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A model of road traffic as a resource risk loss in the elderly population of Croatia

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Abstract

Background and Purpose: *Use of the road traffic resource inevitably leads to significant human and material losses. Thus, the standardized death rate among older people (≥65years) in the European Union was 19.8 in 2000 and 11.9 in 2011. A model is proposed of human loss through RTA to establish the main resource losses and major risk loss factors for victimization of the elderly population (≥65years), as compared to the risk prone young population (18–24 years).*

Materials and Methods: *Data on RTA in Croatia are obtained from the official government bulletin for road safety of the Ministry of the Interior for the period 2000–2011. Minimum and maximum number of victims and mean expected loss are used for determination of environmental risks and risk proneness.*

Results and Conclusions: *A comparative victimization analysis for Croatia for the period 2000–2011 shows significant losses for mild and severe injury to younger RT participants, increased mild injury to elderly drivers, and increased severe injury among elderly pedestrians. Risk is mostly expressed in fatal RTA for younger participants with risk proneness of 32.4 %. The most exposed RT users are: severely injured elderly drivers with unprofitable and profitable risks between 32.8 % and 50.9 %, fatally injured elderly drivers with unprofitable and profitable risks between 43.2 % and 66.1 %, and fatally injured elderly pedestrians with unprofitable and profitable risks between 93.9 % and 86.3 %. These facts demand preventive actions for these users on the side of car and road designers and traffic educators as well.*

INTRODUCTION

During the period 2000–2011 mortality in RTA decreased in the EU. SDR (Standardized Death Rate) of the younger population (≤ 64 yrs.) was 13.5 in 2000 and 8.1 in 2011; SDR of older people (≥ 65) was 19.8 in 2000 and 11.9 in 2011. Although SDR has decreased in both age groups, it is significantly higher in the older population *(1)* thus indicating a necessity to make a tool for better analyzing the losses in the RTA process.

A complex man-made system such as road traffic, air traffic, an electric power grid, a financial system or a distributed data-base system must calculate with losses and risk in its proper work and existence *(2, 3)*.

All these systems are technologically designed, lead by human agents, goal-oriented and based on non-living artifacts. These nonliving artifacts are resources that exhibit certain throughput or capacity, such as number of vehicles per hour on a particular road, thus fulfilling particular agent goals. When working towards the limit of its capacity each resource exhibits a risk of malfunction generally described as loss. Risk can be diminished by the agent's use of the infrastructure environment for example while not using maximum vehicle speed one has a reserve for avoiding a possible accident by temporarily accelerating the car – it is extremely difficult to comprehend and articulate all the relations that mutually connect resource throughput, losses, risk and environmental conditions *(2)*.

Therefore, as a human factor of professionals that control RT, of supervisors or designers of certain parts: such as vehicle designers and road surface maintenance staff, of RT passengers in various traffic situations, at every moment there exists the possibility of not clearly deciding about the state of a resource state (road, communication, car, brakes), leading to an erroneous action in their behavior or in road or vehicle design. With the increase of traffic throughput this often leads to human victimization with various outcomes *(1, 2, 4)*. Because of the difficulty of detailing all relevant risk parameters of road traffic in all its aspects we propose to take the number of RT victims as a model of its global capacity usage *(3)*.

The purpose of this work is to determine the victimization of elderly people in road traffic accidents starting from the hypothesis that RT throughput is connected to basic system resource and therefore with human participants by the so-called risk equation *(2, 3, 5)*. Expressing RT throughput with one of its resource losses, with human victims, is based on RT nature and on the manner of its participant usage. Exposure to road traffic on the side of its participants is inevitable and their behavior and risk commitment highly depend on their goal at hand, thus they dictate the manner of their own risk commitment. Exposure to road traffic leads inevitably to imminent losses, which are unfortunately basically system-ingrained. Added to these losses are risk losses that are generated by system usage beyond its throughput or capacity, or beyond environmental margins. Risk losses are changeable in the observation period and their amount equals to the mean expected risk loss *(2, 5)*.

We hereby distinguish two types of risk: positive risk which is on average profitable to RT participants – while fulfilling their goal, and negative risk which is not profitable in average for RT participants while fulfilling their goal, all this measurably referring to the attained system capacity, which is measurable by the number of victimized traffic participants. Because, in our approach the system capacity is measured by losses in this paper risks are expressed as inverted profitable, i.e. positive risk brings increase and negative risk brings decrease in traffic victimization.

As an investigation example we consider resource losses and their risks for victimization in road traffic accidents in Croatia over the period 2000–2011 year for three types of process outcome: death, severe injury and mild injury. We compare losses and risks for the elderly population, 65 and over, and the younger generation, 18–24 years, as specifically prone to risk. Because all observed risk investigation is quantitative, the results depend on the length of the observation unit's length of one year *(5)*.

METHODS

Theoretical foundation – resource equation, resource loss and its measure, and risk proneness

The basic resource equation is of axiomatic in nature – it is not a subject to proof – and it connects system throughput I for the purpose of this investigation expressed as the number of RTA victims with health consequences, with resource R the corresponding participant age group active in road traffic, and K a system constant, i.e.

$$I = KR \tag{1}$$

Equation (1) linearly connects system throughput, expressed in victimized people, with the resources, expressed in the number of resource users of a particular group. Thus the basic system unit is the traffic participant and the measure of throughput is the number of victimized traffic participants in the road traffic system. According to *(2)* the basic risk equation is

$$I = R[K \pm br(E \tag{2}$$

where the negative symbol denotes risk on average profitable for system participants, and the positive symbol denotes risk on average not profitable for system participants. Item $br(E)$ stands for additional gain or loss when taking risk. Specifically $r(E)$ is resource environment efficiency for a given resource, or it is the measure of risk sensitivity to resource environment, and b is a constant, usually $b = 0.25$. The risk environment is all system resources that are not used to the last limit of their capacity. Thus a road that for safety reasons carries a speed limit of 50 km/h qualifies as a basic system resource and a personal vehicle on the road represents resource environment because it can safely be used up to 100 km/h. Driving that car beyond 100 km/h would designate this parameter as a basic resource.

The measure of throughput loss has two components. The first is probability of loss and the second is the amount of loss all regarding a certain throughput level. Wherever in real life we are exposed to a possible loss we are favored with a possible gain. With the fluctuation of throughput around its mean value we may introduce either standard deviation of throughput as in *(6)* as is conventional in financial systems, or mean expected risk loss (MEL) according to *(2, 4)*. MEL is referred to the most favorable system throughput i.e. when the system exhibits minimum losses. Losses below this minimum loss are not risk but guaranteed system loss.

Risk proneness is the ratio of additional and basic risk i.e. from (1) and (2) as

$$R_p = \frac{br(E)}{K} \quad (3),$$

where

$$r(E) = \frac{MEL}{R} \quad (4).$$

Selection and description of investigation data

Selection of risk populations in RTA

According to official data on road traffic accidents *(7)* two risk populations in the RT process in Croatia are selected: the elderly population 65 years and over and a young population of 18–24 years. They are selected according to significant differences in participation in road traffic for the observed period 2000–2011, for mortality rate Fig.1, severe injury rate Fig. 2, and mild injury rate Fig 3.

Data on the number of road traffic participants 65 years and over according to three outcomes: death, severe injury and mild injury are given in Table 1. for the period 2000–2011.

Data on the number road traffic participants 18–24 years according to three outcomes: death, severe injury and mild injury are given in Table 2. for the period 2000–2011.

Technical information on data processing and its aim

Data processing should articulate the difference between risk loss and guaranteed loss in a particular type of road traffic accidents for a particular age group and participant role in the accident. Therefore extensive analytical tools have been proposed to make possible for such distinctions.

Data processing is exemplified on the data series for death in all elderly road traffic participants as given in row 2 of the Table 1: the data series is given as DS = (101, 120, 107, 129, 92, 96, 114, 111, 105, 116, 97, 74). The mean value (MV) of the data series is 105.16. Mean expected loss is *(2, 3)*

$$MEL = MV - Min(DS) = 105{,}16 - 74 = 31{,}16 \quad (5).$$

System constant K for DS including the mean number of elederly population of Croatia as 700.000 *(6)* is from expression (1)

$$K = \frac{I}{R} = \frac{105{,}16}{700.000} = 150{,}228 \times 10^{-6} \quad (6).$$

From expression (4), $r(E) = \frac{31{,}16}{700.000} = 44{,}53 \times 10^{-6}$.

Risk proneness for minimum data in DS equals to

$$RP^{-} = 1 - \frac{\frac{Min(DS)}{I}}{K} = 0{,}2269 \text{ or } 29.62\ \% \quad (7),$$

and risk proneness for maximum data in DS equals to

$$RP^{+} = \frac{\frac{Max(DS)}{I}}{K} - 1 = 0{,}2269 \text{ or } 22.69\ \% \quad (8)$$

.

Calculation with the usual b value of 0,25 according to *(2)* for mild risk environments gives

$$I - = (R(K - br(E)) =$$
$$= 700.000\ (0{,}00015 - 0{,}25 \times 0{,}00004453) = 97{,}2 \quad (9)$$

for unprofitable risk and

$$I + = (R(K + br(E))$$
$$= 700.000\ (0{,}00015 + 0{,}25 \times 0{,}00004453) = 112{,}8 \quad (10)$$

for profitable risk.

Thus we have included more precise risk calculations for the data series, as the calculation of risk according to *(9)* and *(10)* does not include all DS cases. In paricular the minimum number of RT participants killed in DS is 74 and the calculation according to the literature *(2)* given in equation (9) amounts to 97.2, and the maximum number of RT participants killed in DS is 129 and the calculated number according to expression (10) is 112.8 whererby both results indicate significant difference from the literature values *(2, 4)*.

RESULTS

The calculations of RT system constant K, mean expected loss MEL, resource environment efficiency $r(E)$, system throughput for additional positive I^{+} and negative I^{-} risk impact for different values of b viz. $b = 0{,}25$, $b = 0{,}66$ and $b = 0{,}88$ applied to data from Table 1 for all elderly RT participants and using expressions (1), (2), (3), (4), (5), (6), (8), (9) and (10) are given in Table 3.

The calculation of RT system constant K, mean expected loss MEL, resource environment efficiency $r(E)$, system throughput for additional positive I^{+} and negative I^{-} risk impact for different values of b viz. for $b = 0{,}25$ and $b = 0{,}66$ applied to data from Table 2 for all young RT participants age 18–24 and using expressions (1), (2), (3), (4), (5), (6), (8), (9) and (10) are given in Table 4.

A more analytical examination is oriented toward specific road traffic participants thus differentiating between drivers and pedestrians as the majority of users. A detailed risk proclivity according to expressions (7) and (8) for these two RT user groups of the elderly population 65 and over is given in Table 5.

DISCUSSION

A simplified approach to road traffic accidents, modeling the whole process as a single infrastructural resource and observing its throughput by counting the number of victims and thus indirectly inferring on the complexity of the case, entails several valuable points:

1. The model separates imminent RT health losses from risk caused RT health losses. While some RT ac-

cidents exhibit a high level of imminent health loss compared to moderate risk loss such as severely and mildly injured elderly people, some RT accidents indicate possibilities for further improvement in risk decrease as for example in younger pedestrians age 18–24.

2. The widely accepted ignorance on the high level of imminent loss of health in accidents in the RT process in elderly people requires further analyses of the seasonal effects in RT victimization – by using the proposed resource equation for time intervals of RT observation shorter than one year.

3. Study of specific RT victims such as death in elderly pedestrians and in elderly drivers with high risk proneness indicates reconsideration of RT victimization in order to focus on essential risk contributions to RT fatality in elderly people.

The proposed calculation of risk proneness with separation of profitable impact factor b^+ from unprofitable risk impact factor indicates high levels of both factors of greater than $b = 0{,}66$ or $b = 0{,}88$ as compared to the usual amounts of $b = 0{,}25$ for financial risks *(4, 6)* and risk in technical processes such as in data communication infrastructure *(2, 5)*.

The proposed method can be applied to other risky processes such as for health risks analyses as well.

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