

Planning of Road Infrastructure Financing: Computational Finance Viewpoint

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Abstract—Lack of resources for road infrastructure financing is a problem that currently affects not only eastern European economies but also many other countries especially in relation to the impact of global financial crisis. In this context, we are talking about the so-called short-investment problem as a result of long-term lack of investment resources. Based on an analysis of road infrastructure financing in the Czech Republic this article points out at weaknesses of current system and proposes a long-term planning methodology supported by system approach. Within this methodology and using created system dynamic model the article predicts the development of short-investment problem in the Country and in reaction on the downward trend of certain sources the article presents various scenarios resulting from the change of the structure of financial sources. In the discussion the article focuses more closely on the possibility of introduction of tax on vehicles instead of taxes with declining revenue streams and estimates its approximate price in relation to reaching various solutions of short-investment in time.

Keywords—Road financing, road infrastructure development, system dynamics

I. INTRODUCTION

GOOD-QUALITY road infrastructure is considered to be one of the cornerstones of economic development. To ensure the required quality level governments have to invest considerable amount of financial sources into the road network. Demand for road infrastructure investments currently in many countries exceeds their financial capability and the importance of financial planning is increasing. In this context, the paper deals with so-called short-investment problem as a result of investing insufficient amount of financial resources into the road infrastructure. The short-investment problem contains the short-investment of planned road network and the short-investment of existing road network. Short-investment of planned road network is represented by the amount of financial sources required at a given time to finish the construction of planned backbone road network and the short-investment of current road network reflects the amount of financial sources required at a given time to repair the existing road network into the desired technical condition. Currently the short-investment problem has to be solved not only by Eastern European economies, but also by other countries as a consequence of the global financial crisis. In connection with the recent financial crisis the importance of investing in transport infrastructure further increases as a basic tool for restarting economic growth. The longer the problem is not solved by the government, the trickier and longer-range will be the solution.

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Although investments in development of transport infrastructure allocate considerable part of governmental budget, their strategic planning and management processes are still far from optimal. Based on an analysis of road infrastructure financing in the Czech Republic this paper points out at weaknesses of current system and proposes a long-term planning methodology supported by system approach. Within this methodology and using created system dynamic model the paper predicts the development of short-investment problem in the Country and in reaction on downward trend of certain sources the paper presents various scenarios based on structural change of financial sources. In the discussion the paper focuses more closely on the possibility of introduction of tax on vehicles instead of taxes with declining revenue streams and estimates its approximate price in relation to reaching various solutions of short-investment in time. Solutions of short-investment contain the steady state, partial and full elimination.

II. RELATED WORK

The changes in society and its needs are more and more dynamic, the uncertainty within planning increases with time and the planning process together with used tools must adapt [1]. There is a wide range of tools, approaches and methods used for transport infrastructure planning. Among the best known example may be mentioned the scenario analysis [2] or Monte Carlo as a tool to rationalize the planning process by quantifying risk and its simulation [3]. Some authors suggest the mutual combination of benefits of different methods for the planning process, both the more and the less traditional. These can include for example the COSIMA method which interconnects the Cost benefit analysis and the Multi-criteria analysis [4], or the Analytical hierarchy process as a tool supporting multi attribute decision making problem [5]. Along with changes in society also changes the role of governments in the planning of road infrastructure. Different countries apply at the time different approaches [6]. Despite the different approaches all governments are aware of the positive effect of investments in transport infrastructure on economic growth of the region or the whole country [7], [8]. In connection with the recent financial crisis the need for investment in transport infrastructure further increases as a basic tool for restarting the economic growth [9]. Because the planning of road infrastructure at the state level in the Czech Republic depends on the system of road financing, the article considers the use of system dynamics created during the mid-1950s by Professor J. W. Forrester of the Massachusetts Institute of Technology. System dynamics is an aspect of systems theory as a method for understanding the dynamic behavior of complex systems and its application in transport infrastructure, economy and government finance has already been confirmed many times [10], [11], [12].

III. SYSTEM OF ROAD INFRASTRUCTURE FINANCING IN THE CZECH REPUBLIC

The Czech Republic, with its location in the center of Europe, is an important transit country and good-quality road infrastructure is one of the most significant prerequisites for its economic development. Road infrastructure in the Czech Republic includes highways, roads of national, regional and local importance. The analysis in this article focuses only on highways and roads of national importance which are owned by the State (1st class roads).

Sources for road infrastructure financing contain road tax, share of excise tax on mineral oils, road tolls, vignettes, privatization and dividends of state enterprises, subsidies from the state budget, EU grants, EIB loan, Treasury Bonds.

Road tax applies to road vehicles and trailers used for business and to all cargo vehicles with a weight exceeding 3.5t registered in the country. The tax calculation is based on the engine capacity and emission class. Road tax is of lower efficiency. The net tax income is estimated at 85% of gross revenue and the cost of tax payers is estimated at CZK 1bn annually. The net tax income shows downward trend as a consequence of renewal of the vehicle fleet with lower emission cars. Currently, about 9.1% of revenues from excise tax on mineral oil flow back into the transport infrastructure at the central level. There is an upward trend in the amount of tax collected reflecting the increasing fuel consumption.

The toll applies to trucks weighing over 3.5t and its price rate depends on the road class, the length of the toll section, day of the week, number of vehicle axles and emission class. Toll belongs to less efficient source because the cost of the toll varies between 20-50% of the total amount collected. The ministry of transport announced the toll rates will be increased by 25% in 2012 and 2013.

Vignettes apply only to cars (weighing up to 3.5t). The fee can be paid for the year, month, or 10 days. Vignettes are highly efficient because the net income represents 93% of gross revenue.

Income from privatization and from dividends of state enterprises is a financial source historically used, but at present belongs to highly volatile and bonus resources. The future usage is expected to be minimal.

Subsidies are instable contributions from the state budget. The main factor influencing its level is the subjective perception of political leaders who make decisions about the allocation of state budget.

EU Grants (Operational Program for Transport) is an important source which is in the Czech Republic dedicated exclusively to finance new investments. There is necessity of co-financing from the state budget. OP Transport is financed from two funds: the European Regional Development Fund and Cohesion Fund. In the follow-up season 2014 - 2020 the amount of CZK 113.65bn is expected to be drawn.

The existing credit facility provided by the EIB is specifically designed to supplement national resources necessary to co-finance the OP Transport 2007 - 2013.

The usage of this resource depends on the comparison with alternative sources of funding available at the time.

Treasury Bonds D47 is a one-time and special purpose resource designed exclusively for financing the construction of the D47 highway. There is no possibility of future use of this resource due to the completion of D47. The basic strategic document for the development of road infrastructure in the Czech Republic is Transport Policy for the years 2005 – 2013, which sets priorities, goals, main tasks and tools. Another key document is the long-term concept of Transport Sector Strategy, which relates to the Transport Policy by accomplishing its goals and refining the action plan until 2013. There are no other valid strategic documents determining the long-term development of road infrastructure in the Czech Republic. In response to actual conditions the Ministry of Transport designate strategic investments in the next two years. The fundamental planning process determining future development of transport infrastructure is the annual process of approving the budget of State Fund for Transport Infrastructure for the following year and the medium-term outlook for the next two years. Composition of a real plan depends on the anticipated financial resources available for the next planning period and on the political agreements regarding the priorities adopted.

The current system of road infrastructure financing is significantly influenced by following negative aspects:

- 1) Tax revenues dedicated to road financing do not cover the needs at the time, and therefore the infrastructure development is dependent on the amount of state subsidy which considerably varies from year to year.
- 2) Continuing lack of funding sources together with the increasing demand for investment leads to an increasing short-investment problem.
- 3) The entire tax system allows an extensive legal and illegal tax evasion and the enforcement system is of the low efficiency.
- 4) High cost for collecting certain sources reduces the total amount of funding sources.
- 5) Gradually decreasing amount of road tax collected due to renewal of vehicle fleet with lower emission class.
- 6) A significant portion of national resources is used to co-finance the EU funds which are intended only for construction of new roads and therefore remain insufficient financial sources for the reconstruction of the existing network.
- 7) Lack of approved long-term strategy for the period after 2013 which would be also supported by real financial sources.
- 8) Absence of long-term binding plan of investment projects ordered by priorities of realization.
- 9) The whole system of planning and development is influenced by one-year planning cycle of financial sources and investments.
- 10) The uncertain amount of financial sources leads to inefficiencies of its usage reflected in high level of construction without enough sources to guarantee completion.

IV. PROPOSED METHODOLOGY

As a result of described shortcomings of current system of road infrastructure financing in the Czech Republic, insufficient amount of resources has been invested into the road infrastructure for a long time period and the short-investment problem is incessantly increasing year to year.

To improve the planning process we propose to create a long term investment plan for both construction of new sections and reconstruction of existing network sorted by priorities (need for its realization). Then assign investments to free financial sources optimized in long-run according to the desired level of short-investment (complete elimination, reduction to a certain level, steady state, etc.). Optimization of financial sources is a decision - making problem which includes linear relations which change over time (dynamics), a large number of factors and relationships between them (multi-dimensionality and causality), subjective factors and uncertainty. Currently applied planning tools are deficient for described type of problem. As a suitable tool for analyzing the dynamic problem we propose to develop a system-dynamic model.

Strategic planners of large projects strive to employ such models, which are understandable for the widest possible spectrum of their stakeholders. This attitude naturally leads to the design of intuitive user interfaces, where the rough, e.g. mathematical representation of a real task is surrounded with a package of intermediate layers, containing sub-problems, expressed in graphical or textual programming languages. The reason is that the layered architecture allows keeping both wide usability and rigorous formalism of processed task, along with an appropriate level of internal heterogeneity. According to our experience, every stakeholder can find own internal niche within such model, corresponding with the particular knowledge and expertise. Accordingly, we also believe that the system dynamics modeling, generating difference equations on the basis of graphical "stock and flow" representation satisfies exactly this strategy.

V. MODEL DESCRIPTION

Based on the analysis of the system of road infrastructure financing in the Czech Republic a system dynamic model has been developed. The model describes the cycle of resources for financing of the road infrastructure in relation to economic growth, and the use of those resources for new investment, operation and maintenance as a tool to reduce short-investment. The developed system dynamic model contains two basic cycles. First one is the cycle of funding sources represented by an excise tax, road tax, toll, vignettes, direct subsidies from the state budget and funds from the EU. These are intended to finance road infrastructure which is directly connected with economic growth.

Economic growth is in conjunction with traffic volume and fuel consumption. The road usage generates sources which are intended to finance road infrastructure in following period.

The second cycle expresses the cycle of expenditures on road infrastructure and its impact on short-investment. From public sources at first the operating costs are covered. Remaining funds are invested in construction of new roads or in reconstruction (heavy maintenance) of existing road network. Both types of investment have a positive impact on the short-investment. Short-investment creates pressure on politicians to deal with adverse situations and to determine contribution from the state budget intended for road infrastructure financing.

The model also includes alternative financial sources that are currently not used, but their involvement is being discussed - bank loan, bond issuance or usage of private capital - e.g. in the form of public partnership projects. The common feature of alternative sources is the necessity of its repayment. Repayments increase the budget deficit and reduce the available public resources for road infrastructure financing throughout the repayment period.

Additionally a tax on vehicles has been implemented to the model. The road tax is paid by each registered vehicle every year as a yearly fee. The model allows the user to replace selected sources by the tax on vehicles to find its price setting necessary to reach the required solution of short-investment.

VI. EXPERIMENTAL RESULTS

Using developed system dynamic model a simulation of a several sample scenarios was conducted in order to study how the change of financial sources affects the short-investment problem. Simulation time was set on a period of 50 years.

A. Current System without Changes

The first simulated scenario represents the situation where the current system remains unchanged. According to the current set of parameters, the development would proceed as in Fig. 1.

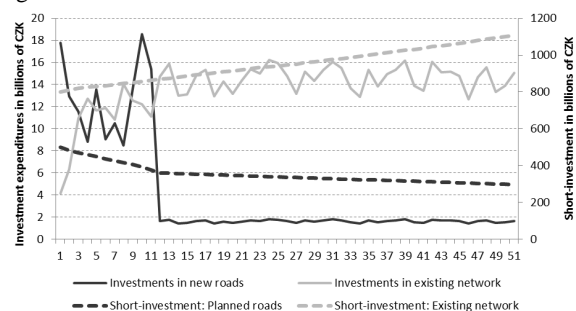


Fig. 1 Current system (values of short-investment are expressed on the right axis)

TABLE II
PRICE SETTING OF TAX ON VEHICLES – DECREASE BY 50%

| Price Group | Value in CZK |
|-------------|--------------|
| Cars | 1200 |
| Trucks | 10000 |
| Motorbikes | 300 |

Fig. 1 shows that the short-investment problem resulting from insufficient financial sources for reconstruction of existing roads is getting worse. The sources from the EU have a positive impact on the construction of new road sections. This situation is illustrated by the sharply decreasing trend of line “Short-investment: Planned roads”. The model assumes that the Czech Republic will be entitled to receive EU grants for next 10 years and afterwards this source will be lost. In the period, where no more funds from the EU will be available, the trend significantly changes. EU funds are currently in the Czech Republic intended only to finance new investments and after subtraction of co-financing from the state budget there remains insufficient amount of funds for reconstruction of current road network. This situation is illustrated by the line labeled “Short-investment: Existing network”.

B. Tax on Vehicles and Full Elimination of Short-investment

Current system in the Czech Republic contains various inefficiencies. There are high costs for collecting certain sources, especially for collecting road tax and toll. The amount of road tax collected gradually decreases due to renewal of vehicle fleet with lower emission class. The renewal of vehicle fleet for cars with lower fuel consumption has also a negative effect on the amount withdrawn from excise tax on mineral oil. Decreasing amount collected will cause an increasing gap between the amount of required sources and the amount of sources available. Fig. 2 represents a situation where road tax, toll and vignettes are replaced by tax on vehicles. Tax on vehicles is paid per registered car and its price depends on the payment group. There are only three groups in our exemplary case: motorbikes, cars and trucks (all cars which are not motorbikes or cars). The prices of all three groups reflect the target of the government to reach the full elimination of both parts of short-investment within the simulation period of 50 years and are modeled as a yearly fee.

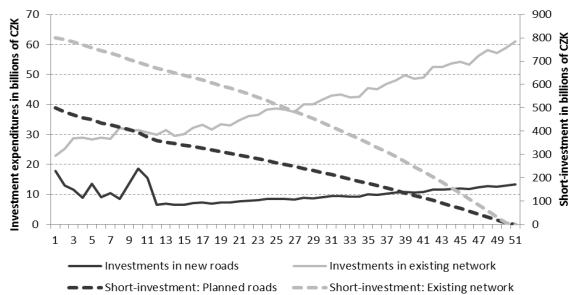


Fig. 2 Tax on vehicles and full elimination of short-investment

Fig. 2 shows that full elimination of both parts of short-investment can be reached by replacement of road tax, toll and vignettes by a tax on vehicles.

An example of price setting of a tax on vehicles by which the full elimination can be reached is shown in Table I.

C. Tax on Vehicles and Decrease of Both Parts of Short-investment by 50%

If the government decides that price setting of tax on vehicles necessary to reach the full elimination of short-

investment is not feasible due to high prices, an alternative option must be found. One of possible alternative options is to decrease both parts of short-investment only partially. Selection of partial decrease as a target state of short-investment will allow the government to set lower prices of tax on vehicles. The decision of the government to implement a tax on vehicles instead of road tax, toll and vignettes in order to decrease both parts of short-investment to 50% of its original value within the simulation period of 50 years is shown in Fig. 3.

TABLE I
PRICE SETTING OF TAX ON VEHICLES – FULL ELIMINATION

| Price Group | Value in CZK ^a |
|-------------|---------------------------|
| Cars | 1500 |
| Trucks | 13000 |
| Motorbikes | 500 |

^a CZK/EUR = 24.51 (National Bank of Czech Republic, 16.3.2012)

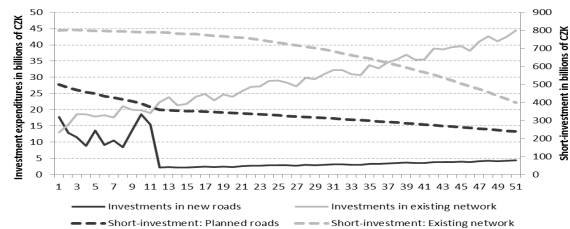


Fig. 3 Tax on vehicles and decrease of short-investment by 50%

The decrease of both parts of short-investment by 50% can be reached by price setting indicated in Table II. In comparison with the solution of full elimination, the partial elimination requires significantly lower prices.

Tax on Vehicles and Completion of Planned Road Network while Keeping the Short-investment of Existing Road Network at Initial Level. Another option, in case of full elimination is not feasible, is to fully eliminate one part of short-investment while keeping the other part at a stable level. Prices of toll, vignettes and road tax are set by political decision which reflects not only needs of the society but also personal and other needs. From this point of view the solution of construction of all planned roads while keeping the current road network at the same level of short-investment can be for decision-makers more attractive. This scenario is shown in Fig. 4.

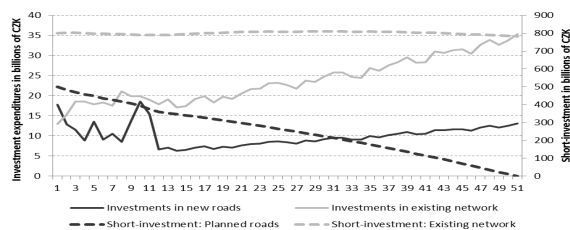


Fig. 4 Tax on vehicles and completion of all planned roads while keeping the short-investment of existing network around original level

The solution where all planned roads are constructed and the short-investment of existing road network oscillates around its original value can be reached by the same price setting as in Table II. The difference is in the setting of model parameter "Division of investment sources between construction of new roads and investments in current road network". To reach a 50% decrease of both parts of short-investment within the simulation period of 50 years, only 9% of investment sources should be intended for construction of new roads while to finish the construction of all planned backbone roads in Fig. 4 is the ratio 27%.

VII. CONCLUDING REMARKS

Current system of road infrastructure planning and setting of system of road infrastructure financing in the Czech Republic has number of weaknesses which do not allow inserting sufficient amount of investment sources into road infrastructure. This long-term lack of investment sources results in the short-investment problem. If the government will not solve the problem we can expect its significant worsening. As a suitable tool for observation and prediction of short-investment a proposed system-dynamic model can be used. To solve the short-investment at first the required solution has to be chosen (full elimination, partial elimination or other) and then the way how to reach the preferred solution can be found. The user of the model can easily find the way towards required solution by changing factor settings and by rerunning the simulation model.

In the Czech Republic decreasing revenue streams of road tax together with high costs for collecting road tax and toll are examples of system weaknesses causing the financial gap resulting in short-investment problem. Possible solution of this situation is to replace inefficient revenues by tax on vehicles which is based on an increasing number of registered vehicles and on low costs for its collection (same principle as vignettes). This action would decrease the operation costs and bring more sources for investments. On the other side by the replacement of toll the government will lose valuable information provided by toll system and the tax on vehicles does not follow the current trend that payments should be made only for road usage (toll system).

Performed experiments confirm that proposed methodology can simplify, improve and accelerate the planning of road infrastructure financing. Using the methodology the right way towards preferred solution of short-investment can be easily found.

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