

Analysis of factors influencing toll amount collected on the Czech roads

Milena Botlíková,¹ Šárka Čemerková²,

Abstract. The problem of fee for using the highways and first class roads (toll), collected in the Czech Republic is investigated in this paper. Legal basis for the tolling are the “Act on the toll”, “notice on the using charging roads”, and also in a near future forthcoming “Act to extend the toll”. Currently State Fund of Transport Infrastructure (SFTI) faces a lack of funding; therefore it is necessary to analyze the various items of income for subsequent determination of the amount. Tolls as one of the most important component part of the revenue budget SFTI of the Czech Republic determine the further development of transport infrastructure. The development must be in accordance with Transport Policy of the Czech Republic and European agreements. Collected toll amount may be influenced by different factors e.g. the number of registered vehicles, road transport performance, or intensity of traffic, etc. Because the influence of these factors on the toll varies, it is necessary to determine the significance and the relationships between these factors. Analysis of the toll impact can then be used to determine the correct amount of tolls. This will create proper conditions for further development of sustainable transport.

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JEL Classification: C44, C01, C51

AMS Classification: 62P20, 62J12, 91B70

1 Introduction

Development of transport infrastructure is earmarked as one of the priorities of the strategic plans of the CZ. According to many sources indicated the development of road infrastructure as one of the most important instruments having a significant multiplier effect leading to the stimulation of economic development of the CZ. Construction and modernization of road infrastructure experienced a big boom in recent years. The construction of many roads of national and European nature has happened during the past years. The need to build high-quality transport infrastructure is resulting from a strategic position of the CZ and the need for the road network connecting European transport corridors.

Original intentions have changed in recent years. Due to political instability and economic situation, there was a reason they are impeding the development of decreasing financial resources. State Transport Infrastructure Fund, which provides financing and development of transport infrastructure, finance and disposing of state funds from the European Union, recorded since 2008, is decreasing national expenditure framework. Insufficiency cover construction and modernization of transport infrastructure and national resources in recent years has been dealt with by EU finance and the CZ exceeded the principle of additionality, which would ensure that funds will not be from the European Structural Funds used to replace national structural subsidies for public financing and similar expenditure would otherwise be funded from the state budget.

Although the convergence programs of governments define the development and modernization of transport infrastructure as a priority to increase the competitiveness of the CZ in the EU, with the advent Nečas governments seeking to reduce the public deficit has been a drastic reduction of funds for development and much of the transport structures remained in various stages under construction, some projects were not started at all. For example, in 2010, was stopped 12 vehicles, including the strategically important crossroads Silesian cross forming in the European transport corridor.

¹Silesian University in Opava, School of Business Administration in Karvina, department of Logistics, Univerzitní nám. 1934/3, 733 40 Karviná, Czech Republic, botlikova@opf.slu.cz .

²Silesian University in Opava, School of Business Administration in Karvina, department of Logistics, Univerzitní nám. 1934/3, 733 40 Karviná, Czech Republic, cemerкова@opf.slu.cz.

2 The toll

Result of efforts to increase national expenditure framework has been gradually in previous years to increase the income of individual items of the State Transport Infrastructure Fund. Over the years, payments from income were gradually increasing, i.e. income from fuels and lubricants, the signs and highway tolls.

The introduction of tolls in 2007, should contribute not only to obtain funds to fund transport infrastructure [5], but also to fulfill the control function, to eliminate congestion and externalities in the traffic flows, when the introduction of a toll in Germany and Austria became the Czech Republic – one of the transit countries.

Toll rates and their changes

Pay toll payment for actual mileage, the amount of which is differentiated according to the season and the environmental burden, and in recent years has seen several changes. Individual changes in the above toll from both those related to highways, and on the expressways and roads. In completing individual sections of the motorway and road network is to expand the number of sections subject to toll charges. Since 1997, when there were about 1 160 km charged roads, it is now charged about 1300 km road network (which is about 2% of the total length of road infrastructure). In 2010 the extension of the payment obligations to vehicles from 3.5 tons was realized. Until this year there was obligation to pay a toll only on vehicles from 12 tones. Other changes in toll scope can be seen in Table 1.

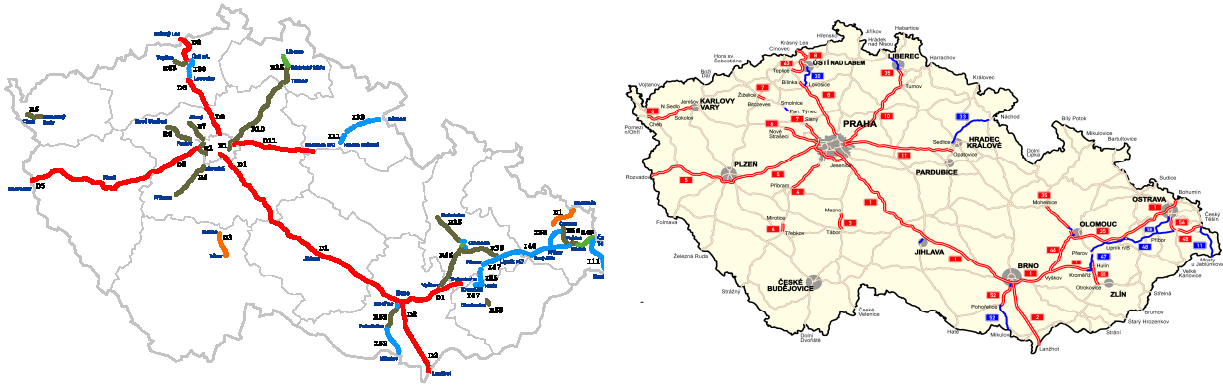
2011	2012
Increase in toll rates by 25%	Increase in toll rates by 25%
Implementation of a compensation system	Possible introduction of 20% VAT
Online system for monitoring of arrears	Quantity discounts
Friday discount on toll rates	

Table 1 Current changes in toll

Between 2010 and 2011, there were no changes in the amount of toll. The increase is related to that year only runs Friday, which was connected with an effort to reduce freight during weekend days. Years 2012 has seen an increase not only in Friday, but even ordinary days and were compared to previous years vehicles to charge EURO V and above, which by this time were exempt from tolls. Toll rates are shown in the following table 2.

Emissions	Axle vehicle	highway			first class roads		
		2010	2011	2012	2010	2011	2012
			Ordinary/Friday	Ordinary/ Friday		Ordinary/ Friday	Ordinary/ Friday
EURO II	2	2.3	2.26 / 2.88	3.34 / 4.24	1.1	1.08 / 1.37	1.58 / 2.00
	3	3.7	3.63 / 5.55	5.67 / 8.10	1.8	1.77 / 2.70	2.74 / 3.92
	4+	5.4	5.30 / 8.10	8.24 / 11.76	2.6	2.55 / 3.9	3.92 / 5.60
EURO III and more	2	1.7	1.7 / 2.12	2.61 / 3.31	0.8	0.79 / 1.00	1.23 / 1.56
	3	2.9	2.9 / 4.35	4.45 / 6.35	1.4	1.37 / 2.10	2.14 / 3.06
	4+	4.2	4.2 / 6.30	6.44 / 9.19	2	1.96 / 3.00	3.06 / 4.38
EURO V+	2			1.67 / 2.12			0.79 / 1.00
	3			2.85 / 4.06			1.37 / 1.96
	4			4.12 / 5.88			1.96 / 2.8

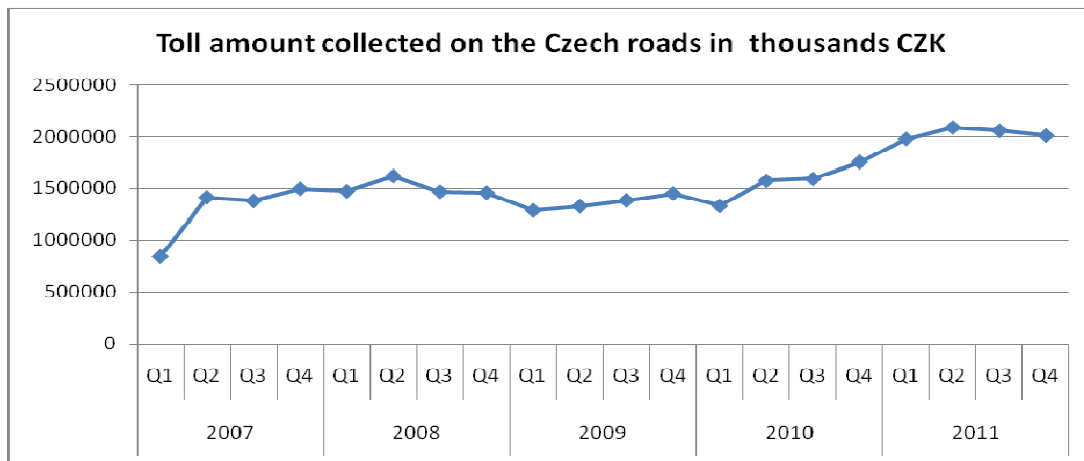
Table 2 Rates of toll (in CZK/km) [8]



Picture 1 Czech sections Toll roads in 2008 and 2012 [6]

Increase in toll rates along with the increase in the number of kilometers of toll, however, did not bring the desired effect. The increase in revenues of the State Fund for Transport Infrastructure Development of the toll is still not sufficient and in the second half of 2011 declined.

Many analyses are based on the assertion that if the toll increases further, the individual carriers, burdening the already high price of fuel, try to search cost-free route – route without tolls. Of the factors that need further analyze the different factors that selected toll on the amount of influence.



Picture 2 Toll amount collected on the Czech roads, in thousands CZK [4]

3 Factors affecting the selected toll and finding a mathematical model

In search of factors affecting the amount of tolls the following factors were selected: price of diesel at filling stations in the CR (X_1 explanatory variable), transport performance (variable X_2) and the number of goods vehicles of categories N2 and N3 split into second-hand vehicles (X_3) and the newly registered vehicles (X_4). These factors were selected for the following reasons:

- The price of oil affects the volume of traffic.
- It is assumed that increasing the transport performance will match the growing volume of selected toll.
- The old trucks do not meet the higher standards and meet the EURO higher toll rates. It can be assumed that with the increasing number of these vehicles there will be selected higher toll.
- In contrast, newly registered vehicles are mostly new vehicles meet the highest standard EURO and they therefore correspond to the lowest toll rate, i.e. with the increasing number of these vehicles at the expense of used cars it will reduce the toll.

Since some factors are only available quarterly data for the other factors were adjusted so that the data corresponded to the same time sections. From the daily price of oil released by the Czech Statistical Office [4] were calculated quarterly arithmetic averages and were calculated for the other quarterly totals.

The aim was to find multiple linear regression model:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4. \quad (1)$$

The advantage of linear economic models is particularly illustrative in the economic interpretation and the possibility to estimate and test the standard and simple procedures, which cannot always tell the models that are linear in the parameters.

First, a linear relationship has been studied above the selected toll on oil prices. Found regression function has the form (model 2)

$$Y = -768940.31 + 77184.9 X_1 \quad (2)$$

with the value of the coefficient of determination 0.636, adjusting coefficient of determination 0.616, p -value of the individual t -test of parameter β_1 is $2.5 \cdot 10^{-5}$.

The final model was then tested. In case acceptance of the model with criterion „price of fuel“ then the model (2) is autocorrelated ($d=1.38$).

$$DW = d = \frac{\sum_{t=2}^n (e_t - e_{t-1})^2}{\sum_{t=1}^n e^2} \quad (3)$$

where: eresidue

Other assumption for verification of significance of the regressive model is satisfying homoscedasticity condition. This test for model (2) was done using Golfeld – Quandt test (C-Q test [1] by comparing test criterion (4) and critical value (5).

$$F = \frac{s_1^2}{s_2^2} \Rightarrow s_1^2 > s_2^2 \quad (4)$$

where: F test criterion

s^2variance

$$F_{1-\frac{\alpha}{2}}(q-p, q-p) \quad (5)$$

where: $q - p$. when q – number of observations, p – number of parameters

α ...level of significance

Homoscedasticity is confirmed when:

$$F > F_{1-\frac{\alpha}{2}} \quad (6)$$

Using G-Q test (6) there was confirmed homoscedasticity ($4.05 < 5.05$)

To increase the relevancy of the model the second explanatory variable (vehicle performance) was added. Found regression function has the form (7)

$$Y = -852115.83 + 46988.62 X_1 + 79.95 X_2. \quad (7)$$

The inclusion of this explanatory variable in the model has only a slight increase in the coefficient of determination (0.698). Since the p -value of the individual t -test for parameter β_2 was 0.079 and the for variables X_1 and X_2 was found a high correlation coefficient value (0.782, see Table 3), second explanatory variable was excluded from the model due to multicollinearity.

	Transport performace X_2 (in tshousands.tonnes)	Average price of diesel in CZK (X_1)
Transport performace X_2 (in tshousands.tonnes)	1	
Average price of diesel in CZK (X_1)	0.781868	1

Table 3 Correlation coefficient value

If we consider the above-selected tolls dependence on oil prices standing and registered second-hand trucks, we obtain the regression function of the form

$$Y = -371218.72 + 80823.83X_1 - 620.19X_3 . \tag{8}$$

Other results are shown in the following table 4.

correlation coefficient R	0.88	p -value F test	$3.16 \cdot 10^{-6}$
coefficient of determination R^2	0.775	adjusting coefficient of determination $adjR^2$	0.748
p -value for β_1	$1.44 \cdot 10^{-6}$	p -value for β_3	0.005

Table 4 Quality of the regression function

The fourth explanatory variable X_4 , newly registered vehicles, was added to the model last. Found regression function has the form

$$Y = -181539.01 + 76038.06X_1 - 857.86X_3 + 73.47X_4 . \tag{9}$$

Delivery of the explanatory variables in the model did not increase the coefficient of determination ($R^2 = 0.783$, $adjR^2 = 0.742$). The p -value of the individual t -test for the parameter β_4 is 0.431. Because between second and newly registered trucks there was also found a correlation coefficient 0.813 (see Table 5), the fourth variable was also excluded from the model.

	Newly registered vehicles (X_4)	Second-hand vehicles (X_3)
Newly registered vehicles (X_4)	1	
Second-hand vehicles (X_3)	0.813362	1

Table 5 Correlation coefficient value

From the originally planned four explanatory variables only variables X_1 and X_3 were finally included in the model and the resulting regression function has the form (8).

This regression function was then examined in terms of heteroscedasticity using the Spearman correlation test sequence, using the Durbin-Watson test (3, 11) was examined first order autocorrelation.

$$DW = d = \frac{\sum_{t=2}^n (809216.391)^2}{\sum_{t=1}^n 631675.713^2} = 1.6411 \tag{11}$$

In both cases, the function appears to be satisfactory. The perimeter of the regression function is also well suited in multicollinearity (see Table 6).

	Second-hand vehicles (X_3)	Average price of diesel in CZK (X_1)
Second-hand vehicles (X_3)	1	
Average price of diesel in CZK (X_1)	0.100556	1

Table 6 Correlation coefficient value

4 Conclusion

After examining the various factors depending on the toll based on multiple linear regression, which allows easy interpretation of results was found to be above the carrying capacity of newly registered vehicles and shall not affect the tolling. On the contrary, the price of oil and the amount of used commercial vehicles related to its size. According to the resulting model it is thus clear that if the unit price will rise the price of fuel (diesel) then the amount of the national budget framework will grow to 80 823.83 CZK as well as an increase of unit used vehicles then decreases the amount of the toll – 620.19 CZK.

The positive effect is probably caused by trying to minimize transportation costs. Using routes is paid not only to shorten transport routes but also reduce transport times, which also allows transport operators to increase competitiveness. Whether the positive effect of oil price increases in the total toll is to be determined by assessing the mutual impact of toll levying excise taxes on fuel. But it is not clear whether increased toll on the fuel price increase will cover any drop in income tax on diesel fuel caused by reluctance to buy at a higher price.

In the case of reducing the toll and increasing the number of used vehicles, it can be concluded that these carriers do not use paid sections. It is obvious that these vehicles trying to use the roads leading cities and communities and thus negatively contribute to environmental quality.

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