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COST ASSESSMENT METHODS AND MODELS OF NEGATIVE EXTERNALITIES OF MOTORIZED VEHICLES

Doctor dissertation summary

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GENERAL DESCRIPTION OF THE RESEARCH

Topicality of the Theme

The role of transport has been growing continuously over the recent past. Motorized vehicles have basically become the link between various economic sectors and consumers. Without them the modern life and economic development, in the way that we know it, would be hardly possible. The growing level of social welfare and the fact that almost every individual in Latvia, who is not unemployed, can afford to purchase an automobile (at least, on basis of a lease agreement) both account for the growing intensity of transport exploitation in our country. Nevertheless, despite the multiple advantages and economic benefits of such transport, the adverse impact of transport use on the human health, the environment and the public in general calls for serious consideration. The main categories of transport externalities include air pollution, traffic jams (TJ), traffic congestions (TC) and traffic accidents (TA).

Already in the mid-20th century many of the environmental and health problems caused by air pollution went beyond the borders of individual countries. At this point the global character of the problems related to the impact of transport externalities was recognized by interdisciplinary experts, scientists, national leaders and specific issues were first addressed by several working groups within the United Nations (UN). According to the data of the World Health Organization (WHO), {on annual basis} on average 2 millions of TA involving injuries take place in the territory of Europe, affecting approximately 2.5 million individuals and amounting to 120 000 human victims per year.

Since the regain of the national independence of Latvia, the impact of transport externalities has become an issue of major concern, as over the recent past the number of automobiles has escalated from 0.3 million in 1990 up to 0.53 million in 2002 (the number of vehicles has almost doubled over the relevant period). Yet in 1990 there was on average one automobile per every 10 residents, then in 2002 there was already one automobile per every 4 residents and it is estimated that by 2015 this indicator could rise up to one car per every two residents.

One of the main factors attributing to the technical condition of a vehicle is its service runtime (age) and there is a clear link between this and environmental externalities. It is noted that in 2003 a reported relatively large proportion of old vehicles was registered in Latvia. Out of 619 000 vehicles, 539 000 exceeded the age of 11 years. This factor gives rise to excessive emission of pollutants in the atmosphere, increasing noise levels and growing risk of TA occurrence, etc.

The rapidly growing number of vehicles has not, however, contributed to the construction of new street sections, roads, bridges or any other objects related to transport infrastructure. Due to financial constraints the progress of infrastructure development is lagging behind compared to the rapidly growing number of vehicles. Since 1990 the total length of hard-surfacing motorways has basically remained unchanged. By 2003 the state-run motorway network has accumulated an excessive amount of outstanding renovation work for the total cost 337 million LVL. The adverse consequences of the deficient pace of infrastructure development can be well observed on the streets of Riga, as due to lack of financing the infrastructure development lags behind compared to the increase in the number of vehicles and the growing demand for good quality roads. This situation has lead to increasing duration of time consumed in TJ & TC, increased operating costs for vehicles, increasing volumes of pollutants emitted in the atmosphere and growing risk of TA occurrence.

The main deficiencies of the municipal Riga street infrastructure is the fragmentary nature of the existing main streets and the outstanding issue regarding the integration of River Daugava crossings in the municipal street network. Another major impediment hindering the development of transport infrastructure is related to restored ownership rights for land estates located on the designed street routes. Many of the controlled traffic intersections and single-level railway crossings found in the city area fail to meet the demand in terms of throughput capacity, and this highlights the need to elaborate and introduce a multi-level transport organization scheme.

OBJECTIVE & TASKS OF THE RESEARCH

The objective of this Research is to develop country-specific economic-mathematical models and methodology for the assessment of transport externalities in Latvia, required to facilitate the assessment of the economic efficiency of traffic optimisation plans.

The above objective shall imply the following tasks:

•To analyse the dynamics of the numbers of vehicles purchased and infrastructure development trends;
•To identify the main categories of transport externalities;

•To estimate the negative external costs related to air pollution;
•To study the generic trends of TA occurrence in Latvia and to compare the results of this study to the relevant experience in other countries;
•To establish the circumstances generating TC in the territory of Riga;
•To review and evaluate the existing methodology for the assessment of negative external costs relating to air pollution and TA;
• To review and evaluate the multiple aspects of TC assessment;
•To propose a set of activities for minimizing the losses related to transport externalities;
•To develop a mathematical model for the assessment of transport externalities;
•To develop methodology for estimating the TC costs;
•To develop a time model for the recovery of public investment in human resources in relation to the risk of TA occurrence.

Selection of Topic

The major environmental externalities related to transport, including the adverse effects on human health and other natural resources, the actions taken by other nations in regard to the assessment and minimization of transport externalities, as well as the activities brought about by other international organizations in this field — all of the above served as preconditions for the selection of this topic. Until now in Latvia the presence and the associated negatives costs of such transport externalities have been neglected to a great extent.

Subject and Object of the Research

Object of the Study - the three main categories of transport externalities - air pollution, TJ & TC and TA.

Subject of the Study - impact of transport externalities and the associated negative external costs in Latvia, in particular, in the urban territory of Riga City, where the external impact has proved to be the worst.

REASERCH METHODS & CONSTRAINTS

Research methods

Generally accepted qualitative and quantitative economic research methods have been applied in the elaboration of this study. In general, these are analysis and synthesis based methods for studying individual problem elements and process components in order to synthesize the correlations or to establish the underlying interactions. I have applied also the scientific induction method to develop general conclusions and establish the relationship between individual facts. The study involved also an analysis of the possible applications of various mathematical research methods for the assessment of the impact of transport externalities and the associated external costs. Based on the results derived from the study and the observations made hereunder, a country-specific mathematical model has been developed for the assessment of the impact of transport externalities in Latvia and upgrading the methods for estimating the negative external costs of TJ & TC.

Constraints

This study focuses only on the three main categories of transport externalities - air pollution generated by mobile sources (stationary pollution is not covered under this study), TJ & TC, and TA. There is also a number of other transport externalities, which are not analysed in detail as part this study: lack of physical activities related to excessive driving "abuse", psychosocial effects, noise disturbance, traffic accidents during the transportation of hazardous cargoes etc. Likewise, this study does not cover also the problems related to utilization of natural resources, market of transport services, problems related to individual types of transportation, technical and operational issues etc.

Scientific publications and Conference Papers

In total, the author has prepared 10 publications on a wide range of problems related to transport externalities and the associated negative costs, delivered lectures to students on the problems and disadvantages of market development; besides, the Author has also delivered speeches in 7 international scientific conferences in Latvia and abroad. List of scientific publications:

1. L. Adamsone, M. Šenfelde. Atsevišķu satiksmes sastrēgumu problēmu iespējamie matemātiskie risinājumi Rīgas pilsētas apstākļos// Tautsaimniecības un izglītības attīstības problēmas mūsdienu periodā. Starptautiskās zinātniski praktiskās konferences zinātniskie raksti.-R: RTU, 2003, 16.-24. lpp.
2. L. Adamsone, M. Šenfelde.Ceļu satiksmes negadījumu izmaksu noteikšanas iespējamās metodes// RTU zinātniskie raksti. 3.sērija. Ekonomika un uzņēmējdarbība. Tautsaimniecība: teorija un prakse. 4.sējums.- R,:RTU,2001, 15.-22. lpp.

3. L. Adamsone, M. Šenfelde. Satiksmes sastrēgumu galvenās problēmas un ar to saistītās izmaksas// Inženierekonomikas nozīme uzņēmējdarbības attīstībā. Starptautiskās zinātniski praktiskās konferences zinātniskie raksti.-R: RTU, 2002, 177.-184. lpp.
4. L. Adamsone, M. Šenfelde. Transporta līdzekļu ietekme uz vidi un tās novērtēšana// Baltijas reģiona valstu integrācijas problēmas ceļā uz Eiropas Savienību. Starptautiska zinātniska konference.- Rēzeknes: 2000, 17.-22. lpp.
5. L. Adamsone, M. Šenfelde. Transportlīdzekļu sertifikācijas ieviešana Latvijā// Rūpniecības attīstība pārejas periodā. Starptautiski zinātniski praktiska konference.-R: RTU, 2000, 124.-131. lpp.
6. L. Adamsone, M. Senfelde. Environmental management//21 st century: Expected Realites in Business and Management. Volume 1. - Svishtov, Bulgaria: D. Tsenov Academy of Economics Publishing House, 2001, p. 84-91.
7. L. Adamsone, M. Senfelde. The Human Resources Management in the Field of Road Safety// Economics and management -2002. International Conference Proceeding. Vol.1.-Kaunas University of Technology, 2002, p. 13-14.

Other publications:

1. L. Adamsone, M. Šenfelde. Autotransporta izmantošanas negatīvo seku novērtējuma nepieciešamība un pielietojums// Inženierekonomika nozīme uzņēmējdarbības attīstībā. Starptautiskā zinātniski praktiskā konference.- R,:RTU, 2000, 39. lpp.
2. L. Adamsone, M. Šenfelde. Ekonometrijas pielietojums Rīgas pilsētas atsevišķu transporta problēmu risinājumos// Tautsaimniecības un izglītības attīstības problēmas mūsdienu periodā. Starptautiskā zinātniskā konference, veltīta IEF 35. gadu jubilejai. -R,:RTU, 2002, 6.1pp.
3. L. Adamsone, M. Šenfelde. Satiksmes negadījumi un to iespējamie novēršanas varianti Latvijas apstākļos// RTU 42. starptautiskā zinātniskā konference. Sekcija: Inženierekonomika un tautsaimniecības attīstība. R.: RTU, 2001, 8.1pp.

Participation in Scientific Conferences:

1. "Rūpniecības attīstība pārejas periodā", Rīgas Tehniskajā universitātē, 1999. gada 10. decembrī;
2. "Baltijas reģiona valstu integrācijas problēmas ceļā uz Eiropas Savienību", Rēzeknes augstskola, 2000. gada 3. martā;
3. "Inženierekonomikas nozīme uzņēmējdarbības attīstībā", Rīgas Tehniskajā universitātē, 2000. gada 24. novembrī;

4. "Ekonomika un uzņēmējdarbība", Rīgas Tehniskajā universitāte, 2001. gada 12. oktobrī;
5. "Tautsaimniecības un izglītības attīstības problēmas mūsdienu periodā", Rīgas Tehniskajā universitātē, 2002. gada 17. maijā;
6. "XX -ви век: очаквани реалности в бизнеса и мениджмента". Юбилейна международна конференция. Стопанская Академия "д.А. ненов", Свицов, Болгария, 26 октября 2001года;
7. "Теория и практика управлений организацией". Международнае научно практическае конференциа. Киев: Киевский Технический университет. 24 мая 2001 года;

Since 2003, in cooperation with the Swiss Gebert Ruf Fund in the framework of the Swiss Baltic Net programme the Author has introduced in the study process a business game "Ecosys".

Theoretical framework

In Latvia the existence of transport externalities and the associated negative external costs so far have been neglected to a great extent. On the one hand, it could be related to the fact that the theory of social welfare deals mainly with the average level of social welfare and focuses on the assessment of current trends in the development of social welfare. On the other hand, it could also be related to the necessity to develop a new, country-specific model for estimating the negative costs of transport externalities in Latvia, i.e., to establish the monetary value of transport externalities, which are not reflected in the market prices. The main categories of transport externalities include TA, air pollution caused by emissions from mobile transport facilities and traffic congestions. To estimate the negative external costs incurred to any third parties or the society as a whole, the Coase theorem is usually applied. The study also draws on the results of research work done by the most distinguished foreign and Latvian scientists in the field, e.g., V.Bise, C.Nass, G.F. Nuels, N.Sprancmans etc.

SCIENTIFIC NOVELTIES AND MAIN RESULTS

Scientific novelties introduced in the Research

This is the first study done in Latvia on the impacts of transport externalities and the associated external costs. The scope of the study comprised the development of the following elements:

Mathematical model for the assessment of transport externalities;

• Methodology and a new general formula for calculating the negative external costs related to TJ & TC;
• Linear regression equations for calculating the negative external costs of TC;
• Matrices of negative external costs related to TJ & TC;
• Time model for recovery of public investment in human resources in relation to the risks of TA occurrence;
• Forecasted decrease of transport density in the central area of Riga City as result of the implementation of "Park and ride" system;
• Methodology for modelling the quantitative probability of traffic congestion occurrence;
• A comparison of alternative proposals for the reduction of transport density (in the central area of Riga City) based on cost-benefit analysis.

The practical application of the Research

The results of this study can be applied in practice as follows:

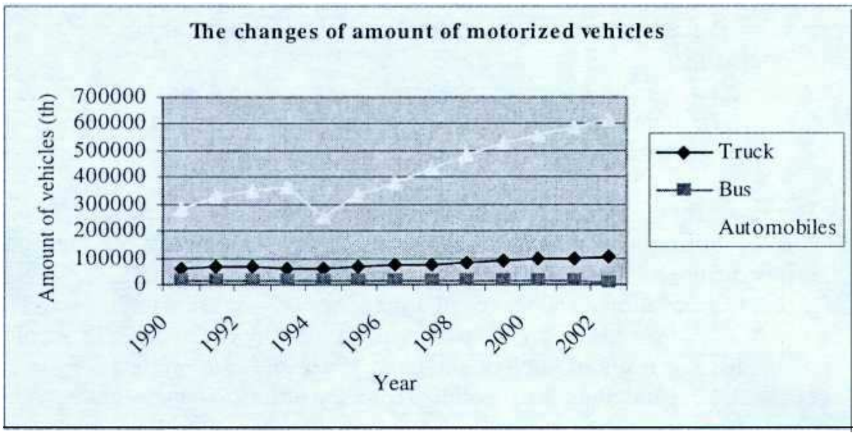
1) The results of studies are incorporated in the contents of lectures delivered by the Author in Riga Technical University (Problems and Disadvantages of Market Economy);
2) In supervising the elaboration of diploma designs, course papers and studies done by students of Riga Technical University;
3) The results of this study have been introduced to scientists and entrepreneurs in Latvia, Lithuania, Ukraine and Bulgaria, as witnessed by the publications in scientific and empirical periodicals;
4) The results of this study have been approbated by the Latvian Investment and Development Agency;
5) The results of this study have been reported also in international conferences held in Latvia, Ukraine and Bulgaria.

Structure and Scope of Dissertation

The Dissertation consists of 3 chapters. The total volume of the Dissertation is 173 computer pages plus annexes. The Dissertation comprises 65 tables, 43 pictures, 49 formulas and 15 annexes clarifying and illustrating the contents of this study. The Dissertation is structured as follows:

The study was conducted in Riga Technical University, Faculty of Engineering Economics, Institute of International Economic Relations and Customs, in adherence with the requirements of the Law on Scientific Activity and Cabinet Regulations No. 134 issued on 6lh April 1999, as well as in line with the requirements of the Scientific Advisory Council of Latvia and Senate resolutions of Riga Technical University.

The first chapter comprises an analysis of the problems relating to transport externalities. This includes the analysis of the increase in the quantity of automobiles in certain regions in Latvia, an estimated breakdown of automobiles according to their age and type of fuel, as these indicators are linked to air pollution. The adverse environmental impact of the individual components and quantities of transport exhaust fumes, including the impact on human health and climate, has been established hereunder. Thus, based upon the estimated negative costs of transport externalities, it has been concluded that the development of transport infrastructure lags behind compared to the intensive increase in the number of registered transport units.



Picture 1. The changes of amount of motorized vehicles.

This has had a negative effect, especially in the territory of Riga, on the velocity of individual transport units and public transport (buses, trolleys and taxi buses) leading to the occurrence of TJ and TC and augmenting the negative external costs of these transport units. This chapter includes also the analysis of problems related to traffic accidents and the associated negative external costs for Riga. In addition, an overview of the most critical road safety issues in Latvia compared to other European countries is given hereunder.

Second chapter is basically constituted of two parts. The 1st part is a summary of the prevalent methods developed by the leading scientists and transport experts around the globe, appropriate for use as a reliable and easy-to-use tools for estimating the negative external costs related to air pollution, TJ & TC and TA. A comparison of the various alternative methods has been conducted hereunder. The analysis was focused on the strengths and weaknesses of each of those proposed methods.

The second part of this chapter presents a "Mathematical model for the assessment of transport externalities". Within this mathematical model the economic correlations are expressed by means of efficiency functions. To facilitate the application of the model, efficiency sub-functions are introduced, which can be calculated separately one by one and then inserted into the aggregate efficiency function. Taking account of the lack of a country-specific model, tailored according to the situation of Latvia, for calculating the external time costs of TC & TJ, a study was conducted and a model for calculating the time costs of TC was developed hereunder. New factors have been introduced correlating to the function and the model. Based on the study, a generic formula has been developed for calculating the time costs of TC as well as a formula for calculating the total negative external costs related to TJ & TC. For the purpose of developing simplified and easy-to-use equations, linear regression equations were introduced to facilitate a prompt extraction of the result data. Three different econometric matrices have been developed according to the duration of TC. The application of the matrices enables an immediate derivation of data regarding the time costs of TC.

A time model for the recovery of public investment in human resources in relation to the 1 risk of TA occurrence. This model can be used to calculate the year "n", when investments in human resources are recovered in full amount. Within the model, upon the occurrence of a TA, two options are studied: 1) if an individual has been killed in a TA before year "n", then the state not only suffers losses, but it has also failed to recover its investments; 2) if an individual has been killed in a TA after year "n", in which case the state has managed to recover its investments, however, it still suffers the losses related to the value of the forecasted, but outstanding production to be produced by victims of TA (wages are normally used for the purpose of these estimates).

The third chapter is a summary of activities proposed for the reduction or elimination of transport externalities. For example, a decrease in the traffic density in the central area of Riga is forecasted to occur as a result of the implementation of the "Park and ride" system. Modelling of the possible frequency of TC occurrence has been done in Riga-specific circumstances, based on the statistics for Kr. Barona Street. In addition, specific organizational, financial/economical and political arrangements are proposed for the minimization of transport externalities. In order to assess the effectiveness of the individual methods and models proposed hereunder, approbation of the derived data has been conducted, as well as a cost-benefit analysis thereof. Three different alternatives are evaluated, the implementation of which could facilitate the reduction of traffic density and the related transport externalities in the central area of Riga:

1. Dislocation of the personnel (or pupils, students) of a number of administrative institutions, offices and educational establishments for work or study purposes to other new or appropriately renovated premises outside the central area of Riga;
2. Construction of six parking lots outside the central area of Riga or the implementation of the "Park and ride" system by constructing three parking lots;
3. Construction of the North Crossing (Ziemeļu šķērsojums).

Alternative No.1. As part of this alternative, an administrative reduction of the number of civil servants, pupils and students working in the central area of Riga is proposed by dislocating the educational (working) premises outside the centre of Riga to new or renovated premises. Three possible solutions are proposed to achieve this objective: 1) dislocation of the staffing of a number of departments of Riga City Hall; 2) organizing the study process of a number of educational establishments or their sub-structures outside the central area of Riga; 3) dislocation of the civil personnel of a number of ministries (or other governmental institutions), dealing with the provision of public services to the general public or other companies, institutions and organizations outside the central area of Riga.

Alternative No.2. In order to reduce the number of persons getting around in the urban area by automobiles with the average vehicle occupancy not exceeding one or two passengers, and to encourage them to use public transport, which would lead to a substantial reduction of traffic density in the centre, convenient and economically driver-friendly parking lots should be provided adjacent to the central area of the city, including, bridges. This requirement is based on the fact that the most critical TJ-s during morning and evening peak hours occur mainly on bridges. Considering the costs of energy resources, the inflation and the impact of other factors, it is also possible that due to lack of appropriate funds the construction of only three parking lots will be feasible, as opposed to the originally proposed six parking lots. In that case these parking lots should be provided in the proximity to the railway lines incoming to Riga (from Jurmala, Jelgava, Daugavpils, Valmiera). In these circumstances the two following solutions are possible: a) construction of six parking lots, or b) construction of three parking lots.

Alternative No.3. The construction of the North crossing across the River Daugava in the area of Spilves iela and Bukultu iela would result in a substantially reduced frequency of TJ & TC occurrence on Vanšu, Akmens and Salu bridges.

The relevant estimates and a comparison of the above alternatives were done based on a cost-benefit analysis. A summary of the results is provided in Table 1.

Table 1

Comparison of marginal benefits and marginal costs for each of the proposed alternatives

Altern.	Public Benefit		Project costs	
No.	Benefits LVL per year	MB, LVL	Costs TC, LVL per year	MC, Ls
0	0		0	
		5 840 012		5 800 000
1	5 840 012		5 800 000	
		2 414 688		2 545 000
2 (a)	8 254 700		8 254 000	
		5 932 744		6 254 000
2 (b)	14 187 444		14 508 000	
		-9 411 897		27 492 000
3	4 775 547		42 000 000	

Based on a number of economic laws and following the approach of Cost-Benefit analysis, the best viable alternative is selected at the point, when the marginal costs (MC) are equal (or proximate) to the marginal benefit (MB), i.e., when MC=MB. Alternative No.l corresponds to this position (or transition from Alternative No.0 to Alternative No.l), whereby it is proposed to dislocate the personnel (pupils, students) of a number of administrative institutions, offices and educational establishments for work or study purposes to other new or appropriately renovated premises outside the central area of Riga City. This means that the implementation of this alternative could help to achieve equilibrium between the passengers' requirements and the public (governmental, municipal) investments aimed at meeting these requirements and corresponding to the actual level of service quality. As regards the alternative proposing the construction of six parking lots (2.b), MC>MB. As part of this alternative, to find a new equilibrium the implementation of the "Park and ride" system is analysed, whereby the number of parking lots to be constructed is reduced to three (2.a). By comparing the marginal benefits with the marginal costs it is clear that MC>MB. Alternative No.3, however, is a relatively costly solution, nevertheless, it is of a major importance for the general public.

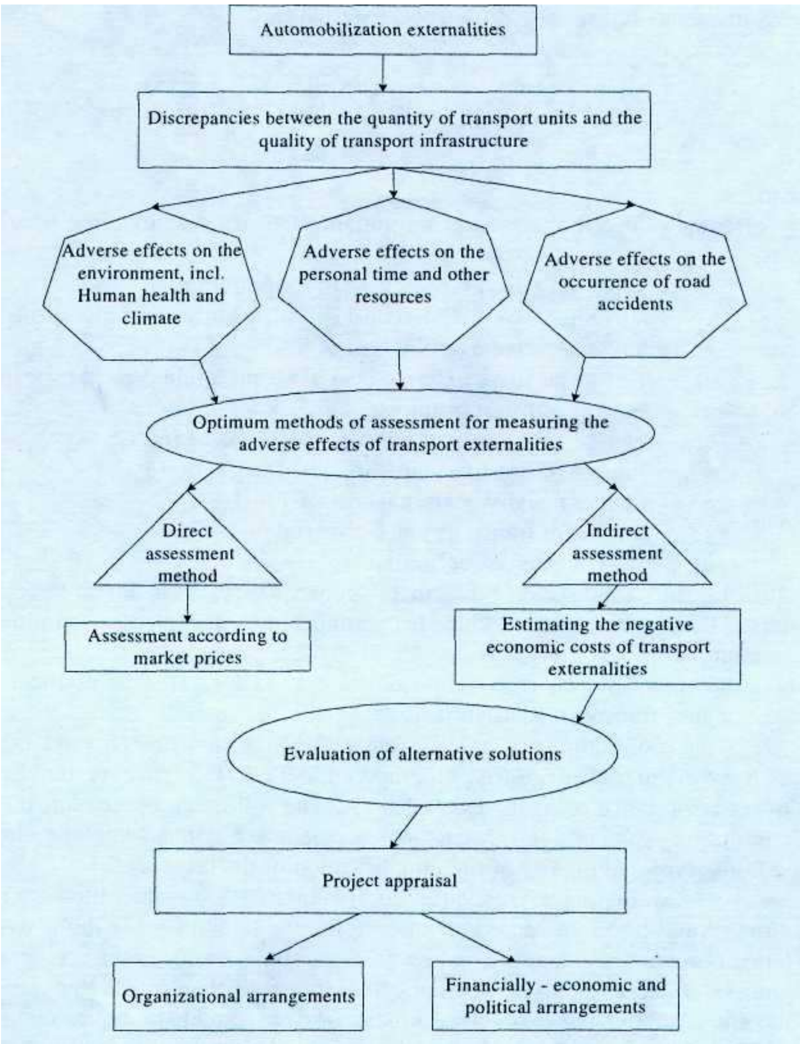
The provisions put forward in Alternatives No.l and No.2 create favourable pre-conditions for encouraging the car drivers to opt for public transport whenever they need to get to the centre by leaving their cars outside the central area of the City.

THE MAIN SCIENTIFIC ELABORATIONS

In order to avoid any subjectivism and to expand the scope of the assessment of negative external costs and to create new tools for a quantitative analysis thereof, as well as to enhance the quality of traffic planning activities, specific methods and models must be developed and introduced for the above purpose.

The Author has proposed the following flow chart - mathematical model for the assessment of transport externalities:

Flow chart - mathematical model for the assessment of transport externalities:



Picture 2: Flow chart - mathematical model for the assessment of transport externalities.

The Author has proposed the following mathematical model for the assessment and adjustment of transport externalities:

$$Z=\alpha_1 z_1+\alpha_2 z_2+\alpha_3 z_3=\alpha_1\sum_{i=1}^{m}\sum_{j=1}^{n}c1_{ij}\cdot x1_{ij}+\alpha_2\sum_{i=1}^{m}\sum_{j=1}^{n}c2_{ij}\cdot x2_{ij}+\alpha_3\sum_{i=1}^{m}\sum_{j=1}^{n}c3_{ij}\cdot x3_{ij} \qquad (1)$$

where:

Z - efficiency function, aimed at minimizing the negative external transport costs;

z_1 - relative negative external cost of air pollution;
z_2 - relative negative external cost of traffic jams and congestions;
z_3 - relative negative external cost of TA;
cl_{ii}- relative negative external cost of air pollution caused by traffic;
xl_{ii} - number of transport units;
$c2_{ii}$ - relative negative external costs of TC & TJ (LVL);
$x2_{ii}$ - number of transport units involved in TC or TJ;
$c3_{ii}$ - relative negative external cost of TA (LVL);
$x3_{ii}$ - number of transport units involved in TA.
α_1, α_2, α_3- relevance coefficient.

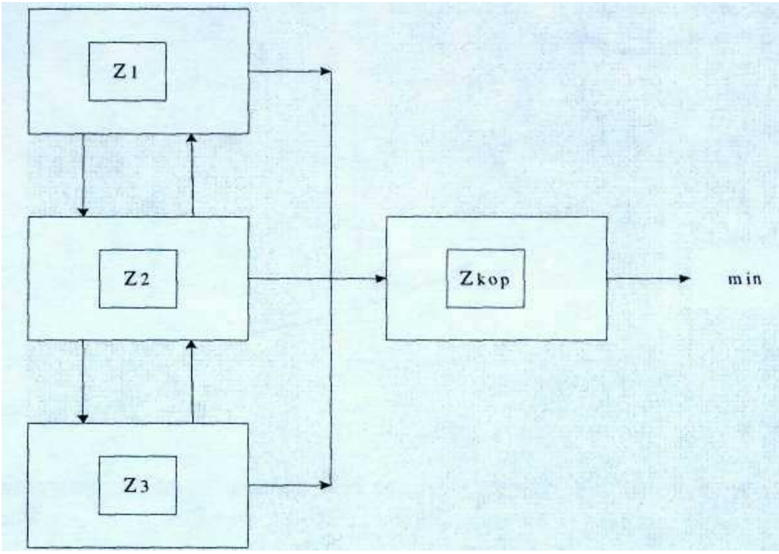
Following an analysis of the main consequences related to transport externalities, the Author within her competency accepted the following conventional values: α_1=0,35, α_2=0,15, α_3=0,50.

The following flow chart is proposed as a model for the assessment and adjustment of transport externalities:

Air pollution (α_1)and its impact on the environment and human health are given higher priority, if compared to TJ & TC, however, they are of a lower importance than, for example, TA. The following factors attribute to air pollution: vehicle age, presence of accelerators in the vehicle, technical condition, type and quality of fuel, qualification of the drivers etc.

By evaluating the relevance coefficient of TA (α_3) the following main factors should be addressed: value of each individual human life in the case of a lethal outcome, accident prevention costs and the severity of the accident. As a general rule, it is highly complicated to establish a life value, as this concerns also the issue of how ethical it is to establish the value of an individual human life. Nevertheless, it was possible in the development of the theory of Economics, and it is still possible, and, moreover, necessary to establish the value of life. It is conditional also on the socially economical level of the society, legal basis etc. As witnessed by the history of different nations, the value of a life can vary to a great extent. The costs related to saving human lives are also conditional on the scope of the required rescue arrangements. The costs of such rescue arrangements are growing in proportion to the increasing scope of such arrangements.

With the help of the relevance coefficient (α_2), TJ & TC are directly linked to the demand for road width and the capacity of the existing infrastructures. However, the following phenomenon can be observed - the demand is growing in parallel to the investments made and the development of the infrastructure. Here it should be noted that the demand is not unlimited. Infrastructure development attributes for numerous improvements within transport systems. In the applied formulas each of the items is correlated and conditional on the other items. Thus, also the efficiency sub-functions z_1, z_2 and z_3 are interrelated.

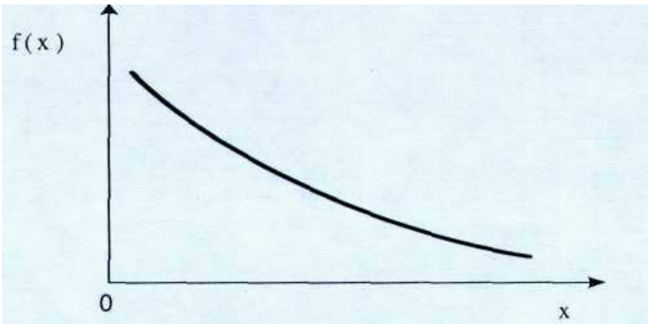


Picture 3: Illustration of the role of the efficiency function and the interrelations between the efficiency sub-functions.

This model provides a simplified description of transport externalities. Simplifying of a more complicated function - estimation of the negative external costs with the use of such models allows to analyse the process by means of scientific methods.

There have been estimates done in Latvia regarding the amount of negative external costs of TA and air pollution, therefore it is possible to establish the relevant efficiency sub-functions. However, the negative external costs of TJ & TC were not calculated up the present day. In order to calculate indicator z_2 of the efficiency sub-function, i.e., the negative external costs of TJ & TS, a new methodology had to be developed, tailored according to specific context of Riga.

A survey was conducted on the intersection of Kr Barona Street and Blaumana Street in Riga. As part of this survey, the time of arrival of cars and trams was registered and the time when they crossed the intersection. These empiric data were obtained by conducting time measurements on the above street on two different times - during morning and evening peak hours. The empiric data obtained as result of the above survey was subdivided in 10 categories. As a result of the subsequent data processing, development of a column diagram and aligning of the empiric data with the curve, a hypothesis was put forward regarding the congruence between the incidental quantity and the exponential distribution.



Picture 4. The curve of exponential distribution.

In order to provide a more accurate characterization of the congruence between the empiric and hypothetical distribution, Pirson hi - square hypothesis check χ^2 criterion was applied. Two hypotheses were put forward:

1) The empiric distribution is congruent with the hypothetical distribution (Ho:ni= nj);
2) The empiric distribution is not congruent with the hypothetical distribution (H_0:n≠ nj)

where:

n_i - frequency of the i-th interval of the empiric distribution;

n_j - frequency of the i-th interval of the hypothetical distribution [3,93].

To compare the actual value of χ^2 with the hypothetical value, χ^2_{act} is calculated according to the following formula:

$$\chi^2_{act.} = \sum_{i=1}^{k} \frac{(n_i - \overline{n_j})^2}{\overline{n_j}} \quad (2)$$

The frequency of the i-th interval of the empiric distribution, i.e., n_i is registered, but the frequency of the i-th interval of the hypothetical distribution, nj , is unknown. It can be calculated by using the following formula:

$$\overline{n_j} = P_i \cdot N \quad (3)$$

where:

Pi - probability that the value of an exponentially sub-divided incidental quantity t falls within the interval $[t_1;t_2]$ or $P(t_1<t<t_2)=F(t_2) - F(t_1)$ [13,456],
$F(t_i)$ - probability distribution function;
N- total number of observations.
To calculate the probability that that the value of an exponentially sub-divided incidental quantity t falls within the interval $[t_1; t_2]$, a formula for the
breakdown of exponential distribution probabilities was applied:

$$F(x) = \begin{cases} 0, \ jax < 0; \\ 1 - \lambda e^{-\lambda x}, \ jax \geq 0 \end{cases} \quad (4)$$

And the following interrelation, that $P(t_1<t<t_2)=F\{t_2) - F(t_1)$
The probability is calculated by using an MS Excell function (see Column 1, Table 2).

Table 2

Calculation of the exponential distribution probability density function and its main index λ

Column 1	Column 2	Column 3	Column 4	Column 5
Probability $P(t_1<t<t_2)$	f(x)·10 sec.	Hypothetical Frequency (number of times)	Empiric Frequency (number of times)	Error e^2
0.1905	0.1902	14.85	14	0.74
0.1542	0.1539	12.02	12	0
0.1248	0.1246	9.74	10	0.07
0.1011	0.1009	7.88	11	9.72
0.0818	0.0816	6.38	12	31.58
0.0662	0.0661	5.17	8	8.04
0.0536	0.0535	4.18	6	3.31
0.0434	0.0433	3.39	3	0.15
0.0351	0.0351	2.73	1	3.03
0.0284	0.0284	2.21	1	1.48
			Total:	59.11

The exponential distribution is established by using the probability density function [13,472]:

$$f(x) = \begin{cases} 0, \ jax < 0; \\ \lambda e^{-\lambda x}, \ jax \geq 0, kur\, \lambda > 0 \end{cases} \quad (5)$$

Area S is presented in Column 2, which allows to establish the approximate probability, that t is found within the area f(x) -10 sec. As the probability P $(t_1<t<t_2)=F(t_2)$ - $F(t_1)$ has already been calculated in Column 1, then in Column 2 the values of the approximate probability are presented. Based on the results of Column 1 and Column 2, it can be stated that by applying the probability density function and calculating the probability area, as well as by establishing the probability as an expansion (difference) of the probability distribution function, the indices of these columns are very proximate or equal.

Since the sum of P $(t_1<t<t_2)$ must be equal to 1, but in our case it is 0.9, then an error was derived. As a result of using the Solver programme and

seeking to minimize the error and to find the optimum λ, the minimum error = 59.11 and the optimum λ = 1.2680 were established.
As the hypothetical frequency indices have been found, then the Pirson hi criterion can be calculated.

Table 3

Values of the Pirson hi criterion

$\frac{(n_i - \overline{n_j})^2}{\overline{n_j}}$	0.05	0	0.01	1.23	4.95	1.56	0.79	0.04	1.10	0.67

$$\chi^2_{fakt} = \sum_{i=1}^{k} \frac{(n_i - \overline{n_j})^2}{\overline{n_j}} = 10.40$$

In MS Excell λ^2_{Crit}. is calculated at the materiality level 0.05 and number of degrees of freedom - 8 (v=10 category-2 limits=8).
χ^2_{crit}.=15.507.
If χ^2_{act}-=0, then ni= nj the distribution curves are congruent;
If $\chi^2_{act} > \chi^2_{crit}$, then the difference between the distribution curves is relevant upon probability P=l-α;
If χ^2_{act}-< χ^2_{crit}, then the probability P=l-α is not enough to dismiss the assumption that the difference between the distribution curves is incidental [3,93].
Since $X^2_{act} < X^2_{crit}$ (10.40<15.51), then a probability of 95 % is not enough to dismiss the zero hypothesis stating that the empiric distribution is congruent with the exponential distribution.
One of the tasks of this analysis is to establish also the parameters of this distribution. This distribution is predetermined by the main index λ.
According to the theory of exponential distribution of probability, the mathematical expectation is equal to 1λ, [13,472]

$$M(x) = 1/\lambda \quad (6)$$

M(x)= 1/1.268=0.79

Standard deviation $\sigma = 1/\lambda$ [13,473]. (7)

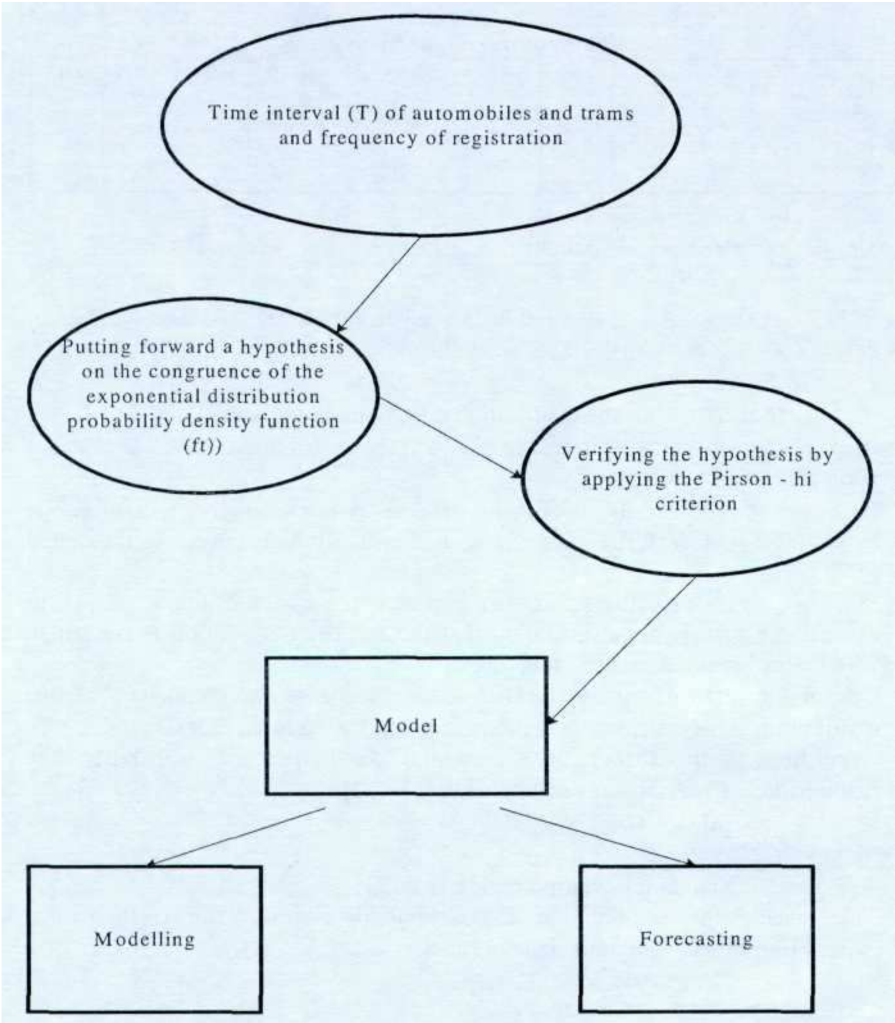
This means that within the exponential distribution the mathematical expectation M(x) is equal to standard deviation M(x) $=\sigma = 1/\lambda.= 1/1$.268=0.79

$$D(x) = 1/\lambda^2 \quad (8)$$ [473, 12 page].

D(x) = 0.62

By establishing the law of the incidental quantity distribution, the distribution parameters can be calculated as well as the credibility intervals at

varying levels of impact by the relevant factors; it is also possible to view the changes generated in the above manner.
As a result of the study a model for estimating the costs of TC was developed:



Picture 5: Developing a model for estimating traffic congestion costs.

This model can be used as a tool for forecasting or modelling purposes, in case if any of the indices should change (for instance, λ). Likewise, it can be used to estimate the time costs of TC. The model can be applied also within such MS software as Stella, Witness etc. The model can be also applied to model the changes in the exponential distribution probability density function if the latter is subjected to impact by any of the external factors.

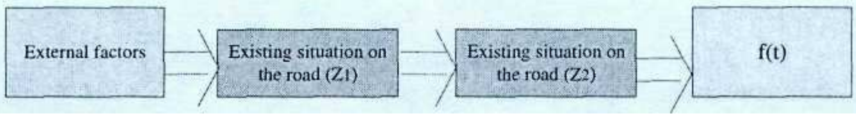
It has been established by the Author that the following factors influence the exponential distribution probability density function f(t):

$$f(t) = f(F_i, F_v, I_{nf}, \text{etc.}) \quad (9)$$

where:

f(t) - exponential distribution probability density function;
Fi - a/m flow intensity factor (unit);
F_v - a/m flow type factor;
I_{nf} - information factor.

The recording frequency of the above indices is conditional upon a number of factors. Here a conclusion can be made that the exponential distribution probability density function f(t) is equal to a function from the above-mentioned factors.



Picture 6: Influence of factors upon the model.

Developing a formula for calculating the time costs of TJ & TC. Since the occurrence of TC leads to the incurrence of public expenditures, it is essential that the losses suffered by the public are duly assessed.
If the time interval (Ti minutes) is known, then by multiplying it with the time value of 1 minute (c_i) and the recording frequency of this interval and the average number of passengers in a transport unit (k_i), a new generic formula for calculating the time costs of TC can be developed:

$$\sum_{i=1}^{n} T_i \cdot c_i \cdot m_i \cdot k_i = C \quad (10)$$

Developing a formula for calculating the total costs of TJ & TC. Since traffic congestions costs (C) are composed by time costs and operational costs, the Author has developed the following formula for calculating the total traffic congestions costs:

$$C = \sum_{i=1}^{n} T1_i \cdot c_i \cdot m_i \cdot k1_i + \sum_{i=1}^{n} T2_i \cdot c_i \cdot m_i \cdot k2_i + \ldots + \sum_{i=1}^{n} Tx_i \cdot c_i \cdot m_i \cdot kx_i + C_{ekspl} \quad (11)$$

where:

Tl_i - time interval (between the arrival of the automobile at the queue and the moment when it has crossed the intersection), min;

$T2_i$ - time interval (between the arrival of the tram at the queue and the moment, when the automobile has crossed the intersection), min;

Tx_i - time interval (between the arrival of another type of vehicle at the queue and the moment, when the automobile has crossed the intersection), min;

C_i - time value, LVL/min;

m_i - recording frequency of the time interval, number of times;

kl_i - average number of passengers in a car;

$k2_i$ - average number of passengers in a tram;

kx_i - average number of passengers in another type of vehicle;

The total operational costs (C_{oper}) can be derived by aggregating the operational costs of the individual types of vehicles.

C_{oper} - total operational costs;

$$C_{oper} = C1_{oper} + C2_{oper.} + \ldots + Cx_{\ oper}$$

where:

Cl_{oper}.- operational costs of automobiles;

$C2_{oper}$ - operational costs of public transport;

$Cx_{\ oper}$ - operational costs of other types of vehicles (n).

The operational costs are calculated using the following equation:

$$C_{oper} = n \bullet C_{oper} \quad (13)$$

where:

n - number of the relevant type of vehicles;

C_{oper} - - operational costs of a single vehicle.

Here it should be noted that based on the studies conducted by scientists Ramierdi and Larsen in 1991, the increase of operational costs of automobiles during traffic congestions accounts from 2 to 8.3% of the total time costs of traffic congestions. And as the time costs in their turn account for the major proportion of the traffic congestions costs, it explains the focus on the possible ways for estimating this item of the costs.

Developing linear regression equations and econometric matrices. In case of emergency decisions, when due to time constraints it is not possible to make an accurate calculation of the time costs of TC, the most convenient option would be to use linear regression equations, where y denotes the time costs of TC and x_1 - the number of trams, or x_2 - the number of automobiles, or matrices presenting the time costs of TC. To establish the time costs of TC incurred as a result of delaying a varying number of trams or means of public transport by using a linear regression equation, a generic equation for calculating the time costs of TC is applied:

$$C2 = k2_i \cdot n2_i \cdot c_i \cdot t_i \qquad (14)$$

where:

C2 - time costs of a traffic congestion incurred as a result of delaying the trams and their passengers, LVL;

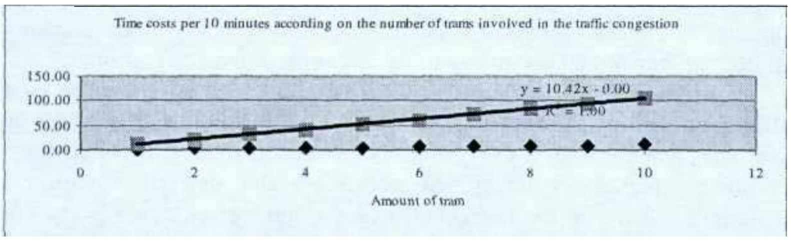
$K2_i$ - total number of passengers found in the trams that are involved in a congestion; persons;

$n2_i$ - number of trams involved in a traffic congestion;

ci - time value of a minute, LVL/min;

t_i - duration of the traffic blockage.

As result, a straight line is designed and a linear regression equation and a determination ratio R^2 are derived in MS Excell.



Picture 7: Time costs of TC per 10 minutes according on the number of trams involved in the traffic congestion.

Various linear regression equations were derived according on the duration of the time spent by automobiles in traffic congestions:

Table 4

Linear regression equations applicable when automobiles are involved in traffic congestion for the duration of 10, 20 or 30 minutes

10 minute congestion	20 minute congestion	30 minute congestion
$y = 0.0902 \cdot x_1$	$y=0.1603 \cdot x_1$	$y=0.24 \cdot x_1$

The derived equations can be used to calculate the time costs of TC at any number of cars delayed (x_1). ($R^2=1$; $r^2=1$; $R^2=r^2$).

Table 5

Linear regression equations applicable when trams are involved in traffic congestion for the duration of 10, 20 or 30 minutes

10 minute congestion	20 minute congestion	30 minute congestion
$y = 10.42 \cdot x_2$	$y=20.84 \cdot x_2$	$y=31.26 \cdot x_2$

These equations can also be used to establish the time costs or TC. at any number of trams delayed (x_1). Analogical equations can be developed for calculating the time costs of TC regarding the delays of any other type of public transport.

The main advantage of such equations is that they are easy to apply and enable a prompt derivation of quality data. Owing to these features, they can be used for the purpose of daily planning activities, also in meetings, working groups, by transport and municipal specialists.

These equations can be adjusted depending on the variable index - amount of wage, which can vary among different professions.

Cooperation and coordination between the experts of interdisciplinary sciences is an imperative for addressing the issues related to the consequences of transport externalities and the associated negative external costs. To facilitate a prompt decision-making process when addressing the issues related to traffic congestions, ready-made econometric matrices can be applied according to the duration of the congestion.

Structure of matrices intended for calculating the time costs of traffic congestions. In order to obtain a material that could be used for taking immediate decisions for solving the issues related to traffic congestions, an econometric matrix is developed based on the derived equations and calculations, where on the horizontal axis the number of trams is set, and on the vertical axis - the number of automobiles.

Depending on the duration of the congestion: 10, 20 or 30 minutes, three matrices have been developed. A matrix has been developed to enable derivation of the time costs of TC directly from the matrix, without any additional calculations. From this matrix information can be derived on the time costs of TC, according to the number of vehicles involved in the traffic congestion (starting from one automobile and one tram up to 10 trams and 50 cars. Within this quantity interval of the number of vehicles it is possible to establish the time costs of TC at varying proportions of the number of those types of vehicles involved in traffic congestions.

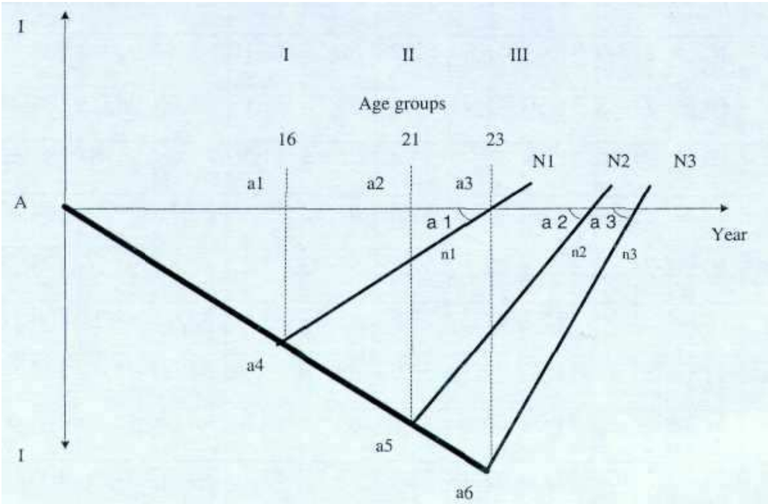
Table 6

Matrix of the time costs of TC
(according to the number of automobiles and trams involved in
a 10-minute traffic congestion)

	1 tr.	2 tr.	3 tr.	4 tr.	5 tr.	6 tr.	7 tr.	8 tr.	9 tr.	10 tr.
1 car	10,50	20,92	31,34	41,76	52,18	62,60	73,02	83,44	93,86	104,28
2 cars	10,58	21,00	31,42	41,84	52,26	62,68	73,10	83,52	93,94	104,36
3 cars	10,66	21,08	31,50	41,92	52,34	62,76	73,18	83,60	94,02	104,44
4 cars	10,74	21,16	31,58	42,00	52,42	62,84	73,26	83,68	94,10	104,52
5 cars	10,82	21,24	31,66	42,08	52,50	62,92	73,34	83,76	94,18	104,60
6 cars	10,90	21,32	31,74	42,16	52,58	63,00	73,42	83,84	94,26	104,68
7 cars	10,98	21,40	31,82	42,24	52,66	63,08	73,50	83,92	94,34	104,76
8 cars	11,06	21,48	31,90	42,32	52,74	63,16	73,58	84,00	94,42	104,84
9 cars	11,14	21,56	31,98	42,40	52,82	63,24	73,66	84,08	94,50	104,92
10 cars	11,22	21,64	32,06	42,48	52,90	63,32	73,74	84,16	94,58	105,00
...	...	...	...	...	...	...	...	...	...	...
45 cars	14,03	24,45	34,87	45,29	55,71	66,13	76,55	86,97	97,39	107,81
46 cars	14,11	24,53	34,95	45,37	55,79	66,21	76,63	87,05	97,47	107,89
47 cars	14,19	24,61	35,03	45,45	55,87	66,29	76,71	87,13	97,55	107,97
48 cars	14,27	24,69	35,11	45,53	55,95	66,37	76,79	87,21	97,63	108,05
49 cars	14,35	24,77	35,19	45,61	56,03	66,45	76,87	87,29	97,71	108,13
50 cars	14,43	24,85	35,27	45,69	56,11	66,53	76,95	87,37	97,79	108,21

Time model - recovery of public investments in human resources in relation to the risks of TA occurrence

Any national economy suffers losses when people lose their lives in TA-s. Human resources are considered to be one of the most important production factors. What is more, public funds are invested to facilitate the reproduction of this factor. Therefore the issue regarding the recovery of these investments should be duly addressed. Hence the following working model is proposed for solving this problem.



Picture 8: Time model - recovery of public investments in human resources.

On continuous basis the state invests funds to ensure a certain level of living standard and welfare for its citizens. The following designations are used in the picture:

11 - the axis characterizing the amount of public investments;

a_1a_4 - public investments in human resources apportioned to the age group <16 years;

a_2a_5 - public investments in human resources apportioned to the age group < 21 years;

a_3a_6 - public investments in human resources apportioned to the age group < 23 years;

n_1 - number of working years required for an individual to recover the public investments, received during the first 16 years of his/her life;

n_2 - number of working years required for an individual to recover the public investments, received during the first 21 years of his/her life;
n_3 - number of working years required for an individual to recover the public investments, received during the first 23 years of his/her life;
a_4N_1 - a line characterizing the intensity of the recovery of public investments in human resources, for investments apportioned to the age group < 16 years;
a_5N_2 - a line characterizing the intensity of the recovery of public investments in human resources, for investments apportioned to the age group < 21 years;
a_6N_3 - a line characterizing the intensity of the recovery of public investments in human resources, for investments apportioned to the age group < 23 years;
I. - I^{st} relative group of population with the smallest angle (α_1) characterizing the intensity of the recovery of investments;
II. - 2^{nd} relative group of population, where the angle (α_2) characterizing the intensity of the recovery of investments is larger if compared to the angle characterizing group I;
III. -3^{rd} relative group of population, where the angle (α_3) characterizing the intensity of the recovery of investments is the largest and the time period required to recover the investments is the shortest, which can be explained by the fact, that persons with highest education are inclined to higher salary rates;

Here the following interrelation can be derived: $a_1n_1 > a_2n_2 > a_3n_3$. By mathematical means the public investments in human resources (I) and the time period required for the recovery thereof "n_p" can be calculated as follows:

$$I_0 = \sum_{i=1}^{n} \frac{FVi}{(1+r)^i} \quad (15)$$

where:

I_0 - public investments in human resources;

$\sum_{i=1}^{n} \frac{FVi}{(1+r)^i}$ - present value of the expected, but not produced yield of a person (wage) [7,12].

The graphic model clearly illustrates the various patterns of recovering public investments among the three relative groups of population depending on the type of education (elementary education, secondary professional education and higher education) and the duration of studies. Year "n" is the margin, when a person has recovered its proportion the investments made by the state in human resources. Based on this information, the model can be analyzed in the light of the possible TA occurrence. If an individual is killed in a TA before the year "n" (before the person has recovered its proportion of the investments made by the state in human resources), the state not only suffers losses, but also fails to recover the investments made so far. If an individual is killed in a TA after the year "n", it can be assumed that the state has recovered its investments in full. Nevertheless, the state still incurs losses regarding the value of the expected, but not produced output of the victim of TA (usually wages are used for the purpose of these estimates).

Main proposals and arrangements for minimizing transport externalities and the associated external costs

The discrepancy between the growing traffic intensity and the insufficient pace of the development of infrastructure has lead to a series of problems. In the Author's opinion there are two main alternatives for reducing TC and TJ in the urban territory of Riga:

1. To reduce the traffic density in the centre of the City by applying:
   1.1. Appropriate financially economical arrangements,
   1.2. Organizational and political arrangements.
2. To develop the infrastructure - by way of constructing streets, underground tunnels, bridges, traffic bypasses, additional road lanes.

The list includes also a number of issues of national scale, the solving of which would require substantial funds or the solution would affect a significant proportion of the population, or raise certain other essential preconditions.

Specific economic arrangements are proposed hereunder, such as traffic management system, arrangements for legislative amendments, implementation of economic incentive system, and elaboration of pilot studies and conduction of scientific research work in the field of modern and energy-saving technologies. Series of perspective and localized infrastructure development activities have been proposed.

The organizational and technical arrangements include perspective traffic planning in two or even three levels, clearing the central area of the City from car traffic by dislocating a number of public institutions and organizations outside the centre.

In order to reduce or partially eliminate the volume of transport externalities (volume of pollutants discharged in the atmosphere, number of TA and the degree of their severity, time losses related to TJ & TC) by reducing the number of transport units entering the central area of Riga, the following activities should be implemented:

1. The main financially economic arrangements and legislative amendments:

•improving the certification procedure for vehicles and stimulating the application of modern technologies;

•introduction a tax on CO_2 (for exceeding the marginal value) or other incentives encouraging the use of more environmentally friendly types of fuel (bioethanol) or other technologies;

•enforcement of traffic management systems by introducing a fare for using certain roads during rush hours, by restricting the procurement and import of used cars (older than 10 years) by way of increasing the tariff rates on import, by increasing the hourly parking rates at parking lots located in the central area of the City etc.;

2. The major organizational and technical arrangements:

•dislocation of a number of ministries (departments) outside the centre of the City to other areas;
•full or partial dislocation of a number of secondary (higher) education establishments outside the centre of the City;
• implementation of the "Park and ride" system, including the construction of parking lots in the vicinity to the existing railway stations;
•implementation of measures aimed at relocating the transit routes and heavy traffic away from the centre of the City;
•increasing the number of river crossing facilities across Daugava by constructing bridges or tunnels;
• improving traffic organization and road traffic safety;
•augmenting the so-called subjective factor of drivers by improving the process of acquiring practical driving skills and training of drivers, and especially, the beginners, in particular, before the start of winter season;

3. Arrangements for transport infrastructure development:

•alignment of high-speed street network for relocating of transit flows, including {outgoing/ingoing} cargoes of Riga Port bypassing the centre of Riga;
•organizing renovation works by constructing traffic bypasses, including, at the following street intersections:
  •K.Ulmana gatve and Lielirbes iela;
  •Slāvu rotation ring;
  •Juglas iela and Brīvības gatve;
  •Tvaika iela and Viestura prospekts, as well as in other areas of the City;
• as soon as practicable, joining Ģertrūdes and Daugavpils streets under the railway with a tunnel to reduce the traffic density on Lāčplēša iela by at least 20%;
•feasibility study for the construction of additional drive-offs from Vanšu Bridge;
•planning of an, as minimum, two-level traffic organization scheme at intersections with high-speed main streets as well as at those street sections where there is the highest traffic density;
•development of tram and trolley traffic network and promoting the procurement of new and unused means of transport.

CONCLUSIONS

As a result of the elaboration of this Dissertation the following conclusions have been made:

1. The dramatic rise in the number of cars in Latvia has not, however, contributed to an analogue progress in the development of infrastructure. Instead, it has lead to the increase in the total duration of time spent by drivers on the roads, increasing duration and number of TJ & TC and increasing risk of TA occurrence. However, it should be noted that the concentration of pollutants in the atmosphere of Riga, if compared to the beginning of 1990, has even slightly decreased, as part of the industrial plants, local boiler houses etc. have been taken out of operation. Besides, also the growing percentage of cars equipped with accelerators accounts for a substantial decrease in the volume of pollutants in the atmosphere;

2. If compared to other countries, in Latvia the adverse environmental impact, including the impact on human health, as caused by transport externalities, has not been studied in sufficient detail. It may be partially explained by the lack of long-term epidemiological studies in Latvia. Therefore it is complicated to establish the impact of air pollution factors on the human health and provide an explanation for the high death rates in Latvia compared to other European countries. There have only been fragmentary studies on the impact of transport externalities upon the environmental costs (soil, agricultural produce, water basins, forests, wildlife etc.);

3. The mathematical model for the adjustment of consequences caused by transport externalities, as developed by the Author, is to be used as a basis for estimating the negative costs of the critical items of transport externalities. Elaborated models for the assessment and adjustment of consequences caused by specific transport externalities can be effectively used in the specific cases. Owing to their high level of accuracy, some models can be applied in practice as strategy development tools in the elaboration of traffic organization schemes, as well as for the purpose of taking any other economic and managerial decisions;

4. The studies conducted hereunder have proved useful in developing a better understanding of the consequences of transport externalities, their structure, economic impact and their role in the process of economic development;

5. In the process of elaborating this Dissertation, and as result of the studies conducted on a number of streets of Riga, a more detailed and comprehensive understanding has been developed in regard to solving the problems related to TC, including the following:

5.1 The modelling of TC and the external time costs thereof enables scientific approach to be applied in the planning of alternative solutions for reducing traffic density in the central area of Riga and the associated consequences;
5.2. The linear regression equations, developed as part of this study are recommended for use by designers (streets, roads, bridges etc.) in the process of elaborating and evaluating designs, as these equations allow to derive a more precise and operational information;
5.3. The matrices for estimating the time costs of TJ & TC, developed as part of this study, are recommended for use by transport specialists, as well as the relevant officials of local authorities to facilitate a prompt decision-taking process. These matrices can be used to derive operational data regarding the time-related costs of each individual traffic jam;
5.4.The generic formula for calculating the time costs of TC as developed hereunder is recommended to be used whenever accurate information is required for the purpose of elaborating major investment projects;

6. The models and methods developed hereunder can be applied to evaluate the economic efficiency of traffic optimisation plans, as well as for enhancing the efficiency of pollutant elimination activities. Besides, these models and methods are recommended to be used for transport development planning purposes as a methodological basis to enable a more intensive and efficient exploitation of the available resources (saving of energy resources);

7. The time model for the recovery of public investments in human resources can be used to calculate public investments in human resources, to compare these with the discounted total sum of estimated future wages. The model can be also used to calculate the time period required for the recovery of public investments and to estimate the actual losses related to any registered TA occurrence;

The analysis of the conclusions drawn by both international and domestic experts, done as part of this Dissertation, as well as the Author's own experience supports the assumption that in order to improve the situation in Latvia, it is necessary to implement a range of measures, including, the construction and upgrading of street, roads, bridges, tunnels etc. Effective application of traffic management schemes and the associated economic tools can prove to be at least a partial solution for issues related to transport externalities. Additional improvements are required in the field of transport certification, various economic incentives should be put in place. Factors ensuring traffic safety should be improved and brought about effectively. Preconditions need to be put in place for effecting such economic, legal or other instruments that would allow to reduce the impact of transport externalities on both the environment and human health;

9. Based on the results derived from the models and methods, which were developed as part of this Dissertation, as well as based on the approbation of the derived data by means of cost-benefit analysis, a conclusion can be made that such studies are highly topical mind the existing situation in the field in Latvia. The use of the models and methods developed hereunder would allow to establish the monetary value of any potential benefits. This would be a highly useful tool for decision-making purposes as regards the implementation of the most efficient and cost-effective projects aimed at minimizing or eliminating the consequences caused by transport externalities. Besides, the results derived from the promotion activities would enable the relevant municipal or other experts to take prompt and tailor-made decisions for solving local traffic-related problems. Until the recent past, in Latvia there was only a very limited knowledge of the methods used abroad for economic assessment of the consequences caused by transport externalities. Most of these methods to be applied in practice require staff with relevant educational background or they must be trained for this purpose, as the application of these methods calls for special proficiency level in mathematics and other interdisciplinary sciences. As part of this Dissertation a comparative analysis of these methods has been done and, out of these, those methods have been selected and put forward, which would be most suitable for Latvian conditions;

10. The results of these studies can be used for business purposes, in strategic planning or in the practical work of municipalities or the competent government authorities.