ASSESSING THE EFFECTIVENESS OF TECHNICAL MEASURE ON SERBIAN RAILWAY CROSSINGS

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Abstract – *In this paper numerical example are provided to evaluate countermeasure at selected crossings in Serbia. In this way will be shown how the developed statistical models for estimation of Accident Frequency and Accident Severity on Serbian railway crossings can be used to assess the effects of the measures that would be used for a particular crossing.*

Keywords – Railway Crossing Safety, Accident Modification Factor, Active Traffic Control Devices, Passive Traffic Control Device.

1. INTRODUCTION

There are generally three different types of countermeasures that engineers can use to make crossings safer: 1) crossing closure or grade separation, 2) improving crossing geometry (changing road and railway crossing angle, improving type of surface, improving sight distance, 3) upgrading traffic control devices (light signals, half-gates, full gates, extended half-gates, four half-gates, separators, video surveilance, crosing ligtning) [1]. Experts in traffic sometimes have to make tough decisions regarding investments in road safety. Specifically, engineers can be expected to choose between a range of technologies and/or measures to rehabilitate the perceived safety problems when: 1) has little information on the effects of measures on security, 2) information is known, but from different regions, states, or countries from which direct generalization may not be suitable, 3) when technology and/or rates relatively untested and 4) when there are not enough funds that would enable full and careful testing of each of the possible measures through studies before and after the introduction of the measure.

Laughland et al. (1975) [2] introduced the concept of Collision or Accident Modification Factor (CMF or AMF) to reflect the safety benefits associated with different countramesures and to represent the expected changes in collisions after the implementation of countermeasures.

A wide variety of statistical methods have been proposed to estimete the countramesure effect. These metods include the cross-sectional stydu (CS); before–after study (BA); simulation study (simul); on-site engineering evaluation (eval.); survey of motorists perceptions (survey), attitudes, and preferences about measure. Table 1 lists nine measures from the relevant literature, that may offer improvement in safety at railway crossing and expected effects.

Most of these sources are based on data from the US, Canada and South Korea. For their possible application in our conditions should certainly apply some of the calibration factor. The application of these factors is known in the literature. For example, Harkey 2005. [3] investigated the literature from various regions, including North America, Australia and Europe. He was recommended to use at least 20% experience from North America to present the effects of certain measures. Analysts are faced with various problems in this aspect when it comes to this issue. Besides the issue of generalization of previous studies on other populations, there is the question of whether all the studies have the same weight and how to evaluate them in relation to different methodologies conducted research. Methodology for this assesment is given in [4].

Tab. 1. Some of the railway crossing measures and the

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Tab. 1. Some of the railway crossing measures and the expected effects

No	Countermeasure		Sources	Expected effects
1.	From signs to flashing lihgts	Flashing lights are the basic active warning devices used to inform highway users of the approach of a train to a crossing.	Hauer and Persaud (1987) BA [5]	AMF = 51%
2.	From signs to 2-quadrant gates	Automatic gates provide an additional level of control and are normaly used in conjuction with flashing lights.	Hauer and Persaud (1987) BA [5]	AMF = 79%
3.	From flashing light to 2-quadrant gates	Automatic gates provide an additional level of control and are normaly used in conjuction with flashing lights.	Hauer and Persaud (1987) BA [5]	AMF = 60%
4.	Full road 2Q gate	A full road two-quadrant gate is installed to block the entire road such that it prevents vehicles from maneuvering around the deployed gates.	Austin and Carson (2002) CS [6]	Presence of gate shown to be statistically significant; AMF derived from model found to be 0.05.
5.	Four-quadrant gate	A four-quadrant gate is installed at the crossing such that it prevents vehicles from maneuvering around the deployed gates.	Carroll et al. (2002) BA [7]	47 train movements before and 2550 after revealed a 100% reduction in violations.
6.	Constant warning time	Warning time refers to the time between device activation and arrival of a train at the crossing; a constant warning time system provides warning time constantly regardless of train speeds such that excessively long warning times are eliminated.	Berg et al. (1982) Eval. [8]	Long warnings resulted in drivers disregarding information; no AMFs obtained.
7.	Lighting	Lighting is installed to illuminate the crossing at night.	Mather (1991) BA [9]	Small sample of night time crashes (18) before to after (2); thus, AMF for night time crashes is around 0.167.
8.	Violation detection	A violation detection system such as video cameras is installed at the crossing such that when crossing violations are detected, safety solutions are provided.	Carroll et al. (2002) BA [7]	Crossing violations reduced between 36%–92%,while crashes reduced by 70%–100%; conservative AMF inferred is 0.30
9.	Separator	Separators are physical obstacles that are placed in the middle of road on both sides of the level crossing, to supplement the system with 2Q gates, in order to prevent violations of the 2Q gates .	Carroll et al. (2002) BA [7]	Reduce the number of motorist violations by an additional 75 %. AMF = 0.23
			Ko et al. (2003) BA [10]	Reduction in violations from 25 to 1 was statistically significant.

2. ASSESSING THE EFFECTIVENESS OF SELECTED TECHNICAL MEASURES

In this section, numerical examples are provided to evaluate countermeasure at selected crossings in Serbia. This application demonstrates how the proposed model can be used to estimate countermeasure effect for specific crossings. In this way will be shown how the developed statistical models for estimation of Accident Severity and Accident Frequency can be used to assess the effects of the measures that would be used for a particular crossing. This models are presented in [11] and [12].

For the purpose of ilustration upgrading warning devices from signs to 2-quadrant gates, countermeasure are considered.

2.1. Assessing the effectiveness of selected countermeasure according to Accident Severity and Accident Frequency models on Serbian crossings

2.1.1. Assessing the effectiveness of selected countermeasure according to Accident Severity model

In this section upgrading warning devices from signs to 2-quadrant gates countermeasure at a particular crossing are considered according to Accident Severity model.

It should be noted that the characteristics of level crossings in accordance with variables that are accepted models of Accident Severity and Accident Frequency.

First, the ratio of the probability (RRR_1) is calculated before and after the introduction of measures for less severe accidents (y = 1):

$$RRR_1 = exp(-\beta_{1;0} + \beta_{1;1}VOSIG - \beta_{1;2}VOBR + \beta_{1;3}SIRPP + \beta_{1;4}MBRZ + \beta_{1;5}EXPO - \beta_{1;6}BRKOLB - \beta_{1;7}KATPRM) \quad (1)$$

$$RRR_1^p = exp(-5.76 + 1.33 \cdot 1 - 1.28 \cdot 0 + 1.26 \cdot 1 + 0.22 \cdot 8 + 0.08 \cdot 12 - 0.87 \cdot 0 - 0.39 \cdot 1) = 0.43 \quad (2)$$

$$RRR_1^n = exp(-5.76 + 1.33 \cdot 0 - 1.28 \cdot 0 + 1.26 \cdot 1 + 0.22 \cdot 8 + 0.08 \cdot 12 - 0.87 \cdot 0 - 0.39 \cdot 1) = 0.114 \quad (3)$$

$$AMF_{ijm} = \frac{RRR_1^n}{RRR_1^p} = \frac{exp(0)}{exp(\beta_{1;1} \cdot 1)} = exp(-\beta_{1;1}) = exp(-1.33) = 0.264 \quad (4)$$

where:

$RRR_1^p -$ ratio of the probability $y = 0$ and $y = 1$ before introduction 2-quadrant gates,

$RRR_1^n -$ ratio of the probability $y = 0$ and $y = 1$ after introduction 2-quadrant gates,

$\beta_{1;1} -$ constant; $\beta_{1;1} - \beta_{1;7} -$ regression parameters.

Independent variables are VOSIG − warning devices road signs; VOBR −warning devices full gates; SIRPP − crossing width; MBRZ − maximal train speed at a given crossing; EXPO − AADT · daily trains; BRKOLB −number of tracks; KATPRM − railway category.

$AMF_{ijm} -$ the expected reduction of less severe accident on particular crossing i for given countermeasure j from the model Accident Severity m.

As a result, according to Accident Severity model, it can be expected 74 % reduction of less severe accidents after the upgrading crossings from signs to 2-quadrant gates.

Then, the ratio of the probability (RRR_2) is calculated before and after the introduction of measures for more severe accidents (y = 2):

$$RRR_2 = \exp(-\beta_{2;0} + \beta_{2;1}VOSIG - \beta_{2;2}VOBR + \beta_{2;3}SIRPP + \beta_{2;4}MBRZ + \beta_{2;5}EXPO - \beta_{2;6}BRKOLB + \beta_{2;7}KATPRM) \quad (5)$$

$$RRR_2^p = \exp(-5.55 + 0.65 \cdot 1 - 1.93 \cdot 0 + 1.2 \cdot 1 + 0.12 \cdot 8 + 0.05 \cdot 12 - 0.36 \cdot 0 + 0.74 \cdot 1) = 0.245 \quad (6)$$

$$RRR_2^n = \exp(-5.55 + 0.65 \cdot 0 - 1.93 \cdot 0 + 1.2 \cdot 1 + 0.12 \cdot 8 + 0.05 \cdot 12 - 0.36 \cdot 0 + 0.74 \cdot 1) = 0.129 \quad (7)$$

$$AMF_{ijm} = \frac{RRR_2^n}{RRR_2^p} = \frac{exp(0)}{exp(\beta_{2;1} \cdot 1)} = exp(-\beta_{2;1}) = exp(-0.65) = 0.52 \quad (8)$$

where:

$RRR_2^p -$ ratio of the probability $y = 0$ and $y = 2$ before introduction 2-quadrant gates,

$RRR_2^n -$ ratio of the probability $y = 0$ and $y = 2$ after introduction 2-quadrant gates,

$AMF_{ijm} -$ the expected reduction of more severe accident on particular crossing i for given countermeasure j from the model Accident Severity m.

As a result, according to Accident Severity model, it can be expected 48% reduction of more severe accidents after the upgrading crossings from signs to 2-quadrant gates.

2.1.2. Assessing the effectiveness of selected countermeasure according Accident Frequency model

In this section upgrading warning devices from signs to 2-quadrant gates countermeasure at a particular crossing are considered, according to Accident Frequency model.

First, accident number probability at particular crossing is calculated before the introduction of measures.

The following steps are developed:

Step 1: Calculate expected number of accidents on particular crossing, according to ZIP model, before introducing measure:

$$\lambda_i = exp(-1.668 + 1 \cdot 0.984 - 0 \cdot -1.394 - 0 \cdot 0.530 + 12 \cdot 0.020 + 8 \cdot 0.122 - 0 \cdot 0.370 - 1 \cdot 0.228 + 0 \cdot 0.188) = 0.40 \quad (9)$$

$$p_i = exp(-1.159 + 1 \cdot 2.012 - 0 \cdot 0.579 - 0 \cdot 22.4 - 12 \cdot 0.0578 + 8 \cdot 0.0776 + 0 \cdot 0.462 - 1 \cdot 3.860 + 0 \cdot 3.771) = 0.049 \quad (10)$$

According to: $N_{pijk} = (1 - p_i)\lambda_i = (1 - 0.049)0.4 = 0.38$ (11)

where:

$\lambda_i -$ the expected probability of accidents on crossing i before introducing measure, according to count model,
$p_i -$ the expected probability of accidents on crossing i before introducing measure, according to zero model,

$N_{pijk} -$ number of assesment accident on crossing i before introducing j, for model k.

Step 2: Calculate expected number of accidents on particular crossing, according to ZIP model, after introducing measure:

$$\lambda_i = exp(-1.668 + 0 \cdot 0.984 - 0 \cdot -1.394 - 0 \cdot 530 + 12 \cdot 0.020 + 8 \cdot 0.122 - 0 \cdot 0.370 - 1 \cdot 0.228 + 0 \cdot 0.188) = 0.150 \quad (12)$$

$$p_i = exp(-1.159 + 0 \cdot 2.012 - 0 \cdot 0.579 - 0 \cdot 22.4 - 12 \cdot 0.0578 + 8 \cdot 0.0776 + 0 \cdot 0.462 - 1 \cdot 3.860 + 0 \cdot 3.771) = 0.0061 \quad (13)$$

$$N_{nijk} = (1 - 0.00661) \cdot 0.150 = 0.149 \quad (14)$$

where:

$\lambda_i -$ the expected probability of accidents on crossing i after introducing measure, according to count model,

$p_i -$ the expected probability of accidents on crossing i after introducing measure, according to zero model,

$N_{nijk} -$ number of assesment accident on crossing i after introducing measure j, for model k.

Step 3: Calculate AMF according to number of assesment accident on crossing i before and after introducing measure j, for model k:

$$AMF_{ijk} = \frac{N_{nijk}}{N_{pijk}} = \frac{0.149}{0.38} = 0.392 \quad (15)$$

where:

$AMF_{ijk} -$ the expected reduction in number of accident on particular crossing i for given countermeasure j from the model Accident Frequency k.

As a result, according to Accident Frequency model, it can be expected 60.8 % reduction in accidents after the upgrading crossings from signs to 2-quadrant gates

3. CONCLUSION

In this paper numerical examples are provided to evaluate countermeasure at selected crossings in Serbia. This application demonstrates how the proposed model of Accident Severity and Accident Frequency can be used to assess the effects of the measures that would be used for a particular crossings.

Upgrading warning devices from signs to 2-quadrant gates countermeasure at a particular crossing are considered. As a result, according to Accident Severity model, it can be expected 74 % reduction of less severe and 48% reduction of more severe accidents after the upgrading crossings from signs to 2-quadrant gates. According to Accident Frequency model, it can be expected 60.8 % reduction in number of accidents after the upgrading crossings from signs to 2-quadrant gates.

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