Study on Safety of Philippine National Railways Grade Crossings

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Abstract: The Philippine National Railways has been back in operation after a long history of degradation and rehabilitation. In assessing its safety, accidents at the grade crossings should be analyzed since it is the weak point of a railway. This study aims to determine the crossing characteristics that contribute to level crossing accidents and propose mitigating procedures. Each railway crossing was evaluated based on their existing characteristics namely: type of crossing, type of barrier, warning device, and the vehicle traffic volume. Using hazard indices, each characteristic was evaluated individually. Two-way crossing has higher hazard index compared to one-way crossing, full barriers also exhibited higher hazard compared to half barriers. In the case of warning device, crossings with two different sets of warning device on each direction have exhibited the highest hazard index and 30-40 thousand for the vehicle traffic volume. Using the chi-squared test, two combinations of characteristics passed the test. These are vehicle volume traffic presented in AADT versus Barrier Type and Alarm Device Type versus Crossing Type. An assessment of all the characteristics for specific crossings was also made to evaluate the hazard index of a specific crossing.

Keywords: railway safety, railway crossing, hazard index

1. INTRODUCTION

1.1 Background

The Philippines consists of many inter-urban and intra-urban rail systems. One of which is the Philippine National Railways, an intra-island railway on Luzon. Since the laying of its first track as Manila-Dagupan Ferrocaril line, PNR had been running for more than 120 years.

Throughout its history, PNR has constructed five railway lines connecting Metro Manila and the rest of Luzon, notably the Main Line North, running from Manila to San Fernando City, La Union Province, Main Line South, from Manila to Legaspi City, Albay Province, San Jose Branch Line, from Tarlac to San Jose, Nueva Ecija, Cabanatuan Branch Line, from Calamba to Batangas, and Santa Cruz Branch Line, from College to Sta. Cruz, Laguna. Today, only the Commuter Service from Manila to Laguna route remains operational, also referred as Orange line. The Main Line South is also soon to resume operations.

Since the Basic railway structure of PNR was built more than 80 years ago, almost all railroad crossings are at-grade. From Tutuban to Alabang, there exists 40 railroad crossing and more than 400 between Manila and Legazpi.

1.2 Statement of the Problem

Regarding railway safety, grade crossings are considered to be a system's weak point (Silmon and Roberts, 2009), thus, in assessing safety of PNR, it is significant to evaluate its grade crossings which can be done by analyzing accidents and the crossing's present conditions and recommend necessary tools that can be used in future assessment.

1.3 Objectives

This study aims to (a) to determine the percentage of accidents in the crossing to the total accidents in PNR, (b) to determine the characteristics of a crossing affecting its safety and (c) to propose mitigating procedures for railroad crossing safety's improvement.

1.4 Significance of the Study

In sustaining economic growth in the Philippines, there is a need for continuous improvement of mobility across the country by means of an efficient and dependable mass transit infrastructure (Abaya, 2013). It is therefore significant for PNR, being one of the major railway systems in the Philippines, to be a part of this development. To facilitate this, a study regarding PNR grade crossings should be conducted.

1.5 Scope and Limitations

The scope of this study is the safety of PNR's grade crossing within the Commuter Line. Grade crossings that were evaluated are those between Tutuban to Alabang namely Tayuman, Yuseco, Abad Santos, T. Mapua, Avenida, Leonor Rivera, Simoun, Maria Clara, Laong-Laan, Dapitan, P. Margal, P Florentino, España, Lepanto, Lealtad, Honradez, G. Tuazon, Magsaysay-1, Magsaysay-2, Teresa, Beata, Inviernes, Kahilom, Pedro Gil, San Andres, Vito Cruz, Zobel Roxas, Malugay, Buendia, Dela Rosa, Pasay Road, Don Bosco, Nichols, Bicutan, Tanyag, Posadas, Sucat, Concepcion, Buli and Alabang. Data on vehicle collision accidents were used is from year 2010 to August of 2013.

1.6 Study Flow

Literatures regarding railway systems and grade crossings evaluation were gathered and reviewed for this study. Upon having sufficient information about the subject, technical information and records of accidents and crossing characteristics of PNR were obtained. These data were used in the analysis and assessments of level crossings.

2. LITERATURE REVIEW

2.1 Level Crossing

Several studies were made about level crossing since they are considered a weak point in terms of railway safety mainly because it is dependent on the large extent of correct behavior of the road or the foothpath users (Silmon and Roberts, 2009). In relation to this, crossings are vulnerable to different hazards such as collisions between trains, pedestrians, warning devices, and road vehicles. According to Read, Salmon and Lenne (2013), collisions at railway crossings are an international safety concern and have been the focus of considerable research effort. Some studies have come into conclusion that the cause of accidents come from driver behavior. In order to help alleviate future accidents from happening, researches such as evaluating existing warning devices and their effect on driver's behavior and analysis of different elements that contribute to driver's behavior like situation awareness and decision making.

2.2 Types of Crossings

Evans (2011) investigated fatal accidents and fatalities at level crossings in Great Britain from 1946 to 2009. A slow improvement or minimal improvement is the main reason why level crossings were taken into consideration. Level crossings were classified into railway-controlled, automatic and passive. Assuming a Poisson-distributed accident data, a model was made with the use of logarithmic-linear models. Safety performance of each type of level crossing was evaluated and found to be different from each other with the railway-controlled as the best-performing crossing type. Railway-controlled crossing was recognized as the best-performing crossing type since it has falling fatal accident rates. Automatic crossings have higher accidents rates but low in cost and delay. Although passive crossings are dominant in number, the fatal accident rate remained constant since it has low usage by road users.

2.3 Evaluation of Crossing Characteristics

Gitelman and Hakkert (1996) evaluated road-rail crossing safety in Israel to determine the level-crossings that needs to undergo grade separation. Due to the limited volume of accident statistics, the unification of available statistics over the period of six years was used. The crossing characteristics that were selected for handling crossing accidents are warning device category, volume of vehicle traffic, volume of train traffic, and visibility conditions. These characteristics were chosen based on the consideration that these features are presented in safety models of other studies and they indirectly reflect other characteristics of crossings such as number of road lanes and type of road. Individual hazard indices were made for each characteristic. Then using chi-squared method, different characteristics were check if they are mutually exclusive from each other. Pairs of characteristics that passed the test were evaluated in order to create hazard indices. The results of the test were validated with the use of T-estimator which assumes that the data used in the study follows Poisson distribution.

2.4 Level Crossing Hazards

Collisions at rail level crossings are an international safety concern (Lenne et al., 2013). Different studies were made based on level crossings since it has higher hazard in the railway system. Silmon and Roberts (2009) analyzed relationship between existing level crossing functions and new retrofitted systems. There were four enumerated main hazards at a level crossing which are collisions between trains and road vehicles; collisions between trains and pedestrians; collisions between road vehicles and road equipments; slips, trips and fall by pedestrians; and collisions between pedestrians and level crossing equipments. Knowing that road vehicle driver behavior is accounted for most road-rail vehicle collisions, efforts have been made in warning drivers of the dangers of level crossing. For the case of this study, a new technology for detection of obstruction in level crossings will be installed to the originally designed automatic half-barrier crossings. Half-barrier crossing were designed to minimize the time the road is closed which leads to improving flow of road traffic. Using functional analysis, it was concluded that improvement in safety performance may not justify the expense of installing new technology for the detection of obstruction of level crossings. On the other hand, Wullems (2011) analyzed the main problems for the adoption of low-cost level crossing warning devices (LCLCWDs) in Australia. The study tackles major obstacles for the adoption of LCLCWDs such as legal and reliability issues.

Based on the study of Salmon et al., (2012), they were able to concluded that novice and experienced drivers experience the same crossings differently. The study about on-road approach for evaluating driver situation awareness at level crossings was made with the knowledge that crashes between cars and trains at level crossings are existing worldwide problems. Focusing on situation awareness in a level crossing, a network analysis-based approach was used in modeling the driver's situation awareness. On a separate study by Read et al., (2013), the extent to which systems approach was implemented was determined by making a structured review of literature of level crossings. Based on the parameters such as the type of analysis used, number of component relationships, user groups and system levels considered and the type of model utilized on several studies, it was concluded that none of the research reviewed coincides with the systems approach. It was recommended that in order to propose an effective design improvement, future researches should make use of a system approach to the study of the level crossings.

3. METHODOLOGY

3.1 Data Collection

To begin with the research, the information learned from the review of literature was use in the familiarization with the topic and the method to be used. Once a method was chosen, all necessary data needed were identified. The Philippine National Railways was the main source of the data. All technical information of the level crossings was obtained from the Manila Division I Engineering Office. Data on the train accidents and level crossings was acquired from the Transportation Office.

The data for train accidents on was obtained from the PNR. The data covers the number of accidents from 1995 to 2013. A summary of train accidents from 1995 to 2010 contains the data on the type of accident such as derailment, sideswiping, level crossing and stoning per year. A record of the details of the train accidents from 2011 to 2013 includes information on the vehicular and pedestrian related accidents and more types of accidents were added such as pick pocketing and door pinning. Aside from the summary of train accidents, accidents on level crossings from 1995-2013 were also obtained. Level crossing accidents recorded from 2010 to 2013 have details regarding the date, location, and the details of the accident while the record prior to 2011 is composed of total number of accidents per year.

Information on the names of crossings with details on the width of the crossing, date of construction, type of crossing (one-way or two-way), type of barrier (half or full) (Figure 1), warning device (Type A or Type B) (Figure 2) and classification of the road (national road, city road, municipal road, barangay road or private road). A PNR diamond clearance for level crossings which is the guideline for the area that should be cleared from obstruction for visibility was also given by PNR.

The data on the road traffic volume on the level crossings of the PNR commuter lines was attained from the annual average daily traffic which was taken from the Department of Public Works and Highways' atlas. Since the name of the crossings originated from the roads intersecting the PNR railway, the exact locations were pinpointed with the assistance of Google Maps.

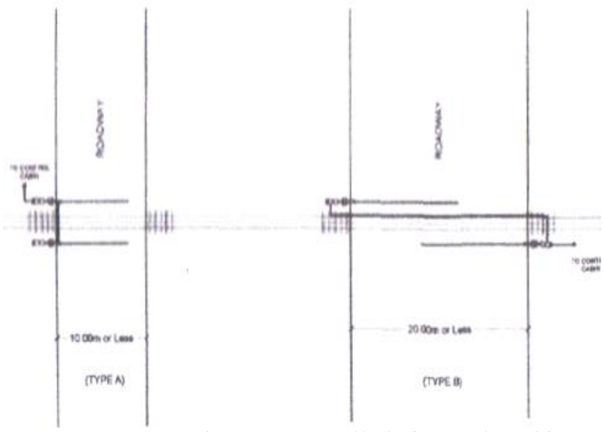


Figure 1. Type of Barrier: Full (left) and Half (right)

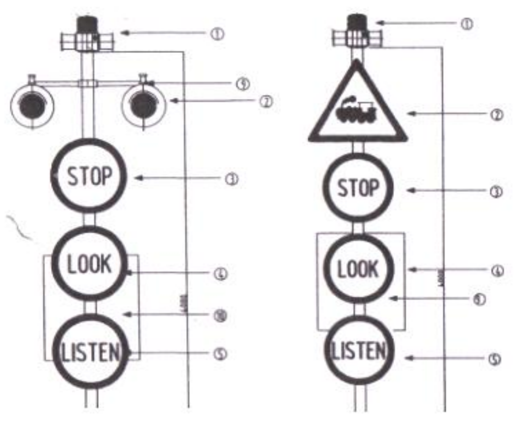


Figure 2. Warning Device: Type A (left) and Type B (right)

3.2 Method of Analysis

The collected data from PNR and other necessary information for the implementation of this study was compiled and summarized using Microsoft Excel. The data analysis ranges from 2010 to 2013 since the data recorded on these years contain the necessary details for the application of this study's method. Before beginning with the analysis of level crossing accidents, it is crucial to establish the necessity of the analysis by illustrating that indeed, the level crossings are the part of the PNR railway system that needs more research and focus. For this study, the researchers tabulated the number of accidents per year and compared the different kinds of accidents to the accidents on level crossings. Pie charts and line graphs were used to represent all the necessary figures.

The crossings were categorized based on different characteristics namely: type of crossing, type of barrier, warning device and road traffic volume. The characteristics such as warning device and road traffic volume were chosen since they are widely used in creating safety models for railways. The same characteristics were also chosen by Gitelman and Hakkert (1996) on their study. Furthermore, the type of barrier and type of crossing were also considered since they are possible features that are different from each crossing and it may contribute to the vulnerability of the crossing to accidents. Another crossing characteristic indicating if the crossing observed the diamond clearance was also considered as a category for the crossings since they indirectly reflect the geometry of the crossing; however, all crossings failed to follow the diamond clearance based on the study of Paragas and Reñeses (2012). The researchers determined which subgroup under each characteristic is deemed safer or has lesser hazard based on practical applications and related literature. Information on the applications and related literature were aided with histograms and bar graphs to observe obvious relationships from the raw data. Results of this analysis were used to verify the results obtained from statistical analysis. After classifying crossings based on the identified characteristics, the number of accidents including the severity of the accident whether there is an injury or fatality were associated with their corresponding crossings. Since the data is limited to four years, unification on the total number of crossings was necessary for statistical analysis later on.

Using the hazard indices applied by Gitelman and Hakkert (1996), the characteristics of the crossing were evaluated individually. The hazard index for each characteristic is given by:

$$HI^{A_i} = \frac{u^{A_i}}{v^{A_i}}, i = 1, 2, \ldots k \qquad (1)$$

where

$$\sum_{1}^{k} u^{A_i} = n; \ \sum_{1}^{k} v^{A_i} = N;$$

n: number of accidents
N: number of crossings

Recognizing the fact that each crossing is made up of different characteristics, evaluation of composite characteristics were also made using hazard indices. Before the application of hazard indices, the possible combinations of characteristics were determined using the chi-square test. Combinations that passed the test (α=0.05) and n degrees of freedom were evaluated. Using the formula for composite characteristics of a crossing obtained from the study of Gitelman and Hakkert (1995), the hazard indices were calculated. The hazard index for compound characteristics can be calculated using:

$$HI^{AB_{ij}} = \frac{1}{\left(\frac{n}{N}\right)} [\, HI^{A_i} \cdot HI^{B_j} \,] \qquad (2)$$

where HI^{A_i}: hazard index of characteristic A
HI^{B_j} : hazard index of characteristic B

A crossing is composed of all the characteristics identified. In order to determine the hazard of a specific crossing, all the characteristics were analyzed by applying the formula for hazard index of joint characteristics given by Gitelman and Hakker (1995). For the combination of all characteristics, it can be determined by the formula:

$$HI^{A \ldots L} = \frac{1}{\left(\frac{n}{N}\right)^{l-1}} [\, HI^A \cdot HI^B \ldots \cdot HI^L] \qquad (3)$$

where HI^A: hazard index of characteristic A
HI^B: hazard index of characteristic B
l: number of characteristics
n: number of accidents
N: number of crossings

By carrying out (3) with l = 4, 40 HI values, covering all possible combinations of four crossing characteristics are supplied. However, since not all combinations exist for a particular crossing, some of the combinations can be disregarded. The calculated results were verified based on related literature and practical implications of the crossing characteristics.

4. RESULTS AND DISCUSSION

4.1 Accidents on Level Crossings

The total number of accidents since 1995 shows that derailment is the major source of accidents (Figure 3) followed by level crossing accidents. Considering the yearly record of the accidents (Figure 5), it can be observed that there is an improvement based on number of derailments since 1995; from 152 cases it fell to around 6 to 0 accidents for the past four years. Stoning was not included in the yearly graph since they are not directly caused by the railway system. For level crossings, although there are lower accidents which are around 20-10 accidents from 2006 to 2009, it rose again to around 40 to 20 accidents the following years. This shows that although there is an improvement in the accidents from 2004 to 2009 compared to the records prior to 2004, there is a more or less constant number of accidents from 2010 to 2012. Compared to other railway system, the level crossing of PNR can also be considered as a weak part of its railway.

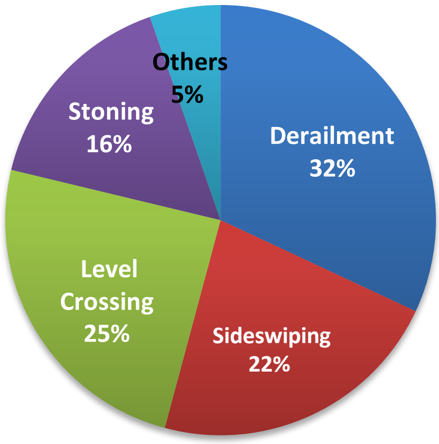


Figure 3. Breakdown of Train Accidents from 1995 to 2013

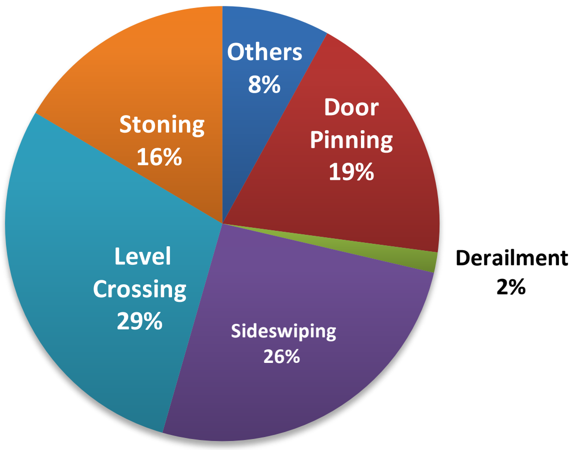


Figure 4. Breakdown of Train Accidents from 2010 to 2013

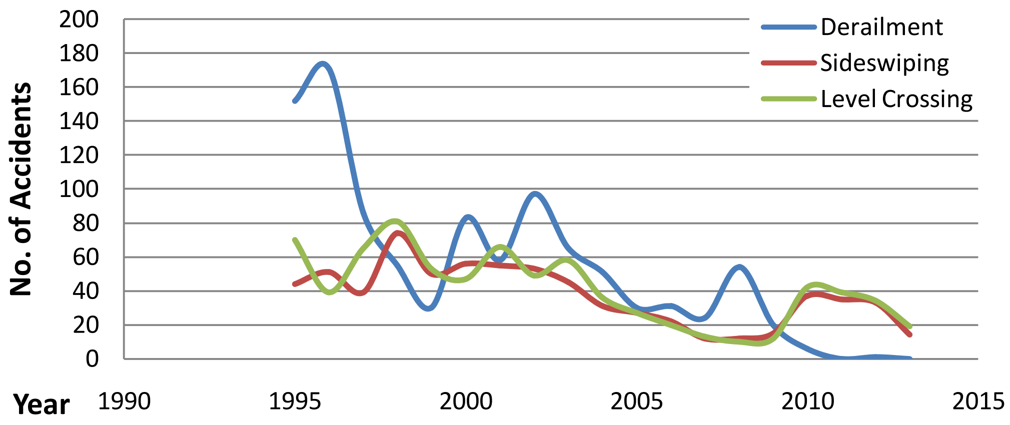


Figure 5. Train Accidents from 1995 to 2013

Given that the accidents recorded from 2010 to 2013 are the only one with details as to the type of accidents and location of level crossings, these were the main data for this study. From 2010 to 2013, accidents on level crossings cover the major part of the totality which is around 29% (Figure 4). Out of 461 accidents, 119 was attributed to the accidents on level crossings while the rest is composed of derailment, door pinning, stoning, sideswiping and other accidents such as mechanical defects.

The main contributor of accidents for the past four years is the level crossing accidents. There is no significant improvement on the data with those years. In order to lessen the susceptibility of level crossings to accidents, different features of a level crossing should be assessed. Therefore, it is necessary to create a model from statistical analysis that can be used as a guide on what to improve on level crossings.

4.2 Injuries and Fatalities

Shown in Figure 6 is the distribution of accidents, injuries and fatalities of each crossing. The most number of accidents occurred in Tayuman with nine followed by Yuesco with seven incidents and Abad Santos, T. Mapua and Avenida which all three have five accidents. In terms of injuries, Abad Santos has most cases of injuries followed by Inviernes and Beata. From 2010 to 2013, there are three fatalities which occurred in Inviernes, Tayuman and Posadas.

4.3 Hazard Indices

Hazard indices for each characteristic were evaluated using equation 1. The value obtained would suggest a relation of the characteristic being evaluated and the occurrence of accidents. The higher the value of the hazard index of a characteristic suggests that a greater possibility that the characteristic contributes to the risk of accidents. It was found that crossings with full barrier has hazard index greater with value 0.69 compared to that of a half barrier with value 0.33. Figure 7 shows the distribution of accidents, crossings and hazard index to barrier type category in percentage.

For alarm device category, the greatest value of hazard index is 1.38 corresponding to crossing with type A alarm device in the north approach and type B in south while lowest value is 0.28 for crossing with type A alarm device in both directions. Hazard indices for crossings with type B in both directions and crossings without alarm device have values 0.73 and 0.40 respectively. Accidents, crossings and hazard indices for each category is shown in Figure 8. However, it should be taken into consideration that the there are two level crossings that has a type A in the north approach and type B in the south. But since a number of accidents occurred on these crossings, a high hazard index was obtained. On the other hand, the main difference between a type A and a type B crossing is an alarm signal lamp. Therefore, the difference between the values of the hazard indices of crossings with type A and type B devices could be due to the existence of the alarm signal lamp.

Hazard indices for one-way and two-way crossings were also evaluated and the computed values are 0.25 and 0.6 with two-way crossings having greater value. Two-way crossings would result to higher hazard compared to one-way crossing because of the nature of the category such as possibilities in overtaking and the capacity of the road which results to a higher number of vehicles. Figure 9 shows the distribution of accidents, crossings and hazard indices in percentage for crossing type.

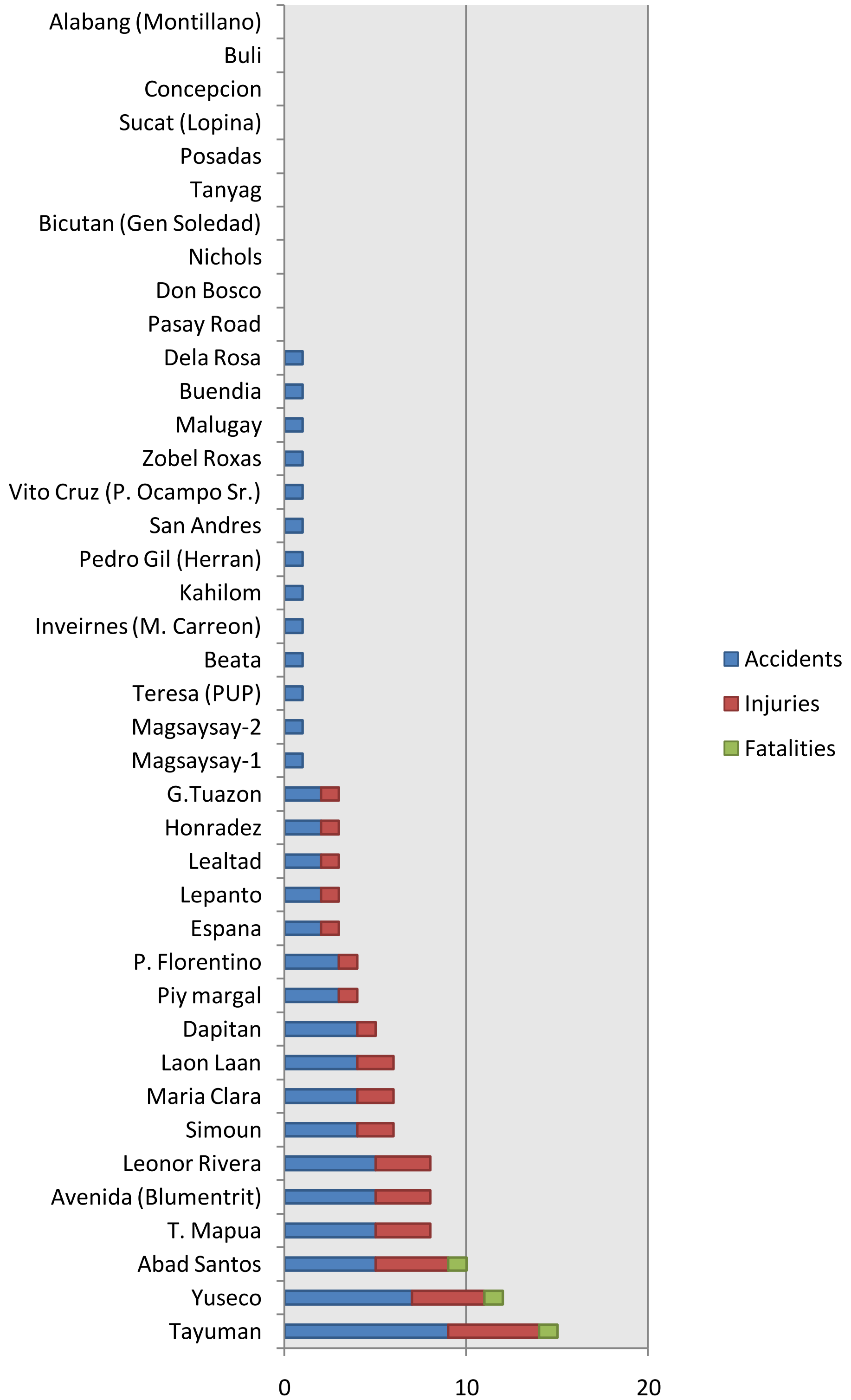


Figure 6. Distribution of Accidents, Injuries and Fatalities for Each Crossing

For the road traffic volume, the category with 30-40 thousand displayed the highest number of accidents. It is expected for the hazard index to increase with increasing annual average daily traffic. However, in this case, the decline of hazard index in the 20-30 thousand and greater than 40 thousand categories was caused by the low accident distribution on the crossings falling on these categories.

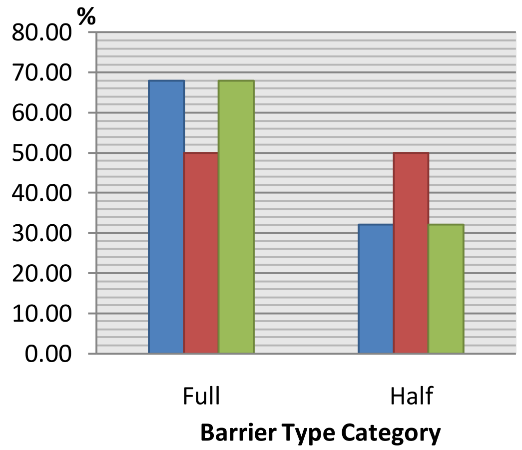


Figure 7. Hazard Index versus Barrier Category

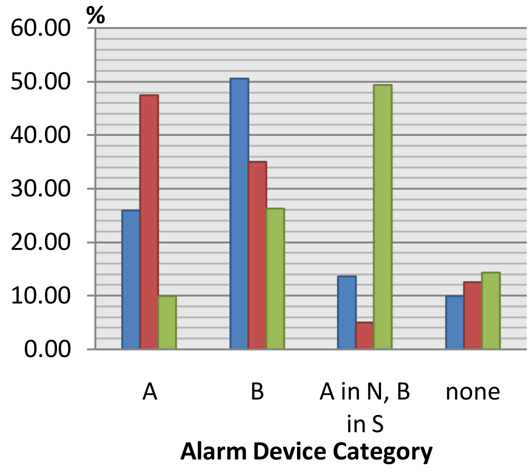


Figure 8. Hazard Index versus Alarm Device Category

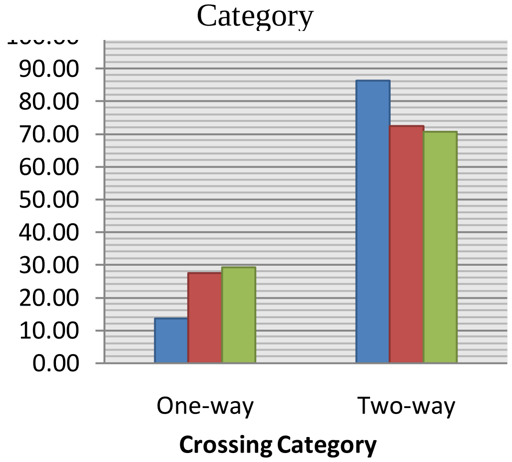


Figure 9. Hazard Index versus Crossing Category

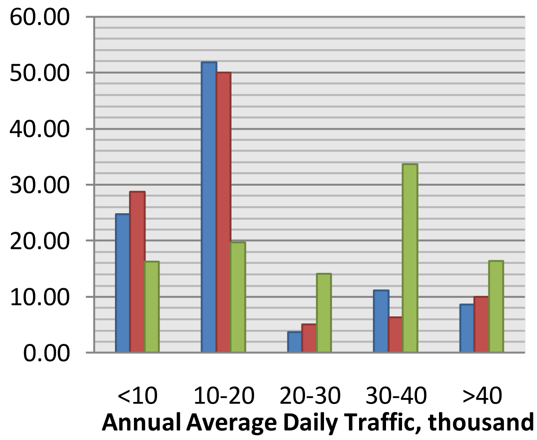
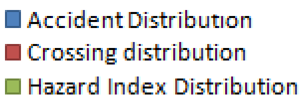


Figure 10. Hazard Index versus Road Traffic Volume



After evaluating hazard indices for single characteristics, dependence of the different categories to each other determined using chi squared test in order to validate approximation for characteristics combination. Computed chi squared value, X^2, for each combination was compared to critical chi squared value, χ^2, for confidence level, $\alpha = 0.05$. Barrier type and road traffic volume were found to be independent with $X^2 = 8.46$. Similarly, crossing type and alarm device type are independent with $X^2 = 5.32$.

Values for composite hazard index for combinations of road traffic volume and barrier category are shown in Table 2. Combination with highest hazard index is that full barrier crossing whose AADT is between 30 and 40 thousand vehicles per day while the lowest value correspond to a crossing with half barrier and AADT between 20-30 thousand. For combinations of alarm device and barrier category, greatest hazard index is that of two-way crossings whose alarm device is type A for North approach and type B for south approach while one-way crossings with type A alarm device attained the lowest value. Values for these combinations are shown in Table 3. Since not all combinations under these categories exist in the crossings, values highlighted in blue indicate that no crossing falls under these combination.

Table 1. Results of Chi Squared Test

	Degrees of Freedom	Critical χ^2 for $\alpha = 0.05$	Computed X^2	Conclusion
Barrier Type vs Crossing Type	1	3.841	5.47	
Barrier Type vs Alarm Device Type	3	7.815	31.35	
Barrier Type vs Traffic Volume	4	9.488	8.46	independent
Crossing Type vs Alarm Device Type	3	7.815	5.32	independent
Crossing Type vs Traffic Volume	4	9.488	10.03	
Alarm Device Type vs Traffic Volume	12	21.026	58.25	

Table 2. Composite Hazard Index for Combinations of Road Traffic Volume and Barrier Category

	Barrier Type	Half	Full
AADT, thousands	**HI**	0.325	0.6875
<10	0.43	0.276	0.583
10-20	0.53	0.333	0.704
20-30	0.38	0.238	0.503
30-40	0.90	0.571	1.207
>40	0.44	0.277	0.587

Table 3. Composite Hazard Index for Combinations of Alarm Device and Barrier Category

	Crossing Type	One-way	Two Way
Alarm Device Type	HI	0.25	0.600
A	0.28	0.135	0.323
B	0.73	0.357	0.857
A in N, B in S	1.38	0.671	1.610
None	0.40	0.195	0.468

Hazard indices considering four characteristics were evaluated using equation 3. Table 3 shows the values for combinations that represents each crossing. Ten crossings with highest values of hazard indices are highlighted. These crossings are Pedro Gil, Leonor Rivera, Abad Santos, Inviernes, Honradez, Alabang, Avenida, Espana, Bicutan, and Tanyag. Seven out of these crossings are part of the ten crossings with highest frequency of accidents for years 2010-2013. Beata and Buendia have two and three accidents respectively.

Table 4. Hazard Index for Combinations of Four Characteristics

Name of Road Crossing	**Hazard Index**				**Multi HI**
	Barrier Type	**Crossing Type**	**Warning Device Type**	**Road Volume Traffic**	
Tayuman	0.688	0.603	0.276	0.525	**0.447**
Yuseco	0.688	0.603	0.276	0.525	**0.447**
Abad Santos	0.688	0.603	0.732	0.900	**2.031**
T. Mapua	0.688	0.603	0.276	0.525	**0.447**
Avenida (Blumentrit)	0.688	0.603	1.375	0.375	**1.589**
Leonor Rivera	0.325	0.603	1.375	0.525	**1.052**
Simoun	0.325	0.603	0.276	0.525	**0.211**
Maria Clara	0.325	0.603	0.276	0.525	**0.211**
Laon Laan	0.325	0.250	0.276	0.525	**0.088**
Dapitan	0.325	0.250	0.276	0.525	**0.088**
Piy margal	0.688	0.603	0.276	0.525	**0.447**
P. Florentino	0.325	0.250	0.276	0.525	**0.088**
Espana	0.688	0.603	0.732	0.438	**0.987**
Lepanto	0.325	0.250	0.276	0.525	**0.088**
Lealtad	0.325	0.250	0.276	0.525	**0.088**
Honradez	0.325	0.603	0.400	0.525	**0.306**
G.Tuazon	0.325	0.603	0.276	0.525	**0.211**
Magsaysay-1	0.325	0.603	0.400	0.525	**0.306**
Magsaysay-2	0.325	0.603	0.400	0.525	**0.306**
Teresa (PUP)	0.325	0.603	0.276	0.525	**0.211**
Beata	0.688	0.603	0.732	0.525	**1.185**
Inveirnes (M. Carreon)	0.688	0.603	0.276	0.525	**0.447**
Kahilom	0.325	0.603	0.276	0.525	**0.211**
Pedro Gil (Herran)	0.688	0.603	0.732	0.525	**1.185**
San Andres	0.688	0.603	0.732	0.525	**1.185**
Vito Cruz (P. Ocampo Sr.)	0.325	0.250	0.276	0.525	**0.088**
Zobel Roxas	0.325	0.250	0.276	0.375	**0.063**
Malugay	0.688	0.603	0.732	0.375	**0.846**
Buendia	0.688	0.603	0.732	0.438	**0.987**
Dela Rosa	0.688	0.250	0.276	0.900	**0.318**
Pasay Road	0.688	0.250	0.732	0.375	**0.351**
Don Bosco	0.688	0.250	0.276	0.375	**0.132**
Nichols	0.325	0.250	0.276	0.525	**0.088**
Bicutan (Gen Soledad)	0.688	0.603	0.276	0.525	**0.447**
Tanyag	0.688	0.603	0.276	0.525	**0.447**
Posadas	0.325	0.603	0.276	0.525	**0.211**
Sucat (Lopina)	0.688	0.603	0.276	0.438	**0.373**
Concepcion	0.325	0.603	0.400	0.525	**0.306**
Buli	0.325	0.603	0.400	0.525	**0.306**
Alabang (Montillano)	0.688	0.603	0.732	0.900	**2.031**

Figure 11 shows the distribution of accidents and hazard indices in percentage for each crossing. A relation between the number of accidents and hazard indices can be observed.

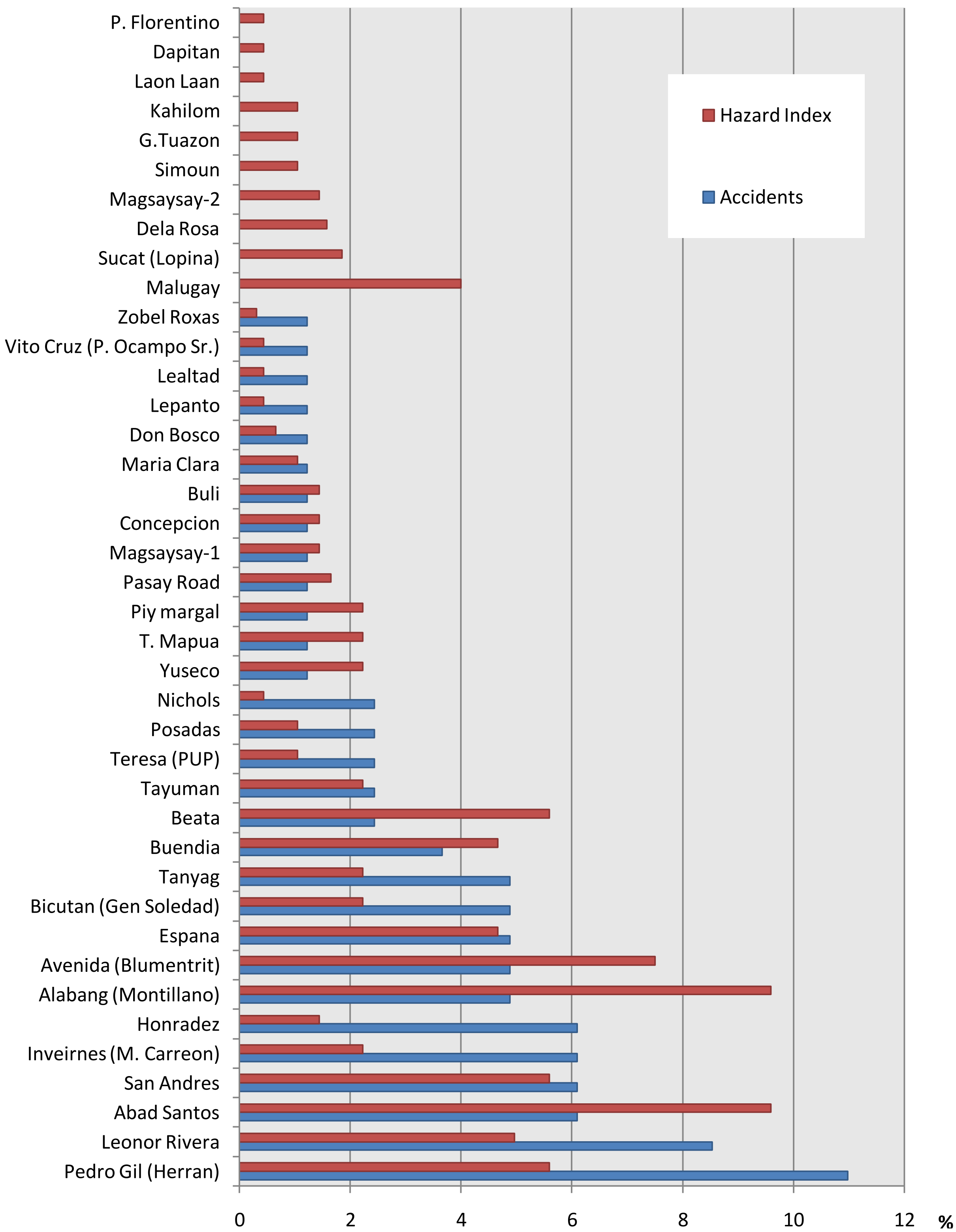


Figure 11. Hazard Index and Accidents for Each Crossing

5. CONCLUSIONS

Based on records from 1995 to 2013, derailments have the highest frequency compared to other types of accidents followed by level crossings. But derailments have significantly decreased over the years while accidents in level crossings have no significant change relative to derailments. Furthermore, breakdown of accidents from 2010 to 2013 shows that accidents on level crossings have the biggest percentage.

Half barriers were found to have smaller hazard index compared to full barrier. The greatest value of hazard index for alarm device category is 1.38 corresponding to crossing with type A alarm device in the north approach and type B in south. Two-way crossings have higher values compared to one-way crossings. Highest hazard index value for road traffic volume is that of crossing with AADT of 30-40 thousand vehicles.

6. RECOMMENDATIONS

Level crossings of the PNR should be assessed and studied. The type of barrier should be evaluated since full barriers denote higher hazard for vehicles and train operations compared to half barrier. Comparing the type of warning devices, installation of alarm signal lamps which is the difference between Type A crossings to Type B should also be considered. Further studies explaining how a certain type of characteristic has higher hazard index compared to other types contribute should also be conducted. Continuous record of the accidents with details should be implemented. A larger set of data will be useful for future studies especially in assessment of the safety in PNR with the use of other procedures.

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REFERENCES

Andrew, E. (2011) Fatal Accidents at railway level crossings in Great Britain 1946-2009. **Accident Analysis & Prevention**, Volume 43, Issue 5, September 2011, Pages 1837-1845.

Cloete, S., Ferreira, L., Tey, L. and Wallis, G. (2013) Modelling driver behaviour towards innovative warning devices at railway level crossings, **Accident Analysis & Prevention**, Volume 51, March 2013, Pages 104-111.

Dong, D., Guo, Y., Li, D. and Wei, Y. (2012) Public Places Safety Management Evaluation of Railway Stations, **Procedia Engineering**, Volume 45, 2012, Pages 240-247.

Katrina, R. and Paragas, L (2012) Assessment of the Philippine National Railway Computer Line Services. University of the Philippines Diliman.

Gitelman, V. and Hakkert, A. (1997) The evaluation of road-rail crossing safety with limited accident statistics, **Accident Analysis & Prevention**, Volume 29, Issue 2, March 1997, Pages 171-179.

Lenné, M., Salmon, P., Walker, G. and Young, K. (2013) An on-road network analysis-based approach to studying driver situation awareness at rail level crossings, **Accident Analysis & Prevention**, Volume 58, September 2013, Pages 195-205.

Lenné, M., Read, G. and Salmon, P. (2013) Sounding the warning bells: The need for a systems approach to understanding behavior at rail level crossings. **Applied Ergonomics**, Volume 44, Issue 5, September 2013, Pages 764-774.

Roberts, C. and Silmon, J. (2010) Using functional analysis to determine the requirements for changes to critical systems: Railway level crossing case study, **Reliability Engineering & System Safety**, Volume 95, Issue 3, March 2010, Pages 216-225.

Philippine National Railways. (2014). *PNR in Philippine History*. Retrieved December 2013, from PNR Official Website: http://www.pnr.gov.ph/history.htm

Wullems, C. (2011) Towards the adoption of low-cost rail level crossing warning devices in regional areas of Australia: A review of current technologies and reliability issues, **Safety Science**, Volume 49, Issues 8–9, October 2011, Pages 1059-1073.