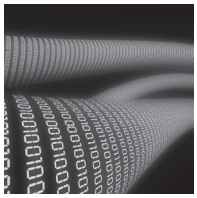

Archives of
Transport System Telematics

Volume 4

Issue 3

September 2011

Cost model of the urban toll system in Žilina

J. ONDRUŠ[a], J. DICOVÁ[b]

[a] University of Zilina, Faculty of Operation and Economics of Transport and Communications, Department of Road and Urban Transport , Univerzitná 1, 010 26 Žilina, Slovakia

[b] University of Zilina, Faculty of Management Science and Informatics, Department of Management Theories, Univerzitná 1, 010 26 Žilina, Slovakia

EMAIL: jan.ondrus@fpedas.uniza.sk

ABSTRACT

Trend related to the city mobility is now focused on limiting access of cars in city centres. One possible solution is traffic calming with urban toll system. In our paper we would like to focus on only one of the most important steps of introduction of the urban toll system - cost model and specifically to determine model process for optimisation of toll price for the limitation of transport intensity and maximize revenue from toll.

KEYWORDS: amount of toll, cost model, transport intensity, incomes, revenues

1. Introduction

Urban toll system can be defined as a special fee that is paid by vehicle for its entrance into the specific area of city.

The amount of toll is usually dependent on number of entrances into the area or time spent there or according to vehicle mode.

There are general reasons to support positive state decision in the question of city fee application:

- it is another financial resource for traffic improvement by improvement of either transport infrastructure or public mass transport,
- it can decrease congestion in certain area, certain communications or in certain hours, and thus increase traffic system accessibility,
- it can improve city living conditions by decrease of noise, emission, accident rate and air pollution,
- it can advance public mass transport demand that means also its better financial sustainability. [7]

2. Characteristics of city Žilina

Žilina is a regional centre of NW Slovakia and the biggest town on the Váh river. Number of the population was 84 546 (31. 05. 2011) and area of city is 80,03 km^2. Number of registered cars in Žilina county: 60 217 vehicles (43 571 passenger cars). Level of automobilization: 510 vehicles/1 000 citizens. [8]

CMZ is a small containment area (2,7 km^2), where can be input cordon defined by 10 entrances (Fig. 1.).

As in many of European cities, as well in Žilina, the traffic situation in the past few years is getting steadily worse. Therefore we tried to suggest a system of town toll, which would partially eliminate load in the Central Town Zone (CTZ).

This problem is too large and complicated. So we focused on only one of the most important steps of introducing the urban toll system – and that is cost model.

Fig. 1. Marking of entrances into solved area
Source: [9]

3. Cost model

It is desirable to make economic and financial evaluation of assets and costs. It is important to find out whether the tool system is a contribution for the town. In few years time, assets summary should be higher than the cost system.

The main outputs of financial analysis are the test results of costs and assets of the proposal. Moreover it is necessary to pay attention not only to technical costs and supplier´s costs, but also to the costs for the information campaign, running costs etc.

It is vital to evaluate or rate the ***socio-economic assets*** for the following:

- Users of individual automobile transport (IAT) – for example decrease of congestion.
- Users of public transport – increasing transport reliability public mass transport (PMT), increasing quality of PMT, etc.
- The city – toll revenue, more attractive and more accessible the city centre, etc.
- Operator of PMT - higher number of passengers, increase of transport reliability.
- Increase of residents, visitors, employees who are not using means of transport in charged areas, also increase of air – pollution, noise, decrease of accident rate, etc.

Economic costs consist of following:

- Financial cost for the city – for example investment costs, operating costs, etc.
- Socio-economic costs for IAT users – toll, increase of time loss, accident rate, asset costs of vehicles, etc.
- Socio-economic costs for PMT users – reduction of waiting time at the station, less transport reliability of PMT on the border zone and outside the traffic peak.
- Socio-economic costs for residents, visitors, employees – increase of emissions, noise, accident rate on the border zone, etc.
- Socio-economic costs for businessmen in the charged area – higher costs for purveyance, decrease of amount of customers in the shops, etc. [1, 3]

Output should be the approach between the economic assets and economic costs of the proposal.

In this step we did not consider all the social and economical costs and profits for introduction of urban toll system in Žilina. We focused mainly on important financial costs, e. i. operations and investments. After their consideration, the following model technique for determination of optimal amount of toll and the supposed urban toll revenues are also accounted.

3.1. Investments and operational costs

In frame of the whole effectiveness of imposing fees on urban roads in CMZ (Central Town Zone), it is necessary to follow systematically not only the limits imposed on automobile traffic, but also the fiscal profit of the mentioned rule. If we want to estimate the precise profit that the Urban Toll will bring, it is necessary to analyse the investment, operational costs and revenues. Finally, the technology is proceeding and getting better. So the things hardly imaginable a few years ago (cameras system was too expensive) is not actual any more.

We can put investment costs into several basic groups. Those are costs put on:

- Enforcement:
  - › costs on road side equipment (RSE), e. g. cameras, equipment to recognise the registration number and local computers, plus their connection to data network,
  - › costs for providing the connection,
  - › working place for controlling operator with necessary technical equipment,
  - › service centre – main role is the maintenance of technical road equipment,
  - › service vehicles – are available for the service centre.
- Working place of financial operator – financial operator checks the financial transactions as well as unpaid balances and fees exacting for not keeping the prescribed dates of payments. He also communicates with financial institutions, mobile operators and other subjects that provide the possibility of payment for the final users. The costs involve the working place equipment and the training of working stuff.

- Working place of customer centre – communicates through telephone lines, emails and other communication channels with system users and solves their complaints. The costs involve the working place equipment and the training of working stuff.
- Working place for manual recognising of registration number – this place is responsible for the right identification of registration number of motor vehicles that was not possible to recognise automatically. The costs involve the working place equipment and the training of working stuff.
- Payment automatic machines – serve to pay the urban toll and they are located in the centre of the town at chosen places. Automatic machines make the cash payments and payments by credit cards possible and inform the user about the number of subscribed drivers. The prices of automatic machines include the installation and connection to data network.
- Costs on software development – include the development of complex communication environment including database operating invoices, etc.
- Communication and information campaign for a system operating without problems, it is necessary to realise a campaign that will inform about the prepared rules and will also explain the profits that the charging will bring. [4, 5]

Total investments costs for this system were estimated at 4 185 858 euros.

Operational costs

Investments costs include the financial means that are necessary for the first investment. Except for these costs, it is needed to analyse carefully the operational costs from the point of view of profitability. We can put the mentioned costs into these basic groups:

- Wage costs – represent one of the highest items of operational costs. These costs involve also the costs on social and health insurance for management workers at individual working places.
- Operational costs – include for example costs for renting the offices and other technological equipment or costs on consumption of energy. For simplification it is accounted as a certain part of wage costs.
- Data transmissions – costs on necessary data transmissions between individual physical components of the system.
- Administration and maintenance of enforcement and payment system – includes especially the costs on parts for equipment by rods and payment automatic machines. For simplification it is accounted as a certain part of investments costs on enforcement.
- Administration and maintenance of software – costs are determined as a percentage of investment costs on software.
- Taxes depreciation – expresses the system amortisation at time and after finishing the period of lifetime, they can be used to its reconstruction and modernisation. The supposed lifetime of Urban Toll system is 10 years. [2, 3]

Total operational costs for this system were estimated at 1 172 737,8 euros.

3.2. Determination of amount of urban toll

It is important to determine the incomes from fee very carefully, so that it is possible to consider the profitability of the system. We also have to consider that the main goal of introduction the urban toll system is to reduce the intensity of automotive traffic in CTZ and not to maximise the incomes from fee.

The height of incomes depends on two basic quantities that are closely connected. It is the amount of toll for the entry and the number of vehicles that enter to the zone and pay the toll.

Basic starting points

Urban toll systems that mean paying the entrance toll for entering the city centres are often discussed lately, especially the way of regulation of individual automotive transport mainly from the pint of view of congestion regulations and the reduction of the amount of emissions produced by automotive transport. It also concerns the augmentation of so called walking transport. Even in this case it is valid that determination of the level of urban toll based on quantification of external costs from congestion and emissions is very difficult, more or less impossible. That is why an approach of so called environmental standards was chosen, considering as well the amount of toll determined on the basis of functional relationship:

$$V_M = f(\Delta I, T) \tag{1}$$

where:

V_M - amount of toll,

ΔI - decrease of individual automobile transport intensity,

T - pure incomes of public budget from urban toll (difference of total incomes and costs on building and operation of system).

The basic starting point is supposing that determination of the amount of toll is a political (social) choice and

it is supposed that with increasing amount of toll, the intensity of transport in city centre will fall, which will influence the urban toll.

In general we can determine the role of amount of toll by following way. Individual transport flows I1, I2,…In enter to chosen area, where the basic role is to find out how these transport flows will react on imposing the entrance fee.

Let's suppose for the moment that the decrease will depend on exponential function, so:

$$I_i' = I_i \cdot e^{-c \cdot V_M} \qquad (2)$$

where:

I'_i - intensity for the i-entry after the introduction of toll,

I_i - intensity for the i-entry before the introduction of toll,

V_M - amount of toll,

c - coefficient, negative number sign indicates the assumption of decrease of transport intensity after the introduction of toll.

Another question is the amount of toll, which will depend on requirements of this system and will be a function of two variables – decrease of transport intensity in CTZ and pure incomes from payments. The already mentioned research of acceptance was made with this aim. One of the main questions was where the respondents were to express their will to enter to CTZ with certain toll. This research found out the results mentioned in following table 1.

The chart evidently shows that the amount of entrances will fall according to augmented payments. It is very difficult to pronounce any prognosis concerning this fact. Finally the transport intensity would probably slightly raise with time, as in case of increase in fuel prices, where after a certain time the passengers will get used to new prices and will use the car anyway, almost as before the price increased. The individual automotive transport demand is not elastic, which is mainly caused by the fact that a comparable substitute does not exist, providing the passengers transport at the same level of quality as a car.

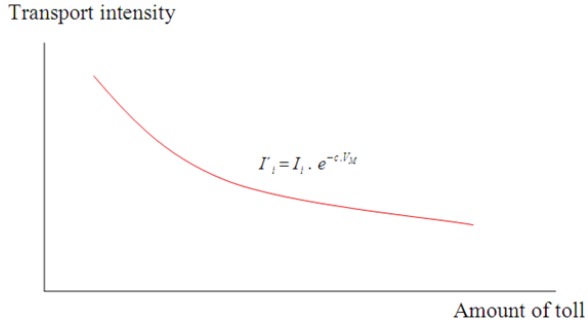

Fig. 2. Procedure of decrease of transport intensity after the introduction of toll
Source: [6]

Table 1. The survey of willingness to enter to CTZ with certain toll

Amount of toll	Percentage representation	
	Yes	No
1 €	95 %	5 %
1,33 €	88 %	12 %
1,66 €	76 %	24 %
1,99 €	63 %	37 %
2,32 €	38 %	62 %
2,66 €	21 %	79 %
2,99 €	11 %	89 %
3,32 €	4 %	96 %

1 Euro (€) = 3,9302 PLN
Source: [4]

Regression of polynomial function

While taking in consideration the table 1 values, we definitely have to state that the amount of entrances to CTZ will fall with raising the amount of toll, which can be characterised by following diagram. Now the question is if by higher values this way reflects the reality where it is evident that by higher values of urban toll (for example 3.3 euros), the intensity of transport will be at a zero level (Fig. 3.).

Intensity fall in area charging is the only criterion that determines the amount of toll. Naturally with the raise of urban toll, the number of entrances into the centre will fall, which will influence the second criterion – the pure incomes from urban toll. We will divide the incomes to fixed ones (from the one-time fee of residents) and variables (from the numbers of one-time entrances into the centre, which will depend on the amount of toll. We will consider the costs as constant (operational and investment costs, which are present in operational costs as depreciations), we get those pure incomes from urban toll and they can be expressed as follows:

$$T = (P_R \cdot V_J + I_S \cdot \frac{-7{,}474\,V_M^{\,2} - 7{,}407\,V_M + 104{,}81}{100} \cdot V_M \cdot d) - N \qquad (3)$$

where:

T - pure incomes per year of public budget from urban toll (difference of total incomes and costs on building and operation of system),

P_R - number of residents, who pay one-time fee,

V_J - amount of one-time fee for residents,

I_S - current number of entrances for one day into consideration area at zero fee,

V_M - amount of toll,

D - number of days in operation in calendar year (d = 250),

N - annual costs including taxes depreciation.

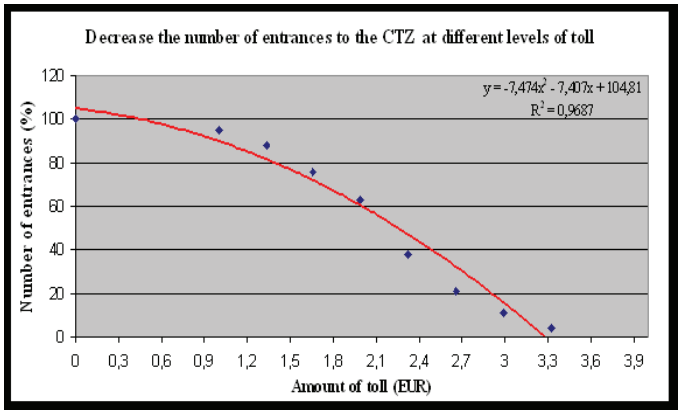

Fig. 3. Decrease the number of entrances to the CTZ - regression of polynomial function
Source: [4]

For any other accounting analysis, it is necessary to find out the supposed number of vehicles which enter presently to the area charging and determine the amount of vehicles which would by obliged to pay as a one-time fee or an annual fee. After that we have to know the supposed operational and investment costs (chapter 3.1.).

If we consider the one-time fee for residents as a 25 – times of urban toll (residents having 90 % discount of daily entrance, number of days - 250), then the pure annual incomes from urban toll will be:

$$T = (P_R \cdot 25 V_M + I_S \cdot \frac{-7{,}474 V_M^2 - 7{,}407 V_M + 104{,}81}{100} \cdot V_M \cdot d) - N \quad (4)$$

and after modification

$$T = V_M \cdot (P_R \cdot 25 + I_S \cdot \frac{-7{,}474 V_M^2 - 7{,}407 V_M + 104{,}81}{100} \cdot d) - N \quad (5)$$

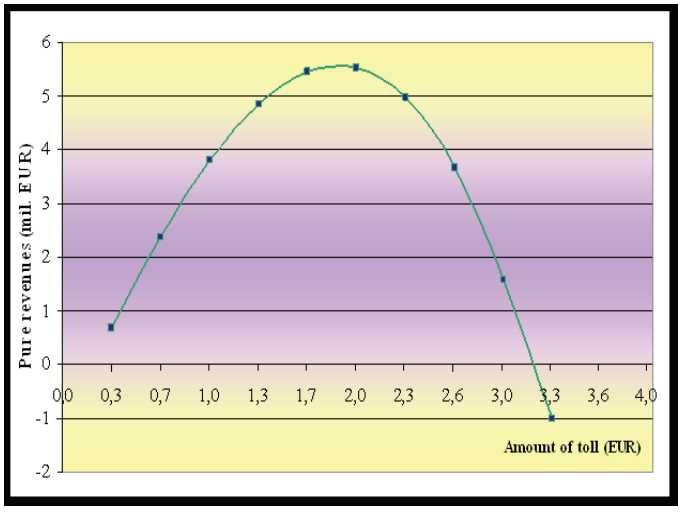

Fig. 4. The trend of incomes by regression of polynomial function
Source: [4]

Function which is gained by approximate values from the research, it is only for the orientation. It is necessary to realize that we are coming from a limited number of respondents and that is why it is necessary to consider this proceeding only as a model instruction to gain the optimal toll price. As except for the price all the other values are constant we can rewrite this equation generally as a relationship:

$$T = V_M \cdot (a + b \cdot V_M^2 + c \cdot V_M + d) - n \quad (6)$$

where:
a, b, c, d, n are constants and V_M is the toll price.

By derivation of this function according to V_M and keeping this derivation equal to zero, we will gain the optimal amount of urban toll price.

$$\frac{dT}{dV_M} = 0 \Rightarrow V_{MOpt.} \quad (7)$$

3.3 Supposed revenues from urban toll system

Expressing the revenues in numbers comes from values and dates which were counted in previous chapters and from the equation 4. Following table 2 documents the trend of pure revenues from urban toll by polynomial regression of intensity development depending on the urban toll price. The result is that the highest pure revenues are by toll 1,99 euros. But we have to remember that the main motivation of urban toll is limiting the automobile transport and not to maximise the incomes from financial means.

Table 2. The trend of incomes and pure revenues by regression of polynomial function

Amount of toll (€)	Incomes from residents (€)	Current incomes (€)	Costs (€)	Pure revenues (mil. €)
0,33	16 500	1 836 043	1 172 738	0,68
0,66	33 000	3 495 408	1 172 738	2,36
1	50 000	4 926 985	1 172 738	3,80
1,33	66 500	5 956 028	1 172 738	4,85
1,66	83 000	6 540 838	1 172 738	5,45
1,99	99 500	6 593 119	1 172 738	5,52
2,32	116 000	6 024 580	1 172 738	4,97
2,66	133 000	4 696 207	1 172 738	3,66
2,99	149 500	2 595 604	1 172 738	1,57
3,32	166 000	0	1 172 738	-1,00

1 Euro (€) = 3,9302 PLN
Source: [4]

4. Conclusion

The estimate of cost model and amount toll is the mainly point of this introduction. Also in our paper we focused on model process for optimization of toll price for the limitation of transport intensity and maximize revenue from toll. Here it is necessary to point out that the toll is not only an economic issue but also the public, especially political and legislative and politicians will decide on individual items, including the introduction of such a system.

Finally, we want to remind, that this procedure is taken as model instruction how to proceed further with introduction of urban toll system and price determination.

Acknowledgements

This contribution is the result of the project implementation:Centre of excellence for systems and services of intelligent transport, ITMS 26220120028 supported by the Research & Development Operational Programme funded by the ERDF. "Podporujeme výskumné aktivity na Slovensku/Projekt je spolufinancovaný zo zdrojov EÚ"

Bibliography

[1] KALAŠOVÁ, A., LATISLAV, R.: Introduction of road charging in city of Žilina - a tool for reduction of negative externalities In: Advances in transport systems telematics 2: Section I: Telematic transport systems. - Katowice: Silesian University of Technology, [2007]. - ISBN 978-83-917156-6-6.

[2] KALAŠOVÁ, A., PAĽO, J.: Electronics fee collection and ITS application in the Slovak republic In: MOSATT 2007: modern safety technologies in transportation: proceedings of the international scientific conference, 25th-27th September 2007, Zlata Idka. - Košice: Slovak Transport Society at the Slovak Academy of Sciences, 2007. - ISBN 978-80-969760-2-7. - P. 120-123.

[3] ONDRUŠ, J., DICOVÁ, J.: Road charging in urban areas in the middle-size. In: Archives of transport system telematics. - ISSN 1899-8208. - Vol. 3, Iss. 1 (February 2010), s. 39-44.

[4] ONDRUŠ, J.: Mýtne systémy v cestnej doprave a ich využitie v mestách, dizertačná práca, 2009

[5] Project: Pricing Acceptability in the Transport Sector (PATS), 2000

[6] Projekt FD ČVUT: Externality v dopravě, 2005

[7] URBÁNKOVÁ, P.: Úvod do mýtneho systému, (http://www.telematix.cz/projekty/zav/index.html)

[8] http://www.zilina.sk/uvod-aktuality-mesto-zilina--informuje

[9] http://www.maps.google.com