ensures one hundred percent toll collection rate, but entails higher costs, the Intelligent Transportation System elements implementation at toll plaza does not guarantee 100% collection rate, but provides costs reduction. Considering the balance of pros and cons for the state, society and toll plaza users, the Intelligent Transportation System elements implementation is found to be preferable, as in case of Intelligent Transportation

System elements implementation the toll collection deficiency would be compensated by costs reduction.

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