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## DEVELOPMENT OF AN EVACUATION SAFETY INDEX (ESI) FOR PUBLIC SCHOOLS

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**Abstract:** Assessment of a disaster risk reduction management plan for each school is of paramount importance as it is the first step in risk reduction and management. In this regard, the authors developed a seismic evacuation safety index to quantify a school's safety in terms of means of egress, disaster preparedness and disaster response. This tool could aid school administrators, disaster management groups, the Department of Education (DepEd) and other stakeholders in identifying risks and evaluating the school's evacuation and disaster management program. This will also serve as a basis for evacuation planning and decision making. Furthermore this study can be used to classify schools according to their level of evacuation safety.

**Key Words:** disaster risk reduction; evacuation safety; disaster preparedness; disaster response; means of egress;

### 1. INTRODUCTION

The Philippines is prone to all kinds of natural hazards as it is situated within the Pacific Ring of Fire. Hence, places it as one of the most earthquake-prone countries in the world. According to the Philippine Institute of Volcanology and Seismology (PHIVOLCS), the country experiences an average of five earthquakes a day. The country experienced several intense earthquakes with magnitude of six (6.0) and higher. Schools are one of the most vulnerable structures to seismic events as it poses the highest threat to human safety especially to children. In Surigao Del Norte last February 2017, twelve schools incurred damage due to a magnitude 6.7 earthquake (NDRRMC, 2017). The 7.2 magnitude Bohol earthquake in 2013 caused significant damage to 600 schools (ASEAN, n.d). The

July 16, 1990 Luzon Earthquake with a magnitude of 7.8 caused extensive damage and destruction of hundreds of schools and hospitals due to ground shaking, liquefaction and ground subsidence (Hopkins, 2001).

The United Nations International Strategy for Disaster Reduction (UNISDR) launched various initiatives and documents promoting safe and resilient schools globally such as the "Global Platform on Disaster Risk Reduction", "One Million Safe Schools and Hospitals", "Comprehensive School Safety Framework" and "Sendai Framework for Disaster Risk Reduction 2015-2030".

The Philippines Department of Education (DepEd) is one sector of the government which advocates disaster risk reduction and resiliency in the school system. Through the Department Order 37 s 2015, "The Comprehensive Disaster Risk Reduction and Management (DRRM) in Basic Education



Framework” this policy serves as a guide in assessing, planning and implementing schools’ specific prevention and mitigation, preparedness, response and recovery and rehabilitation interventions.

Risk assessment is the first phase to risk reduction and management (DepEd, 2008). There are several risk index studies developed, such as Seismic Risk Index (Brizuela & Oreta, 2013), Hospital Safety Index (PAHO, 2008) and Fire Risk Index (Watts & Kaplan, 2001). However research about an evacuation safety index (ESI) has not yet been studied in Philippines. The ESI is an assessment tool that can evaluate a school according to the following parameters: means of egress, disaster preparedness and disaster response. Consequently, this will classify the schools according to their level of evacuation safety.

## 2. METHODOLOGY

Descriptive type of research is employed as observable parameters to formulate the evacuation index. The ESI involves three main factors namely: means of egress requirements (Foz, 2015), disaster preparedness and disaster response.

Weights were established to indicate the importance of each parameter. The parameters were assigned weights based from a survey from experts where a total of 37 respondents from DepEd, different disaster management groups and Bureau of Fire Protection, who are responsible for assessing the DRRM plan of schools, were surveyed. FEMA 455 (2009) methodology was employed to determine the weighted parameter ratings.

A three-point Likert scale with a corresponding nominal rating ( $R_i$ ) classified as poor =1, fair =2 or good =3, was used to grade the parameters. For each parameter, the score ( $S_i$ ) can be evaluated by multiplying the nominal rating ( $R_i$ ) by its corresponding weight ( $W_i$ ).

$$S_i = R_i \times W_i \quad (\text{Eq. 1})$$

where:

- $S_i$  = score for each parameter (i)
- $R_i$  = nominal rating for each parameter (i)
- $W_i$  = Weight for each parameter (i)

Subsequent to the calculation of the

parameter scores, the sum of scores of each category must be evaluated.

$$E_i = \sum(S_{i_E}) = \sum(R_i \times W_i) \quad (\text{Eq. 2})$$

$$P_i = \sum(S_{i_P}) = \sum(R_i \times W_i) \quad (\text{Eq. 3})$$

$$R_i = \sum(S_{i_R}) = \sum(R_i \times W_i) \quad (\text{Eq. 4})$$

The evacuation safety index (ESI) is the scalar product of the three categories computed as:

$$ESI = E_i \times P_i \times R_i \quad (\text{Eq. 5})$$

where:

- $ESI$  = evacuation safety index
- $E_i$  = means of egress requirements
- $P_i$  = disaster preparedness
- $R_i$  = disaster response

The ESI is a single numerical value quantifying the level of evacuation safety of the schools. The minimum score that can be obtained for each category is one (1) conversely; the maximum score is three (3). Hence, the lowest index is one (1) and the highest is twenty seven (27).

The disaster response contains the evacuation time. The evacuation time was established based from the data gathered from the Nationwide Simultaneous Earthquake Drill (NSED) 2016. The quartiles were employed to determine a standard range for the evacuation time.

The ESI were classified as poor, fair and good based on a range of values. From the computed ESI of the schools assessed, the normal probability density function of the values was plotted and the mean ( $\mu$ ) and the standard deviation ( $\sigma$ ) were calculated. The difference between the mean and the standard deviation ( $\mu - \sigma$ ) determines the lower bound. On the other hand, the sum of the mean and the standard deviation ( $\mu + \sigma$ ) establishes the upper bound. The range of values below the lower bound represents Poor Rating. ESI values between the lower and upper bound correspond to the Fair Rating. Whereas, ESI scores above the upper bound is classified as a Good Rating.

Actual earthquake drills and evacuation index assessments were conducted to selected public schools in Baguio City as case studies.



### 3. RESULTS AND DISCUSSION

The importance rating of the parameters is shown in Table 1. The weights were normalized such that the sum of the parameters weights is 1.0.

Table 1. Importance Rating of Parameters

Parameters	Normalized Weight
Means of Egress Parameters (P.D. 1096)	
Number of Exit	0.143
Maximum Travel Distance towards an exit	0.143
Width of Exit	0.143
Corridors	0.143
Dead End Distance	0.143
Doors	0.143
Stairway	0.143
Disaster Preparedness Parameters	
Presence of evacuation plan	0.333
Updating of evacuation plan	0.167
Education & Training	0.333
Emergency Systems, Devices/Supplies	0.167
Disaster Response Parameters	
Evacuation time	0.143
Execution of "DUCK, COVER and HOLD"	0.286
Evacuation Area	0.143
Adherence to designated evacuation area	0.143
Headcount of students and staff	0.286

Table 2 shows the public schools' evacuation time in the last Nationwide Simultaneous Earthquake Drill (NSED) 2016 in Baguio City.

Table 2. NSED 2016 Public Schools' Evacuation Time (Source: DepEd Baguio)

School	Time, mins	School	Time, mins

Josefa Cariño E.	30	Tabora E.	5
Pines City NHS	20	Lucban E.	5
BCNHS	15	San Carlos Height E.	5
St. Joseph De Mary Learning Center	15	Fairview E.	5
Pines City NHS	15	San Luis E.	5
Adiwang E.	15	Mil-An NHS	4.1
BCNHS	15	Rizal NHS	4
Loakan E.	15	Doña Aurora E.	4
BCNHS Annex	14	Fort Del Pilar E.	4
Sto. Tomas E.	14	Mabini E.	4
Quezon E.	12	Magsaysay E.	4
Kias E.	12	Irisan NHS	3
Irisan E.	12	Baguio Central School	3
Elpidio Quirino E.	11	Magsaysay NHS	3
Bonifacio NHS	11	Crystal Cave E.	3
Pinget E.	10.5	San Vicente E.	3
Bonifacio E.	10	Bakakeng E.	3
Doña Nicasia E.	10	Baguio City SPED Center	3
Baguio Central School	10	Dominican Mirador E.	3
Dominican Mirador NHS	10	Pacday (asin)	3
Manuel Roxas E.	10	Don Mariano E.	2.5
Josefa Cariño E.	10	BCNHS Fort Del Pilar Annex	2.5
Gibraltar E.	10	PMA E.	2
Mil-An NHS	8	Happy Hollow NHS	2
Bakakeng NHS	7	San Vicente NHS	2
Joaquin Smith NHS	6	Happy Hollow E.	2
Bonifacio E.	6	Camp 7 E.	2
Pinsao E.	5	Magsaysay E.	1



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Guisad Valley NHS	5	Kias E.	1
Elpidio Quirino E.	5	Spring Hills E.	1
Quirino Hill E.	5	Manuel Roxas E.	1
Lindawan NHS	5	Irisan NHS	1
Pinget NHS	5	Baguio Country Club E.	1
Dontogan E.	5	Pinsao E.	1
Spring Hills E.	5	Pinsao NHS	0.35
Middle Quirino Hill E.	5		
FIRST QUARTILE		3 minutes	
SECOND QUARTILE		5 minutes	

Based from the evacuation time of schools, the first quartile represents the lower limit whereas the second quartile corresponds to the upper limit. Thus, evacuation time less than three minutes (< 3 minutes) is classified as good, time from three to five minutes (3 to 5 minutes) is categorized as fair, while evacuation time greater than five minutes (> 5 minutes) is a poor rating.

Actual earthquake drills and evacuation safety assessments were conducted to 28 public elementary schools and 10 public national high schools in Baguio City, which corresponds to 58% of public schools in the city. The results of the assessment are shown in Tables 2 and 3.

Table 2. ESI of Public Elementary Schools

	Name of School	ESI	Remarks
1	Alfonso Tabora	16.79	Fair
2	Baguio Country Club	12.70	Fair
3	Baguio City SPED Center	16.16	Fair
4	Bakakeng	8.43	Poor
5	Brookspoint	15.02	Fair
6	Camp 7	14.28	Fair
7	Crystal Cave	17.18	Fair
8	Don Mariano Marcos	14.58	Fair
9	Dominican - Mirador	18.99	Good
10	Dona Aurora H. Bueno	15.45	Fair
11	Dona Aurora	9.24	Poor

12	Dona Nicasia J. Puyat	10.54	Poor
13	Dontogan	14.41	Fair
14	Elpidio R. Quirino	17.24	Fair
15	Fairview	17.83	Good
16	Gibraltar	14.82	Fair
17	Holy Ghost	11.20	Fair
18	Jose P. Laurel	13.07	Fair
19	Josefa Carino	14.73	Fair
20	Kias	15.64	Fair
21	Magsaysay	8.84	Poor
22	Manuel A. Roxas	16.98	Fair
23	Pinget	10.13	Poor
24	Pinsao	13.03	Fair
25	Quirino	12.53	Fair
26	San Luis	10.79	Fair
27	Sto. Tomas	15.85	Fair
28	Springhills	17.00	Fair

Table 3. ESI of Public National High Schools

	Name of School	ESI	Remarks
1	BCNHS-Fort Del Pilar Annex	19.02	Good
2	Bakakeng	13.47	Fair
3	Doña Aurora	16.16	Fair
4	Guisad Valley	11.02	Poor
5	Lindawan	15.75	Fair
6	Pines City	16.02	Fair
7	Pinget	17.52	Fair
8	Quezon hill	21.60	Good
9	Rizal National	11.14	Fair
10	Sto. Tomas	14.44	Fair

The range of the ESI values classified as poor, fair or good is shown in Table 4.

Table 4. Classification/Qualitative Rating of ESI

Range of ESI	Classification
<11	Poor
11 - 18	Fair
>18	Good



A descriptive statistics of schools with the corresponding rating is illustrated in Table 4 and in Fig.1.

Table 5. ESI Descriptive Statistics

	Public Schools in Baguio City	
	Frequency	Percentage
Poor	6	16%
Fair	29	76%
Good	3	8%
<i>Total</i>	38	100%

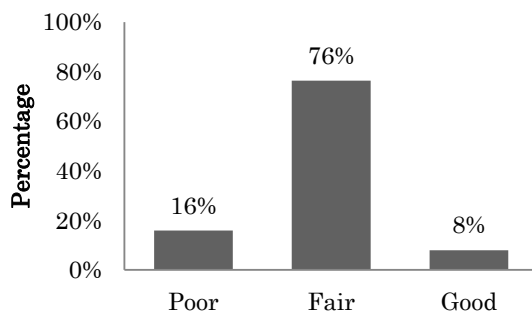


Fig. 1. ESI of Public Schools in Baguio City

Out of the 38 public schools assessed, only eight percent (8%) obtained a good ESI rating, seventy-six percent (76%) gained a fair rating and sixteen percent (16%) acquired poor rating. Hence, there are still schools that need further improvement in terms of their evacuation safety.

#### 4. CONCLUSIONS

Assessment of the evacuation safety is necessary as it contributes directly to effective decision-making, planning and control of the organized response. The ESI was used to evaluate thirty eight (38) public schools in Baguio. The results can be used by stakeholders to conduct further evaluation of the school especially with ESI of fair to poor. Generally, the level of evacuation safety of the public schools in Baguio City is satisfactory based from the results.

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