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Evaluation of External Costs of Traffic Accident in Slovak Republic

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***Abstract*—**The report deals with comparison of traffic accidents in Slovak republic in road and rail transport since 2009 until 2014, with evaluation of external costs and consequently with the possibilities of their internalization. The results of road traffic accidents analysis are realized in line with after-effects they have caused; in line with main cause, place of origin (within or out of town) and in accordance to age of accident´s victims and kind of injuries (easy, hard or fatal). Evaluation of individual after-effects is carried in terms of probability of traffic accidents occurrence.

***Keywords*—**External costs, traffic accident, rail transport, road transport.

I. Introduction

TRAFFIC accident frequency is relevant social and economic problem. Every year more than 250 people die on Slovak roads, thousands of people are injured and material damages reach milliard values.

Removal of transportation from rail to the roads means increased hazards and accident frequency. From long-term statistic results that security of a rail transport is 16 times higher than road transport security and after-effects of rail accidents are less significant. With growing strength of the road transport will be this proportion farther failing in its disadvantage.

II. Traffic Accidents

A. Traffic Accidents in the Road Transport

In road transport, traffic accident is defined [9] as an „...event, caused by vehicle motion in road traffic, whose consequences are mortality, health and material damages, in defiance of the fact whether this incident was classified like delict or violation and whether it was treated by court or by punishable commission of transport inspectorate."

With every traffic accident is verified only the main reason of the accident origin. Accidents caused by "other reasons" are mainly incidents with forest animals, fallen from vehicle during the ride, accidents caused by front passenger and so on.

The number of killed people is calculated only from people, who died in consequence of traffic accidental injury by 24 hours after the accident [10].

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There were registered 25 989 traffic accidents in Slovakia in 2009. The number of traffic accidents is since 1997 minimized due to administration-legislative action, which moved the physical damage level for event evidence as an accident. In 2014, the number of traffic accidents decreased.

TABLE I
TABLE OF ROAD TRAFFIC ACCIDENTS IN LINE WITH AFTER-EFFECTS [8]

Year	2009	2010	2011	2012	2013	2014
Number of accidents together	25 989	21 611	15 001	13 945	13 586	13 307
Number of killed people	347	345	324	296	223	259
Number of hard injured people	1 408	1 207	1 168	1 122	1 086	1 098
Number of easy injured people	7 126	6 943	5 889	5 316	5 225	5 519
Physical damages (in millions €)	101.824	83.697	54.051	46.706	45.337	42.019

TABLE II
NUMBER OF KILLED, HARD, AND EASY INJURED PERSONS IN TRAFFIC ACCIDENTS IN REGIONS ŽILINA AND BYTČA

Age	Number of people	Probability
0 -5	16	17.61
6 – 10	40	27.90
11 – 15	35	40.79
16 – 20	77	55.02
21 – 25	105	68.47
26 – 30	82	78.61
31 – 35	73	83.28
36 – 40	67	81.39
41 – 45	57	73.40
46 – 50	55	61.04
51 – 55	47	46.87
56 – 60	18	33.20
61 -65	15	21.69
66 – 70	19	13.08
71 – 75	15	7.27
76 -80	11	3.73
81 – 85	3	1.77
86 - 91	2	0.77

From statistic results that the most often reason of traffic accidents are drivers of motor vehicles - around 90%. In the second group are pedestrians – around 2%, in the third one are drivers of non-motor vehicles – also around 2%. The other accidents were caused by technical defect of vehicle (0.5%), defect of way (0.3%) or other reason (5.2%). From analyze of traffic accidents number in line with place of origin results, that nearly 75% of traffic accidents originate in the village and 25% outside village [9].

Traffic accidents originated out of village have more

significant after-effects, especially for killed people's part.

Unequal rake-off of traffic accidents appearance in line with the number and weightiness can be on the one hand caused by lower speed in the village and on the other hand by lower density outside the village [7].

From statistical finding is clear that most of the social-economical events have a normal distribution. The normal distribution presents group of distributions, which differ only in mean value μ and variability δ^2. Normal probability density function is symmetrical about its mean x = μ and its shape is depending on parameter δ^2. Characteristic function of the normal distribution $N(\mu,\delta^2)$ is [8]:

$$f(x) = \frac{1}{\delta\sqrt{2\pi}} * e^{\frac{-(x-\mu)^2}{2\delta^2}} \quad (1)$$

It is conformable like in the occurrence of road traffic accidents accordance to the participant´s age. Since the traffic accidents are not recorded according to the age in the official statistic, this hypothesis was verified in two regions – Žilina and Bytča. Data from years 2001 and 2002 are processed from internal materials of police corps of Žilina.

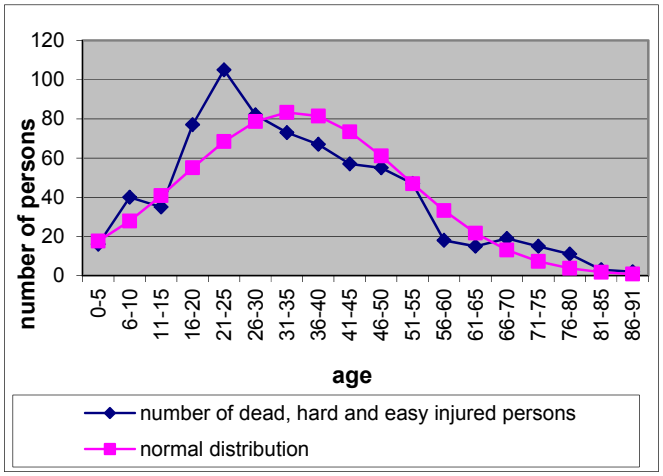

Fig. 1 Number of road traffic accidents according to the age in regions Žilina and Bytča

As we can see on Fig. 1, the number of traffic accidents has in the fact shape of normal distribution. Higher value in intervals of 16-20 and 21-25 years is entailment of the fact, that in these categories are young and raw drivers or youthful front passengers. Soft growth is also at the end of the curve and it is caused by pedestrians over 66 years.

After substitution of mean value μ = 34.07 and mean-root-square error δ = 17.62 to the figure for normal distribution we get following function [4]:

$$f_{(x)} = 0{,}02264^{\frac{(x-34{,}07)^2}{620{,}93}} \quad (2)$$

TABLE III
PROBABILITY OF AGE OF ACCIDENT PARTICIPANT

AGE	Probability	Number of death	Number of Hard Injury
20	0.01643897	4	4.5
21	0.01718185	4	4.75
22	0.01790014	5	5
23	0.01858806	5	5
24	0.01923992	5	5.25
25	0.01985014	5	5.5
26	0.0204134	5	5.5
27	0.02092466	5	5.75
28	0.02137926	6	5.75
29	0.021773	6	6
30	0.02210218	6	6
31	0.02236368	6	6.25
32	0.022555	6	6.25
33	0.02267429	6	6.25
34	0.02272039	6	6.25
35	0.02269286	6	6.25
36	0.02259196	6	6.25
37	0.02241867	6	6.25
38	0.02217467	6	6
39	0.0218623	6	6
40	0.02148452	6	6
41	0.0210449	5	5.75
42	0.02054752	5	5.75
43	0.01999693	5	5.5
44	0.01939807	5	5.25
45	0.0187562	5	5.25
46	0.01807684	5	5
47	0.01736567	4	4.75
48	0.01662846	4	4.5
49	0.01587097	4	4.25
50	0.01509894	4	4.25
51	0.01431795	4	4
52	0.01353338	4	3.75
53	0.01275038	3	3.5
54	0.01197378	3	3.25
55	0.01120807	3	3
56	0.01045734	3	2.75
57	0.00972531	3	2.75
58	0.00901523	2	2.5
59	0.00832993	2	2.25
60	0.0076718	2	2
61	0.00704279	2	2
∑		193	202.75

B. Traffic Accidents in Rail Transport

In rail transport is traffic accident defined as an event, caused by rail vehicle motion, whose consequences are death or mayhem of person, bigger material damage, life and health hazard and damage of environment [11].

Accidental events are split into these categories:

- train collision
- derailment
- collision with level crossing users
- injuries by railway rolling stock
- other accidents (at shunting)

TABLE IV
ACCIDENT ON ŽSR NETWORK [1]-[3]

Indicator	2009	2010	2011	2012	2013	2014
Number of accident events on rail network of ŽSR	250	231	235	216	251	241
From that:	6	13	11	10	7	3
• train collision	3	2	7	4	3	2
• derailment	51	50	50	50	46	49
• collision with level crossing users	130	116	102	106	126	141
• injuries by railway rolling stock	46	41	56	40	39	29
• other accidents (at shunting)	21	34,5	34	29	30	17
Accidents with responsibility of ŽSR						
Harm done in millions €	2.563	2.699	1.488	n/a	n/a	n/a

When comparing road and rail transport, we can say, that rail transport is unambiguously safer, its rake-off is only 2 %. Over the past 15 years there was 1 death of passenger in the rail transport.

III. THE COST OF TRAFFIC ACCIDENTS

We usually know the trespasser and also holder liable of the traffic accident, the value of material damage or cost of treatment of injured persons. This is resolved by means of social policy and policy of responsibility for damage caused by operation of motor vehicle. But traffic accidents bring also other costs. Cost items of traffic accidents include:

- material damages (vehicles, structures, routes and so on),
- cost of treatment (medical devotion a re-education),
- police, salvage and rescue service, law charges,
- loss production for society and for participant,
- pain and suffering of people.

We calculated loss of production of death by [5]:

$$EN_D = \sum_{i=20}^{n} \sum_{j=1}^{n-i} p_i . m_D . LP . (1+r)^{j-1} \qquad (3)$$

where: EN_D = loss of prod. on death; LP – loss of production; m_D – number of death; n – age of pension; p_i – probability of age of accident participant; r – time factor.

The loss on hard injury was calculated by [5]:

$$EN_{HI} = \sum_{i=20}^{n} \sum_{j=1}^{n-i} p_i . m_{HI} . 0{,}25 . IP . (1+r)^{j-1} \qquad (4)$$

where: EN_{HI} = loss of prod. on hard injury; IP –average of invalidity pension; m_{HI} – number of hard injury; n – age of normal pension; p_i – probability of age of accident participant; r – time factor.

TABLE V
CALCULATION OF DAMAGES AND LOSSES FROM TRAFFIC ACCIDENT FREQUENCY BY UP TO INJURY IN TIME

AGE	FOR SOCIETY		FOR PARTICIPANT
	loss of prod. On death in thousands €	loss on hard injury in thousands €	loss on hard injury in thousands €
20	50 383.90	21 896.92	27 621.80
21	48 320.03	22 268.73	27 999.48
22	57 895.35	22 571.62	28 288.56
23	55 463.61	21 722.02	27 136.24
24	53 102.70	21 936.09	27 316.08
25	50 810.55	22 087.65	27 417.41
26	48 585.17	21 214.71	26 250.64
27	46 424.60	21 286.91	26 257.27
28	53 192.35	20 414.87	25 103.01
29	50 748.50	20 412.98	25 022.81
30	48 375.83	19 543.48	23 883.08
31	46 072.27	19 472.42	23 723.33
32	43 835.80	18 606.96	22 599.91
33	41 664.47	17 760.96	21 507.09
34	39 556.38	16 933.98	20 444.03
35	37 509.69	16 125.59	19 409.93
36	35 522.62	15 335.38	18 403.99
37	33 593.42	14 562.93	17 425.45
38	31 720.41	13 255.53	15 814.62
39	29 901.96	12 546.95	36 829.06
40	28 136.47	11 854.31	14 061.00
41	22 018.67	10 711.51	12 669.01
42	20 631.88	10 077.24	11 884.86
43	19 285.49	9 046.04	10 638.50
44	17 978.31	8 081.48	9 477.44
45	16 709.20	7 540.55	8 818.40
46	15 477.06	6 677.88	7 787.91
47	11 424.64	5 876.33	6 834.28
48	10 495.51	5 133.97	5 954.61
49	9 593.45	4 448.92	5 146.08
50	8 717.65	4 058.09	4 681.38
51	7 867.37	3 459.80	3 980.55
52	7 041.85	2 914.04	3 343.76
53	4 680.28	2 419.13	2 768.57
54	4 096.68	1 973.45	2 252.62
55	3 530.08	1 575.41	1 793.62
56	2 979.98	1 223.48	1 389.37
57	2 445.91	1 007.81	1 141.54
58	1 284.93	724.52	818.59
59	949.31	483.45	544.85
60	623.48	283.22	318.40
61	307.13	140.00	157.00
∑	1 118 954.93	479 667.29	604 916.13

IV. INTERNALIZATION OF EXTERNAL COSTS OF TRAFFIC ACCIDENTS

At the internalization of external costs of traffic accidents we result from probability distribution for death, hard and easy injured persons. Amount of external costs, which is possible to internalize is for separately consequences of traffic accidents calculated in this manner [6]:

- external costs of death injuries are given by sum of product of traffic accidents number probability in a given

age interval and average payment lost (12 times monthly payment), which is discounted by up to present value,

- external costs of hard injured persons are given by sum of product of traffic accidents number probability in a given age interval and average value of paid disability pension,
- external costs of hard injured persons are given by sum of product of traffic accidents number probability in a given age interval and average value of costs spent on treatment of these persons,
- in case of the material damages we can directly calculate the amount of costs.

Final amount of the costs calculated in this manner we have to recalculate by up to transport performance unit (ton km or person km).

In this manner we can recalculate amount (in €/ton km or in €/person km) included in internal costs.

V. Conclusion

Submitted traffic accidents data in rail and road transport clearly document adversely priority of road transport, whereat participates especially individual automobile transport, mainly with permanent growth of traffic performances.

External costs of traffic accidents represent nearly 1/3 of total external costs. But this evaluation is all the more complicated by the fact that it is hard to evaluate people´s suffering, pain and loss of human life. These costs present important economical and ethic problem.

As a consequence it is necessary to work out such total policy, where different tools (lawful and fiscal), capital policy, grants, national and regional progress enable better decision policy in permanently maintainable transport advantage. Internalization of external costs is going to be important step towards maintainable mobility and creation of average and effective prices.

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