A Safety Level Index for Grade Crossings

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Abstract

Grade crossings are crossings of road and railroad. The choice of the improvement to be implemented in each situation depends on the conditions of the place, based in parameters that influence the safety of each passage. In this work based on a widely used indicator, the Weighted Factor of Accidents (WFA), related to the number of accidents in the grade crossing, and on a Critical Index (CI) recently developed and related to the physical and operational characteristics of the PN, it is proposed a Safety Level (SL) for grade crossings. This indicator aims to measure the degree of risk of a crossing, prioritize the maintenance according to the criticality and that the risk will be properly treated.

1. Introduction

The search for safety in railways is related to the improvement of physical and operational conditions of grade crossings. These include the intersection of two transportation modes , road and rail, and account for different factors, points to high risks of accidents, depending on the traffic in both systems and their location.

Many factors can contribute to accidents in level crossings. Physical factors, related to the area of the crossing, operational factors of the road and railroad traffic and human factors, related to the way that drivers and pedestrians react to these conditions.

Physical improvements must be made to provide safer conditions in grade crossings, but in Brazil there is a large number of crossings and the resources to treat all at the same time are scare. Thus, it becomes necessary to establish a priority for action related to the risk of accident and the physical conditions of them. In this paper, based on a widely used indicator, the Weighted Factor of Accidents (WFA), related to the number of accidents on grade crossings, and the Critical Index (CI), recently developed and related to the physical and operational characteristics of the crossings, it is proposed a procedure to analyze the safety level of grade crossings, including the propose of Safety Level (SL) for level crossings. This indicator aims to measure the degree of risk of crossings, prioritize maintenance due to the criticality and ensure that the risk will be properly treated.

Therefore, in this paper, based on existing indicators, a Safety Level Index is proposed which seeks to quantify the degree of risk of grade crossings, prioritizes in hazardous level and ensures that risks are successfully managed. This proposed index was applied and its application shows that is possible to establish a program to improve the crossing grade in order to minimize the hazardous level in the railroad and consequently diminish the cost derived from the accidents in these intersection places.

So, the second section of this paper presents a description of the indicators mentioned above (CI and WPA) and the third section presents the Safety Level Index (SLI) proposed. An analysis procedure is presented in the fourth section, including these indicators, and a situation of use in the fifth section.

2. Grade Crossing Analysis Indicators

Carmo et al. (2007) proposed the Critical Index (CI) that uses the basic principles of two known indicators: the Degree of Importance (DI), specified by Brazilian rule NB1238 (1989), and the Moment of Circulation (K) defined by the NB 666 (1989).

The Critical Index (CI) is an indicator set from an analysis of risk parameters and those that comprise the indicators Degree of Importance and Moment of Circulation in order to better define the protection indicated based on actual conditions of the crossing. Thus, the proposal Critical Index (CI) was to use the strengths of these two indicators with some changes, especially regarding the inclusion of parameters not considered. Equation 1 defines the CI:

$$CI = f\left(V_D \times T_D + 1{,}4 V_N \times T_N\right) \qquad (1)$$

Where:
V_D = Number of road vehicles during the day
T_D = Number of road vehicles during the night
V_N = Number of trains during the day
T_N = Number of trains during the night

The factor f represents the physical conditions of the grade crossing as used in the Degree of Importance, however with few changes, as can be seen in Table 1.

Another important indicator is the Weighed Factor of Accidents (WFA) defined by the NB 1239, used to calculate the potential risk of a level crossing based on the number of accidents in the last 5 years, according to the following formula:

$$WFA_5 = 9{,}5M + 3{,}5F + D \qquad (2)$$

Where:
WFA_5 – Weighed Factor of Accidents based on the number of accidents in the last 5 years
M = Number of accidents with death, in the last 5 years.
F = Number of accidents with wounded, in the last 5 years.
D = Number of accidents with material damage, in the last 5 years.

In accordance to the Brazilian Manual of Hi-Rail Crossings (1979), WFA_5 represents the intensity and the severity of the accidents in the grade crossings during the last 5 years. A crossing with high WFA_5 means a potential danger and, consequently, requires a more complete and efficient improvement.

Table 1 - Form factor calculation f with new parameters and weights evaluated

Crossing Characteristics			Value	Weight of Importance	Final Value (2x3)
1			2	3	4
01	Visibility	above 300m	2	10	
02		(150 a 300)m	3		
03		below 150m	4		
04	Maximum slope of road approach	below 3%	2	7	
05		(3 a 5)%	3		
06		above 5%	4		
07	Authorized maximum speed in the railroad	below 40km/h	2	7	
08		(40 a 80)km/h	3		
09		above 80km/h	4		
10	Number of railway lines	one line	2	6	
11		two lines	3		
12		three or more	4		
13	Authorized maximum speed in the roads	below 50km/h	2	5	
14		(50 a 80)km/h	3		
15		above 80km/h	4		
25	Transit of Pedestrians	up to 5%	2	2	
26		(5 a 20)%	3		
27		above 20%	4		
28	Number of Lines	one line	2	5	
29		two lines	3		
30		three or more	4		
31	Conditions of the Pavement	Inexistent	2	4	
32		Not Regular	3		
33		Regular	4		
34	Illumination	Inexistent	2	4	
35		Insufficient	3		
36		Efficient	4		
37	Total				

The values of the WFA_5 expected in typical conditions can be determined by the analysis of the accidents occurred in a crossing with similar characteristics. If such analysis can't be made, generic values of Weighed Factor of Accidents (WFA_T), in the last 5 years, in typical conditions, are presented in Table 2.

Table 2 – Values of Weighed Factor of Accidents
Source: Adapted from Brazilian Manual of Hi-Rail Crossings (1979)

<table>
<tr><td colspan="3"></td><td>WFA_T</td></tr>
<tr><td rowspan="9">Grade Crossings in:</td><td rowspan="4">Urban Areas</td><td>Expressways</td><td>20</td></tr>
<tr><td>Arterial roads</td><td>17</td></tr>
<tr><td>Collector roads</td><td>14</td></tr>
<tr><td>Local roads</td><td>10</td></tr>
<tr><td rowspan="5">Rural Areas</td><td>Class 0 roads</td><td>15</td></tr>
<tr><td>Class I roads</td><td>13</td></tr>
<tr><td>Class II roads</td><td>10</td></tr>
<tr><td>Class III roads</td><td>7</td></tr>
<tr><td>Class IV roads</td><td>5</td></tr>
</table>

By comparing the WFA calculated for the last 5 years with the typical for similar crossings, it can be concluded if the GC has a high WFA, and might require improvements. That is, if

$$WFA_5 > WFAT$$

the grade crossing has a high WFA, and consequently, it has a more dangerous condition than the expected for a typical condition, requiring, then, immediate intervention for improvements.

3. Safety Level

The proposal for a security indicator aims to set a priority for action between the existing grade crossings in a railroad. To this end, it was considered the importance of two indicators described above: CI and WFA. With the first indicator (CI), as mentioned, it is possible to establish a priority for action based on physical and operational characteristics of the crossing to increase safety. With the second, it is possible to establish a priority of action depending on the risk of accidents in each crossing. Thus, it is proposed an indicator called Safety Level (SLI), as shown in equation 3:

$$SLI_i = CI_i / 10000 + 1{,}5 WFA_5 \quad (3)$$

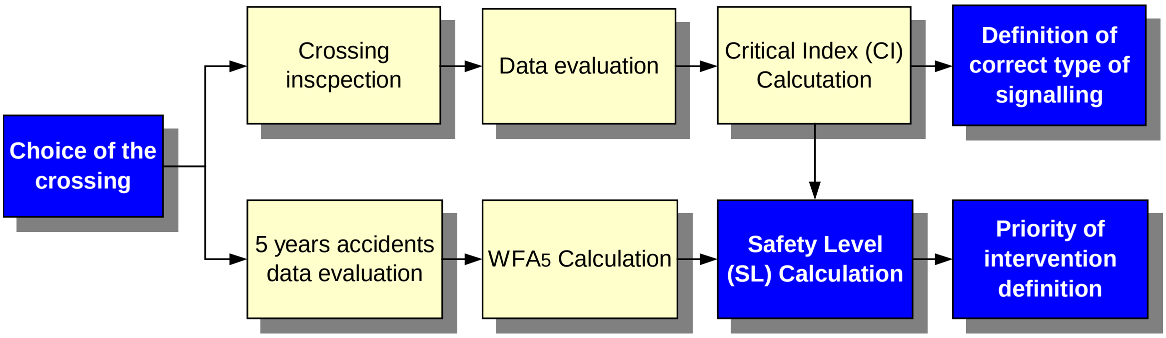
The CI unit is transformed to a value with magnitude on the WFA. In relation to the costs of accidents and their consequences attributed to the Weighted Factor of Accidents (WFA) a 50% greater weight.

The Safety Level, as can be seen, establishes a priority order for action contemplating two important indicators of physical and operational analysis of a crossing. Establish a priority for action is important if you do not have sufficient resources to act on all crossings at the same time.

4. Analysis Procedure

To use the Safety Level (SL) in decision-making a basic procedure of analysis is proposed. The flow diagram in Figure 1 illustrates the "step by step" procedure for applying the proposed method and decision-making regarding the type of protection for each crossing.

Figure 1 – Procedure of Grade Crossings Analysis



All crossings of the railway under study must be evaluated for implementation of the Critical Index (CI). The first step is a physical assessment of each crossing. Based on this inspection, it is possible to obtain all the data of flows of vehicles and trains that pass by the road-rail crossing, beyond the physical parameters that are considered to calculate the factor *f*.

These data are evaluated and with them the Critical Index (CI) will be calcutated(Equation 1). With the result, the Tables 3 and 4 are used to choose the type of signaling must be installed on the level crossing. The values of each class road on the tables 3 and 4 define the phisycal iimprovements and equipment to be implemented on the analyzed crossings.

Table 3 – Improvement proposals in function of the Moment of Circulation for a grade crossing (GC) in rural area

Source: Adapted from Brazilian Manual of Hi-Rail Crossings (1979)

		HIGHWAY CLASS				
	K - (10^3)	**Class 0**	**Class I**	**Class II**	**Class III**	**Class IV**
Without electric energy	0 - 5	For this type of way GC is not allowed. In case that this happens, it is necessary to protect it with cancels until the PN can be separate with passage in unevenness.	1b	1b	1a	1a
	5 - 25		2b	2b	2a	2a
	25 - 50		2c	2c	2a	2a
	50		2d	2d	2c	2b
With electric energy	0 - 5		1b	1b	1a	1a
	5 - 25		3b or 4	3b or 4	2a	2a
	25 - 50		3c	3b or 4	3b	3b
	50		5	5	3e	3e

Weighted Factor of Accidents (WFA_5) should also be calculated for all level crossings of the railway.

With the outcome of the index and Critical Factor Weighted Accidents it is possible to calculate the Safety Level (SL) of the grade crossings analyzed. The results found for SL should be placed in descending order, ie the crossing that has the highest SL should be considered the most critical and thus the crossings will be prioritized to receive interventions. The method is more objective because it considers all factors related to safety in road-rail crossings.

Table 4 – Improvement proposals in function of the Moment of Circulation for a grade crossing (GC) in urban area
Source: Adapted from Brazilian Manual of Hi-Rail Crossings (1979)

			Way Classification			
	K - (10^3)	**Pedestrian Necessity**	**Express Ways**	**Arterial Ways**	**Collecting Ways**	**Local Ways**
Without electric energy	0 - 10		For this type of way GC is not allowed. In case that this happens, it is necessary to protect it with cancels until the PN can be separate with passage in unevenness.	1b	1b	1a
	10 - 50			2c	1b	1a
	50 - 100			2c	2c	2a
	> 100			2d	2c	2b
With electric energy	0 - 10	Low		1b	1b	1a
		High		3a	3a	3a
	10 - 50	Low		3b	3b	2c
		High		4	4	3c
	50 - 100	Low		4	4	3c
		High		4	4	3d
	> 100	Low		5	5	3e
		High		5	5	3f

5. Applications

The proposed method was applied to 10 level crossings of a railway. The results are presented in Table 5.

Table 5 – Safety Level Evaluation

Crossing	CI	WFA5	SL	Recomendation	Priority
01	459.964,68	5,00	468,21	Tipo 5	1ª
02	331.946,72	22,00	364,95	Tipo 5	3ª
03	189.501,39	14,00	210,50	Tipo 3f	4ª
04	148.079,56	7,00	158,58	Tipo 3f	5ª
05	86.000,24	1,00	87,50	Tipo 3d	8ª
06	56.724,30	11,00	73,22	Tipo 4	9ª
07	52.754,56	2,00	55,75	Tipo 4	10ª
08	427.913,02	22,00	460,91	Tipo 5	2ª
09	151.177,92	3,50	156,43	Tipo 3f	6ª
10	81.761,80	22,00	114,76	Tipo 4	7ª

After calculating the Safety Level the grade crossings with the highest Critical Index were prioritized over others. In crossings with similar value of CI the Weighted Factor Accident was decisive for prioritization, as can be seen in the case of crossings 5 and 10.

The evaluation of grade crossings by the Safety Level method allows prioritizing the services to be performed, which means that maintenance can be scheduled depending on the criticality of each site.

6. Conclusions

To reduce the number of incidents and increase the level of safety provided to users of road-rail crossings, it is necessary to make physical improvements in the area of the crossing, such as proper signage. For this, we use an index to evaluate the physical characteristics of the area with a view to determining the type of improvement to be implemented in each crossing. The Critical Index (CI) is a method that leverages the strengths of key indicators found in Brazilian standards and considers all aspects related to the physical safety of a crossing. Using the IC determines the most appropriate type of signaling for each one.

By calculating the WFA_5 and CI it is possible to calculate the Safety Level and the grade crossings can be prioritized for maintenance. Crossings will be sorted in descending order and interventions can be planned depending on the criticality of each.

The use of SL allows a more objective way to identify the problem to be addressed at grade crossings, seeking a reduction in accidents and consequently a reduction in costs. The choice of appropriate signals will also help the costs reduction.

REFERENCES

ABNT – Associação Brasileira de Normas Técnicas – NB 1238, (1989) **Determinação do grau de importância da travessia rodoviária através de via férrea**, Norma Brasileira.

ABNT – Associação Brasileira de Normas Técnicas – NB-1239, (1989) **Determinação do fator ponderado de acidentes de travessia rodoviária em passagem de nível através de via férrea**, Norma Brasileira.

ABNT – Associação Brasileira de Normas Técnicas – NB-666, (1989) **Via férrea – Travessia rodoviária – Momento de Circulação**, Norma Brasileira.

ABNT – Associação Brasileira de Normas Técnicas – NB-114, (1979) **Passagem de Nível Pública**, Norma Brasileira.

Carmo, R. C., Campos V.B.G., Guimarães J.E.(2007) **Method for Evaluation of Grade Crossings**, IHHA, Kiruna, Sweden .

Rio de Janeiro, RJ. Colleman III, Fred; Eck, Ronald W.; Russel, Eugene R., **Railroad-Highway Grade Crossings A Look Forward**.

Departamento Nacional de Trânsito (DENATRAN), (1987) **Manual de Cruzamentos Rodoferroviários***,* Coleção Serviços de Engenharia*,* 2ª edição, Brasília, DF.

Rede Ferroviária Federal S.A., (1986) **Passagem de Nível – Concessão, Projeto, Manutenção, N-DSE-017**, Rio de Janeiro, RJ.

Rede Ferroviária Federal S.A., (1986) **Passagem de Nível – Cadastro, N-DSE-018**, Rio de Janeiro, RJ.

Revista Ferroviária, Ano 67, (2006) **"Brasil tem 2.503 passagens em nível críticas",** páginas 18 e 19, Abril.

Revista Ferroviária, Ano 70, (2009) **"Melhor Operadora de Carga"**, página 22, Abril.

U.S. Department of Transportation (USDT), (2002), **Guidance on Traffic Control Devices at Highway-rail Grade Crossings**, November.

U.S. Department of Transportation (USDT), (1986), **Railroad-Highway Grade Crossing Handbook**, 2nd edition, September.