

THE METHODOLOGY FOR CALCULATION OF ROAD ACCIDENT COSTS

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Submitted 5 December 2013; resubmitted 12 February 2014; accepted 6 May 2014

Abstract. The presented methodology for accounting the costs caused by road accidents is based on the fact that a person who died or was injured in a traffic accident will not contribute to the economic welfare of the country anymore or his/her contribution will reduce. Broken vehicles, damaged cargoes or defected road constructions cause huge losses to the state. A financial assessment of material losses caused by road accidents enables providing a feasibility report in respect of efficiency of newly introduced traffic safety measures. The aim of the presented methodology is an establishment of the road accident costs that would conform to the today's economic level of Lithuania. The developed methodology for accounting road accident costs will enable more precise assessment of a necessity, perspectives and priorities of investment projects in the transport system as well as an accomplishment of funding allocation tasks.

Keywords: traffic safety; accident costs; direct costs; indirect costs; injury severity; output loss.

Introduction

Enterprises involved in manufacturing activities and provision of various services use services of the transport sector for transporting raw materials and employees and for taking out the final products and for provision of services. Functioning of a modern economy is unimaginable without developed and duly operating transport system. From an experience of various countries attests, there is a very close liaison between the economic growth and the development of the transport sector. The road transport grows more rapidly than the economy: it is more flexible and better adaptable to the needs of users, as compared to the other modes of transport. The European Commission believes that till the year 2020 the volumes of transported cargoes will increase by 50% and the number of passengers will increase by 35%. Because the rates of economic growth in Lithuania are considerably higher, compared to the average rates in EU, the more rapid growth of volumes of transportations in future is believable. According to the forecasts of cargo flows up to the year 2015, they should increase (as compared to the cargo flows in 2005) by: 92% (the pessimistic scenario), 144% (the moderate scenario), and 169% (the optimistic scenario) (Transporto sektoriaus įtakos... 2007).

Transport considerably contributes to the economic growth; however, it causes considerable costs for the community as well. The estimated environmental impact of transport in EU amounts to 1.1% GDP.

The European Commission set the task: to cut the number of fatal road accidents in half within the period between the years 2001 and 2010. In course of application of various measures, traffic safety in EU was improved considerably. Since the year 2001, the number of deaths on roads of the European Union decreased by about 43%; however, such striking decrease did not take place in all EU Member States. In the year 2010, 30900 deaths occurred on the roads of the European Union; in addition, 1.47 million persons were injured. This fact confirms that the road transport remains the most unsafe mode of transport.

In 2001–2007, the number of road accidents in Lithuania increased by 8%, the number of deaths increased by 4.8% and the number of injuries – by 13.2%. It seemed that Lithuania does not approach to the standards set in EU and even drifts apart from them. However, in the year 2008, a turning-point was achieved in reduction of the accident rate: within one year only, the number of deaths on Lithuanian road was reduced by 32.6%, as compared to the year 2007. In 2008–2010,

the effective control of traffic participants and their better behavior as well as the safer environment for traffic participants were based on the effective engineering of traffic safety measures, and the duly legal framework caused improvement of the situation. When the data on the accident rate in the year 2001 are compared to the data on the same thing in the year 2010, it may be seen that the accident rate decreased by 40.9%, the number of deaths – by 57.6% and the number of injuries – by 40.4%.

In 2011–2012, the trends attest that no considerable changes of the number of deaths caused by road accidents in Lithuania took place. In the year 2011, the death rate decreased by 3 (or 1%), as compared to the year 2010; however, in the year 2012, 2 more deaths (or 0.7%) occurred, as compared to the same year 2010 (European Energy and Transport... 2003).

The above-described means that the aspiration to reduce the rate of deaths caused by road accidents in course of implementation of the priorities of the European Union traffic safety policy for 2011–2020 will not be accomplished without dynamic actions of state authorities. In addition, the works related to infrastructural improvement, encouraging the purchase of new vehicles, traffic safety and enlightenment of traffic participants as well as improvement of legal norms should be continued in order to minimize the accident rate and consequences.

1. The Review of Methodologies for Calculation of the Costs

The largest share of road accident costs is formed by injuries, disabilities and deaths, so all countries are trying to ensure safety of traffic participants. They try to separate pedestrian flows from the ones of cars, motor-cycles and bicycles. Inside a country, only vehicles that conform to the set standards of active and passive safety are allowed for use. All European countries have a type recognition system that sets the requirements for safety, reliability and exploitation of vehicles. However, a total elimination of road accidents is impossible; only a mitigation of their consequences is possible. So, in this sphere, an important role is played by the vehicle manufacturers that do their best for producing safer vehicles. In addition, every state may influence the compatibility and safety of its vehicle fleet. For the said purpose, a comprehensive investigation on passive and general safety and riskiness of the existing vehicle fleet should be carried out and the relevant decision should be passed according to the assessment of their results (Sadauskas 2000).

Road accident costs may be direct and indirect. In addition, road accident costs may be economic and social. Theoretical calculations of road accident costs where human life and injuries are assessed may be found in the works of many scientists (Ayuso *et al.* 2010; Kapskij, Samoilovich 2009; Al-Masa'ed *et al.* 1999). All authors emphasize that it is most important to develop a simple structure for calculation of road accident costs and to use it for calculating the total economic costs

bound with road accidents. In different countries, the approaches usable for estimating the life value may differ. Kapskij and Samoilovich (2009) explored problems of estimating the life value in Republic of Belarus. The authors assessed the total economic costs bound with road accidents upon using temporary estimated values.

For estimating the economic costs caused by road accidents within a year and deriving unit accident costs for different accident severity levels (Highway Safety Manual 2009), data from various sources, such as Road Police, insurance companies, hospitals and medical centers, should be analyzed. In the study carried out by Jordanian scientists Al-Masa'ed *et al.* (1999), the limits usable for establishing accident severity levels upon applying unit casualty class costs, unit property damage cost, as well as police activities and insurance administration costs were suggested. The output loss-of-output, the loss quality of life, the community and family losses, the temporary and permanent losses, and hospitalization and medical treatment costs were estimated in computing the unit cost for fatalities or injuries of different casualty classes. The vehicle repair cost, detention period cost, and public and private costs were accounted for estimating the unit cost of property damages. The results of the calculations made by Al-Masa'ed *et al.* (1999) indicate that the 1996 traffic accidents cost the country about JD 103 million (\$US 146.3 million).

Road accident costs form an important share of the external component of the traffic costs that's substantial part is bound with fatal accidents. The evaluation of fatal accident costs crucially depends on the availability of an estimate for the economic value of a statistical life. Partheeban *et al.* (2008) developed a model for road accident through the calculation system's dynamics approach. To build an accident model in this case, various factors causing the road accident and costs should be identified. In the study by Partheeban *et al.* (2008), only road accidents caused by buses were considered and the developed model enables predicting the severity levels of future road accidents and their costs. The model predicted the accidents up to 2020 for every 5-year interval, so the outcome of the study is highly useful for the planners, administrators and police to make their decisions effectively for road safety investment projects.

Ayuso *et al.* (2010) analyze accidents with casualties and calculate the influence of major traffic violations on the probability of having a road accident that causes a serious injury or fatal accident, as compared to an accident that cause a slight injury. The authors discuss upon gross traffic violations related to speed limitations, administrative infringements or faults related to the driver are considered. Data were obtained from all available reports on accidents with victims that occurred in Spain from 2003 to 2005. A multinomial logistic regression model is specified to find the probability that an accident with casualties is slight, serious or fatal, given the presence/absence of thirty different types of traffic violations. The average cost per victim and the average number of victims per accident are then used to find the estimated cost of an accident with victims, given the information

on the traffic violations incurred. This demonstrates which combinations of traffic violations lead to higher estimated average costs, compared to cases in which no traffic violation occurred. We conclude with some recommendations on the severity of penalties, and suggest that regulators penalize the occurrences of some specific combinations of traffic violations more rigorously.

Some authors discuss upon only road accident costs bound with a category of traffic participants. Veisten *et al.* (2007) analyze the total number of bicycle injuries in Norway and the total costs related to them. The authors emphasize that there is no complete hospital recording that could provide more correct data on bicycle injuries. Bicycle injuries are underreported in official data. There is a nearly complete omission of single bicycle accidents. Application of case study hospital data from Norwegian towns enabled an estimation of the relationship between these data and the official data, including the distribution of injuries by severity. Costs were then assessed by applying official monetary values for given levels of injury severity. The total annual costs related to bicycle injuries are considerable; however, they are assessed upon taking into account the positive impact of bicycle transport upon the environment and human health.

Road accident costs may be reduced by using intelligent speed adaptation. According to the project implemented by Carsten and Tate (2005) in the United Kingdom, the fitting on all vehicles of a simple mandatory system, with which it would be impossible for vehicles to exceed the speed limit, would save 20% of injury accidents and 37% of fatal accidents. A more complex version of the mandatory system, including a capability to respond to current network and weather conditions, would result in a reduction of 36% in injury accidents and 59% in fatal accidents. The implementation path recommended by the project would lead to compulsory usage in 2019. The cost–benefit analysis was carried out

and showed that the benefit–cost ratios for this implementation strategy were in a range from 7.9 to 15.4, i.e. the payback for the system could be up to 15 times the cost of implementing and running it.

2. The Methodology for Calculation of Costs

The aim of the presented methodology is an establishment of the road accident costs that would conform to the today’s economic level of Lithuania.

Assessment of road accident costs is based on the fact that dead or injured persons do not bring their income to a country or their contribution to its economic wealthiness is reduced. Broken vehicles, damaged cargoes, or defected road constructions cause huge losses to the state. A financial assessment of material losses caused by road accidents enables providing a feasibility report in respect of efficiency of newly introduced traffic safety measures.

The model of road accident costs consists of 5 components. Each component covers a certain sector, such as human health, property damage, investigation, rescuing works and so on. Such a model for calculation of the costs was proposed in order to standardize a price comparison system in models of different types. Road accident costs include both direct and indirect costs. Direct costs can be directly assessed and calculated on the base of the damage caused to human health, property and environment as well as the costs of various investigations and expert’s examinations required for establishment and assessment of the causes and consequences of a road accident. Indirect costs cannot be assessed directly; however, they cause a subsequent negative impact and are calculated according to various methodologies. Such costs may be formed by output losses of the vehicles. The model of road accident costs (Nuostolių, patiriamų dėl neigiamo... 2008) is provided in Fig. In the Fig., each component is divided into additional parts that impact different sectors.

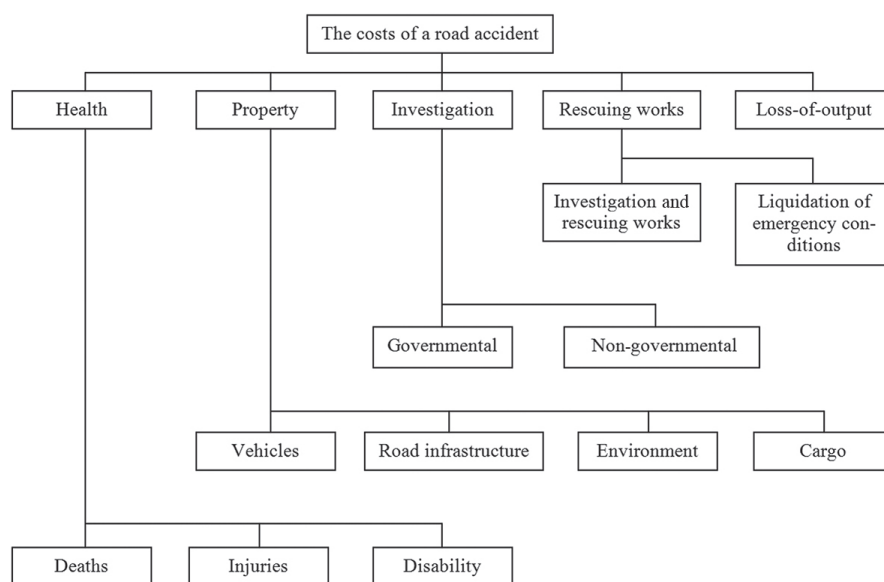


Fig. The model of road accident costs (Nuostolių, patiriamų dėl neigiamo... 2008)

Human health. These costs are attributed to indirect costs. They are divided into 3 categories: deaths, injuries and loss of labour capacity for a certain period. The said costs are calculated according to the methodologies applicable in the country and the available estimations of the life value as well as the losses of the state caused by a death, injury or disability of a person in a road accident. The said costs also include medical treatment costs up to a full recovery and vocational rehabilitation. The medical treatment costs include the ones of emergency medical aid, maintenance and treatment at a hospital and so on. In the costs of injury and disability, the costs related to temporary or permanent incapacity to work, i.e. social costs, may be included.

Property damage. These costs are attributed to direct costs. They are divided into 4 categories: vehicle damage, i.e. the repair costs; road infrastructure damage when road accidents cause destruction of roads, bridges, overpasses, streets, power supply and telephone lines and so on; environmental damage, i.e. damage caused to humans and nature (because of its pollution) as well as damage caused to cargoes transported. In each specific case, such costs differ, so it is important to take into account the maximum possible number of criteria upon calculation of the damage.

In Lithuania, the damage assessment is limited to fines calculated on the base of the chosen methodologies upon taking into account the hazardousness and the volume of the substance having got into the environment as well as the character of the pollution.

Investigation. These costs are attributed to indirect costs, because they do not provide a direct assessment of the damage caused on the moment of a road accident and its consequences. Usually, two types of investigations are singled out: governmental investigations (their costs are covered by the state) that identify the culprit of a road accident and assess its impact upon humans and environment; and nongovernmental investigations (their costs are covered by vehicle manufacturers and various nongovernmental organizations) for preventive traffic safety measures.

Rescuing works. These costs are attributed to direct costs and in Lithuania they are covered by the state. They include the assistance provided by police, medical and rescuing teams during a road accident. The major share of the costs of rescuing works is formed by the costs related to liquidation of consequences of a road accident when hazardous substances get into environment because their cleaning and decontamination are very expensive. The said costs also include the operation costs of special equipment usable for rescuing of humans or liquidation of consequences of a road accident.

Output loss. These costs include output loss of the vehicle when the road accident results as its inability to perform its direct function – transportation of passengers or cargoes. The costs related to output loss of a vehicle include the income that would be received for the completed works and the funds required for renting a new vehicle instead of the damaged one. Downtime of a vehicle because of repairs and the losses caused by such downtime are attributed to indirect costs.

As it may be seen from the model of road accident costs provided in Fig., the total costs of a road accident may be found as a sum of the direct and the indirect costs related to it (Nuostolių, patiriamų dėl neigiamo... 2008).

2.1. Groups of Costs

On assessment of road accidents, two groups of costs are singled out; they are direct (primary) costs and indirect (secondary) costs. Direct costs are formed by:

- costs incurred by owners of vehicles;
- costs incurred by road exploitation services;
- costs of road accident investigation incurred by Lithuanian Road Police Traffic Supervision Service;
- costs incurred by medical institutions.

Indirect costs are formed by:

- costs related to a temporary exclusion of an employee from production;
- social (moral) costs that cannot be directly expressed in monetary terms.

2.2. Economic Evaluation of Road Accidents Costs

On economic evaluation of road accidents, recorded and non-recorded accidents are evaluated individually.

Calculation of recorded road accident costs is singled out for the following cases:

- fatal road accidents;
- road accidents that result a disability;
- road accidents that result serious injuries;
- road accidents that result slight injuries.

The costs of recorded road accidents are calculated by summarizing:

- the costs of repairs of damaged vehicles;
- the losses caused by downtime of transport;
- the losses related to damage of the cargo during the road accident;
- the costs of reconstruction and repairs of the damaged road and road constructions;
- the costs of road accident investigation where employees of Lithuanian Road Police Traffic Supervision Service, the Prosecutor's Office and courts are involved;
- the costs related to casualties of road accidents (treatment expenses, allowances, pensions, losing a part of the national product).

Non-recorded road accident costs are assessed similarly (however, the costs related to casualties of road accidents are not included).

Complexity of road accidents and the amount of the related costs depend on the traffic conditions, so the said conditions should be taken into account in calculation of the costs. On calculation of unit costs of road accidents per person, it should be taken into account that such costs incurred by the community vary from year to year because of permanent growing of the national income and changes of the real wages. So, the year that the costs are calculated for should be specified.

In 2012, on the roads of Lithuania 3173 fatal and injury accidents occurred where 301 people were killed and 3712 were injured (Table 1). Compared to the year 2011, this year 2.8% (93) less accidents and 5.28% less injured people were recorded on our roads. The number of accident fatalities has increased – 5 people more were killed. This publication gives the major accident indices describing traffic safety situation on the roads of our country. It gives 2012 data on fatal and injury road accidents, their types, the number of people killed and injured, the guilty for the road accidents, data on the road users who caused accidents.

2.3. Total Costs Caused by Road Accidents

Total costs caused by road accidents are calculated according to the following formula:

$$A = \sum_{i=1}^6 A_i = A_1 + A_2 + A_3 + A_4 + A_5 + A_6, \quad (1)$$

where: A – total costs caused by a road accident; A_1 – the damage caused to the vehicles, the costs of evacuation and repairs of the damaged vehicles; A_2 – the costs caused by the downtime of the vehicles from the mo-

ment of their damage to completion of their repairs; A_3 – the costs related to damage of cargoes; A_4 – the costs of reconstruction and repairs of the damaged road and road constructions; A_5 – the costs of road accident investigation incurred by Lithuanian Road Police Traffic Supervision Service and other organizations; A_6 – the costs related to casualties of road accidents (treatment expenses, allowances, pensions, losing a part of the national product).

The damage caused to the vehicles A_1 is calculated upon taking into account that the costs related to damaged vehicles are considered the costs of their repair, including the spare parts and the repair works. The said calculation is based on an assessment of current expenses related to the vehicles. It is considered that work input per vehicle equals to 10 hours. The price of spare parts equals to 3% of the average price of a new vehicle. In calculation of the costs caused by damage of road vehicles, it is accepted that the overhead charges equal to 17–20% of the total amount of the costs (RMIIA 2013).

Time input may be calculated for working and nonworking hours. Assessment of time input is bound with the average income of the involved workers.

Table 1. Road accidents in 2012 (Lietuvos statistikos departamentas 2013)

<i>Road accidents and their victims</i>						
	Accidents		Killed		Injured	
Total	3173		301		3712	
1 mln. inhabitants	1065		101		1246	
Per 1000 vehicles	1.42		0.13		1.66	
<i>Road users killed or injured during road accidents</i>						
Road users			Killed		Injured	
Drivers			90		979	
Motorcycle drivers			13		95	
Moped drivers			5		83	
Passengers			51		1149	
Pedestrians			105		1074	
Bicyclists			32		284	
Other			5		48	
Total			301		3712	
<i>Types of vehicles having participated and caused road accidents</i>						
Vehicle type	In accidents					
	Participated		Damaged		Caused	
Bicycles	350	7.16%	343	8.59%	182	7.63%
Carriages	8	0.16%	5	0.13%	5	0.21%
Mopeds	107	2.19%	98	2.45%	68	2.85%
Motorcycles	135	2.76%	123	3.08%	78	3.27%
Cars	3521	72.03%	3002	75.18%	1796	75.27%
Buses	128	2.62%	76	1.90%	51	2.14%
Agricultural machinery	41	0.84%	26	0.65%	28	1.17%
Trucks	282	5.77%	209	5.23%	122	5.11%
Trailers, semitrailers	104	2.13%	58	1.45%	0	0.00%
Other	212	4.34%	53	1.33%	56	2.35%
Total	4888	100.00%	3993	100.00%	2386	100.00%

The amounts of average monthly incomes (gross) may be found online (LRSADM 2013).

In any specific case, the price of the spare parts and the price of the repair works are added to the overhead charges, i.e. 20% of the total amount of the costs.

The vehicle repair and reconditioning costs are calculated as follows:

$$A_1 = A_{1R} + A_{1T}, \quad (2)$$

where: A_{1R} – the costs related to repair works and spare parts; A_{1T} – the costs related to transportation of damaged vehicle to the site of repairs.

The costs related to repair works and spare parts:

$$A_{1R} = N_A \cdot n_A \cdot i_T, \quad (3)$$

where: N_A – the total number of road accidents per year; n_A – the number of damaged vehicles per accident (on the average a road accident causes a damage of 1.62 vehicles) (LKPT 2013); i_T – the average repair costs per vehicle.

The costs related to transportation of damaged vehicle to the site of repair:

$$A_{1T} = N_A \cdot n_A \cdot k_T, \quad (4)$$

where: k_T – the average towing price per vehicle.

The costs caused by downtime of vehicles A_2 are calculated as follows: the costs caused by downtime of a vehicle for a working day conform to the price of its rent for a working day. The average duration of repair of a vehicle damaged in a road accident is considered 20 working days (LRCB 2013). So, the costs caused by downtime of vehicles for one year:

$$A_2 = N_A \cdot n_A \cdot L_{p1} \cdot v_{p1}, \quad (5)$$

where: N_A – the total number of road accidents per year; n_A – the number of damaged vehicles per accident; L_{p1} – the downtime of a vehicle; v_{p1} – the price of rent a vehicle for 20 days.

The costs related to damage of cargoes A_3 . The costs related to insurance benefits for damage of transported cargoes per year (the share of reinsurers is not included) are found according to a document (Nuostolių patiriamų dėl neigiamo... 2008).

The costs of reconditioning and repairs of the damaged road and road constructions A_4 . In calculation of the costs of road engineering constructions' damage, the price of the said constructions and their individual elements as well as asphalt, concrete and so on, and the repair and reconditioning costs are taken into account.

The costs related to the maintenance of road and road constructions are the ones of two aspects:

1. *The traffic-related costs:*
 - reconstruction;
 - pavement replacement;
 - pavement repair.
2. *The costs not related to traffic:*
 - street lighting;
 - maintenance of the drainage system;

- security barriers;
- road marking;
- salt gritting; snow removal;
- traffic lights, the signal system.

The said costs form 0.1–0.15% of the costs of vehicle repair and reconditioning A_1 (Eurostat 2013; RMIIA 2013):

$$A_3 + A_4 = (0.1...0.15) \cdot A_1, \text{ or} \\ A_4 = (0.1...0.15) \cdot A_1 - A_3. \quad (6)$$

The costs of road accident investigation incurred by Lithuanian Road Police Traffic Supervision Service and other organizations A_5 are calculated as follows:

$$A_5 = A_P + A_T, \quad (7)$$

where: A_P – the costs incurred by Lithuanian Road Police Traffic Supervision Service; A_T – the costs incurred by courts.

The costs of road accident investigation incurred by Lithuanian Road Police Traffic Supervision Service are bound with road accident management. They include salaries of employees and other material expenses of legal entities.

The average costs incurred by Road Police per accident:

$$A_P = \frac{V_{assig}}{N_A}, \quad (8)$$

where: V_{assig} – the annual amount of assignments from the state budget provided to Lithuanian Road Police Traffic Supervision Service.

The costs incurred by courts are calculated individually for each case. The experience attests that costs incurred by courts are half as many as compared to the costs incurred by Police per accident (Eurostat 2013; RMIIA 2013):

$$A_T = \frac{A_P}{2}. \quad (9)$$

Within a year, the costs incurred by Lithuanian Road Police Traffic Supervision Service and courts are:

$$A_P = V_{assig};$$

$$A_T = \frac{V_{assig}}{2}.$$

The costs related to casualties of road accidents A_6 are calculated individually and cover the following road accidents:

- fatal road accidents;
- road accidents that result a disability;
- road accidents that result serious injuries;
- road accidents that result slight injuries.

These costs are calculated as follows:

$$A_6 = M_P + I_P + S_S + S_L, \quad (10)$$

where: M_P – the costs bound with a fatal road accident; I_P – the costs bound with a disability of a person; S_S –

the costs bound with a serious injury of a person; S_L – the costs bound with a slight injury of a person.

The costs bound with a fatal road accident are calculated as follows:

$$M_P = M_V + M_7; \quad (11)$$

$$M_V = M_1 + M_2 + M_3 + M_4 + M_5 + M_6; \quad (12)$$

$$M_7 = \frac{\frac{M_V \cdot 45}{100} + \frac{M_V \cdot 70}{100}}{2}, \quad (13)$$

where: M_P – fatal consequences; M_V – all costs, except of social (moral) ones; M_1 – the costs of transportation to a hospital; M_2 – the costs of morgue services; M_3 – a one-time funeral grant; M_4 – payment of survivor’s allowance to the family of the dead; M_5 – the costs of the lost working time of the next of kin of the dead; M_6 – losses caused to the national economy; M_7 – social (moral) costs.

The costs caused by a disability of a casualty:

$$I_P = I_V + I_5; \quad (14)$$

$$I_V = I_1 + I_2 + I_3 + I_4; \quad (15)$$

$$I_5 = \frac{\frac{I_V \cdot 45}{100} + \frac{I_V \cdot 70}{100}}{2}, \quad (16)$$

where: I_P – the consequences of disability; I_V – all costs, except of social (moral) ones; I_1 – the costs of transportation to a hospital; I_2 – the hospital costs; I_3 – the average disability pension per month; I_4 – losses caused to the national economy; I_5 – social (moral) costs.

The costs caused by a serious injury (disablement) of a casualty:

$$S_S = S_{S1} + S_{S2} + S_{S3} + S_{S4}, \quad (17)$$

where: S_S – serious injuries; S_{S1} – the costs of transportation to a hospital; S_{S2} – the hospital costs; S_{S3} – payment of a sick benefit; S_{S4} – losses caused to the national economy.

The costs caused by a slight injury (outpatient treatment) of a casualty:

$$S_L = S_{L1} + S_{L2} + S_{L3} + S_{L4}, \quad (18)$$

where: S_L – slight injuries; S_{L1} – the costs of transportation to a hospital; S_{L2} – the hospital costs; S_{L3} – payment of a sick benefit; S_{L4} – losses caused to the national economy.

2.4. Calculation of the Costs

The costs of transportation to a hospital or emergency medical aid are calculated according to the following formula:

$$(M_1; I_1; S_{S1}; S_{L1}) = N_M \cdot n \cdot i_1, \quad (19)$$

where: N_M – the number of deaths and injuries caused by road accidents within a year; n – the average number of calls per accident; i_1 – the average costs per call.

The international experience shows that 70% of injured casualties of road accidents are transported to inpatient hospitals. 30% of them become disabled and 70% recover. The remained part of the injured, i.e. 30%, is formed of slightly injured that are treated at outpatient hospitals.

The average duration of hospitalization is 30 days. It is accepted that all injured pass outpatient treatment after the road accident. On the average, 44-day outpatient treatment is required.

The hospital costs include the so called ‘bed days’ (the charge for inpatient hospitalization of a patient per day) and medical treatment. According to the calculations of draft budgets of the foundation for Compulsory Health Insurance (Lietuvos Respublikos 2008–2010 metų... 2008), the price of nursing and maintenance treatment services is formed by:

- the price of a bed day;
- the average price of treatment per patient.

The hospital costs are calculated as follows:

$$(I_2; S_{S2}; S_{L2}) = P_n \cdot d_V, \quad (20)$$

where: P_n – the number of patients undergoing a treatment at the hospital; d_V – the average price of treatment per patient (including the price of a bed day).

The morgue costs include the costs of autopsy and other costs. It is accepted that the morgue costs are formed by the price of making the conclusion by the expert from examination of the dead person.

The morgue costs per year are calculated as follows:

$$M_2 = C_M \cdot Z, \quad (21)$$

where: C_M – the unit price of making the conclusion by the expert from examination of the dead (Valstybinė teismo medicinos tarnyba... 2013); Z – the number of deaths.

The costs of one-time funeral grants payable by the state to families of casualties per year:

$$M_3 = C_L \cdot Z, \quad (22)$$

where: C_L – the size of a one-time funeral grant (LRSADM 2013).

The family of the dead is paid a survivor’s allowance. The average size of a monthly survivor’s pension is found on the base of state social insurance data (Valstybinio socialinio draudimo... 2013). The amount paid to families of the dead is calculated as follows:

$$M_4 = C_G \cdot Z \cdot 12, \quad (23)$$

where: C_G – the average size of a monthly survivor’s pension.

The value of the work time lost by members of the family of a dead is found on multiplying the average hourly income by the number of the lost working hours. Usually, 3 working days are provided for a funeral. A statistical family consists of two adults and two children. It is accepted that in case of fatal road accident, 3 persons on the average mourn:

$$M_5 = 72 \cdot N_p \cdot Z, \quad (24)$$

where: 72 – the sum of working hours in 3 working days (24 h) multiplied by 3 – the average number of mourning persons; N_p – the average hourly income.

The social (moral) costs form about 45–70% of the total costs related to a death of a person. It is attested by the results of studies carried out in West Europe. After calculation of all costs of death of a person caused by a road accident, the average social (moral) costs should be added. At first, the minimum (45%) and the maximum (70%) costs are calculated, and then the average value is found.

The average monthly disability pension is available from Internet (Valstybinio socialinio draudimo... 2013). Thus, the amount of pensions paid to persons for disability caused by road accidents per year:

$$I_3 = C_N \cdot D \cdot 12, \quad (25)$$

where: C_N – the size of the average disability pension a month; D – the total number of injured persons.

It is considered that all persons injured in road accidents were temporarily incapable to work. It is accepted that a sick pay per day equals to 85% of the average daily income in a month.

$$(S_{S3}; S_{L3}) = D \cdot 44 \cdot N_D, \quad (26)$$

where: N_D – a daily sick pay for temporary disability because of an injury caused by a road accident; 44 – the average number of days of outpatient treatment; D – the total number of injured persons.

2.5. Partial Losing the Gross Domestic Product; the Lost Productivity

The persons dead, disabled or seriously/slightly injured in road accidents are not involved in production for a certain period. In case of an injury, a period of incapacity to work lasts from one day to several months or years. Thus, such a person is unable to contribute to the Gross Domestic Product. Because of incapacity to work and injuries, the person loses the so called workforce productivity. In case of a death, dependently of the economic situation of the state, productivity also is lost; however, the free job will become accessible for other members of the community. The lost productivity is a difference between the useful work that could be made by the person and his/her consumption, i.e. the amount that could be consumed, if the person is alive.

If a person dies or becomes disabled, his/her lost productivity may be expressed by:

- the total losses of productivity;
- the net losses of productivity;
- the value of the lost years of the life.

Two first methods assess the costs related to death and incapacity to work on the base of the future productivity potential of the casualty of a road accident. Usually, the said potential conforms to the value of the productivity of the casualty.

The community costs are formed by human costs: when a member of the community dies or becomes disabled, the value of such person is based on working time and productivity. The assessment of human costs is affected by the Gross Domestic Product, the national income, the professional income or the minimum wage, the age of the dead or injured persons.

The value of the losses of the national economy depends on the death, on the severity of the injury, the age of the casualties. The said data enable establishing the periods when the casualties are involved in creation of the national product.

In case of death, the losses of the national economy are calculated as follows:

$$M_6 = \frac{GDP \cdot Z \cdot K}{N}, \quad (27)$$

where: GDP – the annual Gross Domestic Product (Lietuvos statistikos departamentas 2013); N – the number of employees involved in the national economy (Lietuvos statistikos departamentas 2013); Z – the number of dead persons; K – the coefficient describing the growing of unproduced national product in the period of incapacity to work.

The coefficient K is calculated as follows:

$$K = \frac{1 - \left(\frac{P_{GDP}}{D}\right)^{n_z}}{D - P_{GDP}}, \quad (28)$$

where: P_{GDP} – the factor of increase of the Gross Domestic Product (Lietuvos statistikos departamentas 2013), so $P_{GDP} = 1.089$; D – the factor of deductions, i.e. the person's consumption, if he/she is not dead (it equals to 1% per year, i.e. $D = 1.01$); n_z – the average number of years of disability of the perished persons.

In Lithuania, the limits of the age of persons dead because of external circumstances are 35–64 years (Lietuvos statistikos departamentas 2013), their average age is 49.5 years $\left(\frac{(35 + 64)}{2}\right)$. The average believable lifespan of females and males is 77 and 65 years, respectively (Lietuvos statistikos departamentas 2013), their average believable lifespan is 71 years $\left(\frac{(77 + 65)}{2}\right)$. So, $n_z = 71 - 49.5 = 21.5$.

Hereinafter, the costs of fatal road accidents are calculated. First of all, the total costs M_V , except of social and moral costs are calculated, and then social (moral) costs M_7 and the costs of fatal consequences M_P are calculated.

The losses of the national economy caused by a disability of a person:

$$I_4 = \frac{GDP \cdot D_I \cdot \left[1 - \left(\frac{P_{GDP}}{D}\right)^{n_n}\right]}{N \cdot (D - P_{GDP})}, \quad (29)$$

where: D_I – the number of persons injured in road accidents and recognized incapable to work; D – the factor of deductions, i.e. the person's consumption, if he/she is not injured in a road accident (as in case of a death,

its value is considered 1%); n_n – the average number of years of disability of the injured persons that became disable (it is accepted that $n_n = n_2$).

Then total costs I_V , except of the social (moral) costs, the social (moral) costs I_5 and all disability costs I_P are calculated.

The losses of the national economy caused by a serious injury of a person:

$$S_{S4} = \frac{GDP \cdot D_{BL}}{N \cdot 365}, \quad (30)$$

where: D_{BL} – the total number of days of hospitalization of injured persons; N – the number of employees in the national economy; 365 – the number of days in a year;

$$D_{BL} = P_L \cdot d_L, \quad (31)$$

where: P_L – the number of patients treated at a hospital; d_L – the average number of days passed by patients at an inpatient hospital (the international experience shows that patients are treated at a hospital for 30 days on the average).

The losses of the national economy caused by a slight injury of a person:

$$S_{L4} = \frac{GDP \cdot D_{BA}}{N \cdot 365}, \quad (32)$$

where: D_{BA} – the total number of days required for outpatient treatment of the injured persons;

$$D_{BA} = P_A \cdot d_A, \quad (33)$$

where: P_A – the number of patients having passed outpatient treatment; d_A – the average number of days re-

quired for outpatient treatment of a patient (the international experience shows that 44 days are required for outpatient treatment of a patient on the average).

If the costs incurred by the state because of serious and slight injuries are known, the costs caused by serious injuries S_S and the costs caused by slight injuries S_L may be easily calculated.

The costs of a road accident without casualties (non-registered) are calculated as follows:

$$A_N = \frac{T + A_P}{N_A}, \quad (34)$$

where: T – the value of the damage caused to the transported cargoes $T = A_1 + A_2 + A_3$; A_P – the costs of Lithuanian Police Traffic Supervision Service per road accident; N_A – the total number of road accidents per year.

The costs related to road casualties:

- fatal – 5245989.53 LTL (1.00 EUR = 3.452 LTL);
- resulting a disability – 5212812.68 LTL;
- serious injuries – 20680.04 LTL;
- slight injuries – 16977.44 LTL.

The costs per accident:

- fatal – 601238.56 LTL;
- resulting a disability – 1397790.50 LTL;
- serious injuries – 12941.06 LTL;
- slight injuries – 6503.46 LTL.

2.6. Calculation of the Total Costs Caused by Road Accidents

The total costs caused to the state by road accidents amount approximately to 13080 billion LTL (3.788 billion EUR) per year (Table 2).

Table 2. Distribution of costs

Description of costs	Costs [LTL/year]	Costs [LTL/day]	Costs [EUR/year]	Costs [EUR/day]
Total costs caused by road accidents, A	13080095507.02	35835878.10	3788257503.19	10378787.68
Damage caused to vehicles, the costs of evacuation and repair of damaged vehicles, A_1	32003197.20	87679.99	9268766.57	25393.88
The costs of the downtime of vehicles from the moment of damage to the final repair, A_2	20891520.00	57237.04	6050602.41	16576.99
The costs of cargo damage, A_3	681400.00	1866.85	197347.08	540.68
The costs of road and road constructions' reconditioning and repair, A_4	3318999.65	9093.15	961248.74	2633.56
The costs of road accident investigation carried out by Lithuanian Police Traffic Supervision Service and other organizations, A_5	8082750.00	22144.52	2340926.20	6413.50
The costs caused road accidents where casualties are involved, A_6	13015117640.17	35657856.55	3769438612.19	10327229.07
The costs per citizen of Republic of Lithuania	3895.55	10.67	1128.23	3.09
The costs per casualty	1457717.10	3993.75	422184.05	1156.67

Note: According to the data from the Statistics Lithuania (Lietuvos statistikos departamentas 2013), the population of Lithuania in the end of the year 2012 was 2974.2 thousand.

Conclusions

1. The developed methodology for estimation of losses caused by road accidents that expresses the negative impact of road accidents in monetary units may be usable for public information on the decisions passed in the sector of transport system and its infrastructure upon reasoned motivation of the measures for reducing the number of road accidents striving to ensure harmonious development and to improve the relations between carriers and users of transportation services as well as between the direct users of the transport system and the part of the community that is not directly bound with the system.
2. The developed methodology for estimation of losses caused by road accidents that expresses the negative impact of road accidents in monetary units highlights the problems of internalization of the external costs of the transport system and will be helpful in more effective involvement of transport infrastructure in interdepartmental development programmes.
3. The developed methodology for estimation of losses caused by road accidents will enable to assess more precisely a necessity, perspectives and priorities of investment projects in the transport system, and to settle problems related to distribution of funding.
4. According to this methodology, it was found that the total costs caused to the state by road accidents annually amount approximately to 13.080 billion LTL (3.788 billion EUR).

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