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A RISK ASSESSMENT MODEL FOR HIGH-RISE SCHOOL BUILDING PROJECT IN METRO MANILA, PHILIPPINES

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ABSTRACT: The rapid increase of school building construction in the country was brought by the implementation of a nationwide reform in pre-university education cycle from 10 to 12 years in June 2012. The change demanded a significant increase in school buildings. However, construction of high-rise school building project is unique due to its varying characteristics as compared to other types of building construction project. Construction of such buildings depends on variables such as site, surrounding, size, structure, student population, resources and culture. As a result, it is subject to numerous risk and weakness, which invariably have significant negative impact on its overall performance. Therefore, risk assessment tools for school buildings must be modified to fit these varying characteristics. However, there are three major challenges during the planning stage of project risk management of such buildings, first is the correct identification of the sources and type of risks, second the necessary statistical information and third, the selection of methods that will successfully estimate the potential impacts and probabilities of occurrence. The study attempted to bridge this gap by using Monte Carlo Analytic Network Process (MCANP) a weighted simulation decision making model. As a result, the proposed method compared to traditional approach can quantify the error of uncertainty in the judgements through the probabilistic judgements with a confidence level of 95%. Thus, the method allows to estimate the probable value of losses and the degree of influence of each risk factor associated in high-rise school building construction in Philippines.

Keywords: High-rise school building, Risk Factor, Risk identification, Risk Assessment

1. INTRODUCTION

School building construction in the Philippines becomes prevalent since the implementation of a nationwide reform in pre-university education cycle from 10 to 12 years in June 2012 [1]. However, such building construction compared from other types is not simple and differs in terms of built environment (private or public). School building construction methods consist of both physical and metaphysical factors. The physical factors that will influence the outcomes are financial resources, limitations of the proposed project site due to its controlled environment, nature of the education program and framework of the age class groups. The metaphysical nature on the other hand is a critical factor before its realization. Compared to other building construction the stakeholders are not limited only to designers, contractors, and project managers but also the participation of school administrators, teachers, parents and age structure of students to be served as well. According to Lunenburg [2], schools buildings deteriorates faster compared to other buildings because the physical facilities such as plumbing, sewer, electric, roof, masonry and carpentry are out of date and below the standard code. For example, according to a Commission on Audit (COA) report dated 2017 that some school buildings constructed by the Department of Public Works and Highways (DPWH) [3] cannot be utilized due to construction issues such as incomplete utilities, structural defects, and delayed completion and turnover of buildings.

Project risk management approach for building new schools is different from a private school to that of a public school. The rules from public schools are not simple, stakes are higher, and considerations are political. Compared in private school projects there are clear answers to questions on the number of students that will be accommodated, location of building site, environmental issues, companies and contractors to hire, funding, attendance boundaries and no voters reaction to deal with [2].Risk conditions are practices or aspects of school building construction environment that may result to risk occurrence. In January 2009, the Center for Research on Epidemiology of Disaster mentioned that approximately 1.2 billion students are enrolled in primary and secondary school; of these, 875 million school children live in high seismic risk zones and hundreds of millions more face regular flood, landslide, extreme wind and fire hazards. School buildings constructed without considering these risks during planning phase not only injure or kill children, but also destroy the physical infrastructure where the cost of repair and reconstruction can be a great economic burden [4]. For instance, super typhoon Durian (2006) in the Philippines caused 20m USD damage to school, including 90-100% of school buildings in three cities and 50-60% of school buildings in two other cities [4]. The failure of the people responsible to consider the threat of constructing school buildings in hazard prone areas resulted not only damages to properties but also loss of lives.

The increasing awareness of the need to establish a best approach for treating these problems has put the focus of stakeholders to consider the various potential risk and impact to prevent any financial losses. However, there are three major challenges during the planning stage of project risk management of such buildings, first is the correct identification of the sources and type of risks, second the necessary statistical information and third, the selection of methods or tools that will be used to successfully estimate the potential impacts and probabilities of occurrence. Presently, professionals in the project organization are having trouble in dealing with risk assessment process due to no formal risk management structure in place and the lack of knowledge in risk management theories and techniques. Intuition and experience were used for risk decision making which is inadequate for a controlled construction such as school buildings resulting to cost overruns, delays, claims, and disputes. The skills gap resulting to ambiguity in risk decision making process during project risk assessment must be bridged.

There are few published local researches of formal risk assessment techniques challenging the traditional approach of assessing risk factors for school building construction projects in the Philippines such as Oreta and Brizuela [5] used a computer-aided earthquake risk management tool that would allow school administrators to participate in the decision-making process. Miyamoto and Gilani [6] also used computer models, to estimate losses of hazard risks in public school buildings. Figueroa, Lim and Lee [1] utilized geographic information system to assess the condition of school building quality affected by geography, climate and societal factors. Also, there are some foreign researchers that developed risk assessment models for school buildings to improve the traditional approach, such as Global Facility for Disaster Reduction and Recovery introduced in 2015 an innovative partnership-based approach an open source mapping platform to provide a global baseline to ensure safety of all school facilities at risk [4]. Theunynck [7], revealed that one of the most economical and effective approaches to a hazard resilient school construction in Africa and Asia is a community driven development approach (CDD). Finn & Dexter [8], applied the probability-impact (PI) matrix in identifying, prioritizing and segregating highly potential risks for a school building project. The Institute of Risk Management [9], also proposed a systematic risk analysis to evaluate risk factors in terms of likelihood of occurrence or probability and consequence of impact using traffic light system or probability impact diagram. The United States Department of Education [10], stated that risk identification on vulnerability assessment for school can be done by various techniques such as brain storming, interview/expert opinion, past experiences and checklists which can minimize cost overruns and scheduling problems. Grant, Bommer, Pinho & Calvi [11], carried out vulnerability assessment using score-and index-based methods to define the earthquake resistance of school buildings. Coronel & Lopez [12], developed a computational tool based on geographical information system (GIS) using modern seismic attenuation relationships to estimates damages and losses of seismic event on school buildings. Mudiyanselage & Marasingha [13], proposed the incremental dynamic analysis (IDA) to assess the performance of a two storey school building for seismic event using nonlinear finite element model. Wetterneck, Sass & Davies [14], assessed risk factors for school buildings using multivariate analyses of variance (MANOVA). Panahi, Rezale&Meshkani [15], developed a seismic vulnerability map of school buildings using on analytic hierarchy process (AHP) and geographical information system (GIS). Mazılıgüney, Yakut, Kadaş & Kalem [16], performed ATC 21 (FEMA 154) seismic vulnerability assessment method for reinforced concrete school buildings to evaluate performance of school buildings [17]. The Construction Industry Institute (CII) developed the project rating index (PDRI) as tool to support school administrators in decision making process during the planning stage [18]. This tool attempts to identify uncertainty before school building construction [19].

Following these developments there is no single technique that can be considered the best technique capable of measuring and treating these uncertainties and risks that affect school building project outcome. The study will attempt to address the gap of traditional risk assessment approach of private school building projects and the limitations of cited techniques by developing a weighted simulation decision support tool using Analytic Network Process and Monte Carlo Simulation technique.

1.1 Framework

The theoretical framework underpinning this study, is anchored on building elements which govern its development form design to completion namely: codes and regulations, structural system, walls, windows and façade, service system and financing. Fig. 1 shows that a risk cannot be accurately analysed and controlled unless its nature and components are first identified and understood.

Standard codes and regulation are indispensible project requirement that all site works be planned and executed in such a manner so as to avoid the risk of danger to site personnel and construction area and the effect to the environment, that all such operations are performed in accordance with the following accepted rules and regulations where the project is located.

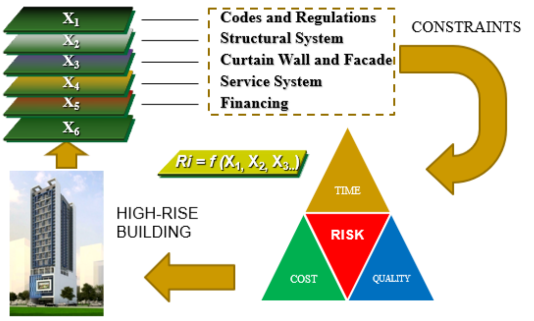

Fig. 1 Building risk framework

The possibility of design errors to occur in today's building construction projects is high due to its time of discovery. The failure to review the plans and specification makes errors to be discovered when works has reached its advanced stage. The attempt to correct the design errors will delay the project and incur additional cost burden to the owner unless otherwise at the account of the designer through the professional indemnity insurance prescribe in other countries. Because of the high level of seismicity here in the Philippines, earthquake loads govern the structural design of all building, in which wind loads assume prime importance. The structural system of a building is designed to transmit vertical and horizontal loads from the point of application to the foundations by the most efficient path with minimum impact on the economy and function of the other elements of the building. The structural engineer must consider many different factors before selecting the final structural system of a school building project. Basic building properties such as height, shape, and usage as well as local economic conditions that affect the materials and labor costs; construction schedule, design loads both vertical and lateral; building behavior and occupant behavior; foundation considerations and coordination with mechanical systems are factors that influence the structural system of a building structure [20]. Generally, structural systems are flexible, and limitations only come from the material used in the construction. Typical materials used for structural systems are steel and concrete.

Buildings today utilize service system and facilities as required by the National Building Code of the Philippines and other related legislature. These facilities are included in the design and construction of a building and are provided for the comfort and safety of the occupants. The following service system in building projects are vertical transportation, electrical systems, HVAC systems (heating, ventilating and air conditioning) and fire protection systems. When specialist designer specifies the materials to be installed and construction details to execute, the contractor should conform to the use of these materials and details. However, it is difficult or impossible for the contractors to determine if the materials and details specified by the designer are suitable and correct. For example, unsuitable materials and connections in plumbing installation will result to damages due to bursting of pipes; unsuitable materials for insulation which can produce toxic gases in case of fire; incorrect sizes of fixtures suspended in ceilings or façade components which can cause injury or damage to property if they fall. The consequential losses for the damages and efforts in the repair works will add on the financial burden of the owner.

Lastly, the element of financing the costs for the construction of a building project is the sole responsibility of the developer. Costs of construction of a buildings range to hundreds of millions of dollars. Financing of building project depends on what type of business is going to be established. Basic sources of capital can be through equity finance, debt finance or internally generated funds. The owner of the building will rarely be willing to shoulder the construction costs without the assistance of outside financial institution. Without sufficient financing during the periods of rapid construction of the building when additional capital is needed to cover operation, to maintain equipment, to procure materials, to pay salaries and wages, to cover storage, transportation and reserve will result to conflicts, disputes and claims which jeopardize the primary aim of the owner to complete the building on time. On the other hand, any delay in completion affects the target date of use producing loss of profit for its owner.

1.2 Developing Risk Assessment Framework for High-Rise School Building Project

The traditional risk assessment revealed by the literature such as brain storming, Delphi technique, interview/expert opinion, past experiences, check lists, influence diagram produced level of uncertainty which are not suitable for projects like school buildings. This traditional approach assumes that precise decisions are provided and there is no venue for statistical interpretation of results on similar or close decisions. Hence, the uncertainties underpinning the risk assessment process in school building environment, both explicit and implicit should be dealt appropriately [21]. Most of the studies concluded in the improvement of these traditional approach using qualitatively and quantitatively methods.

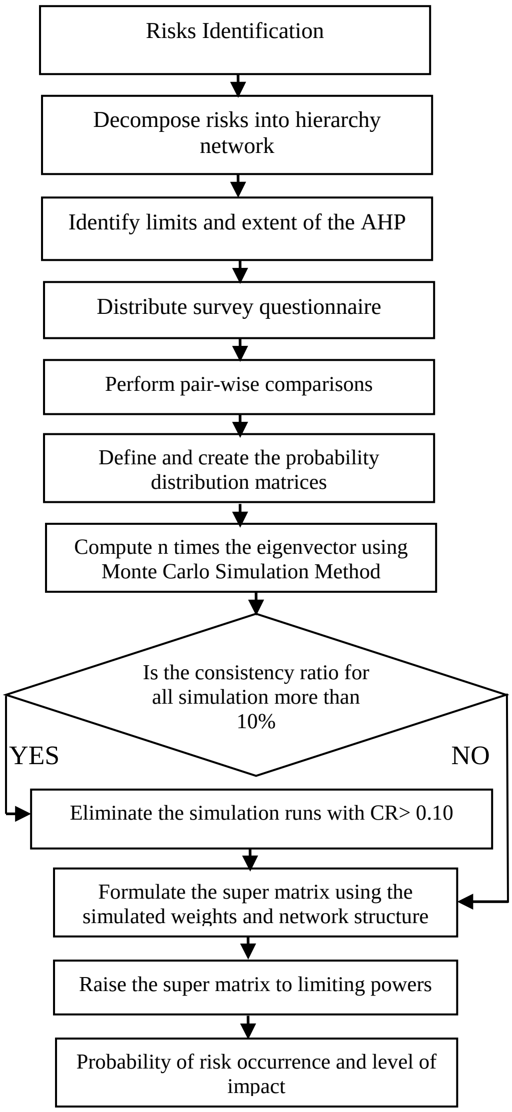

Fig. 2 MCANP weighted simulation framework.

These methods when combined allows the quantification of risk in terms of magnitude/impact and frequency or time frame of each event as well its probability of occurring [22]. Therefore, this study will attempt to develop an effective risk assessment using qualitatively and quantitatively methods such as Analytic Network Process and Monte Carlo Simulation as shown in Fig. 2.

The combination of Analytic Network Process a multiple criteria decision-making method and Monte Carlo a simulation method will produce the following advantages:

1. Provide a more systematic approach;
2. Will handle subjectivity in weighing risks brought by human factors like personal experience, intuition and judgment;
3. Will derive potential relation and level of riskiness between risk factors;
4. Will improve applicability for both quantitative and qualitative features of risk;
5. Will manage uncertainty in the judgments of decision makers by testing the statistical significance of the final rankings of risk factors.

Furthermore, the proposed method will address the following limitations of cited risk assessment techniques such as:

1. inability to model epistemic uncertainty due to lack of enough information,
2. inability of measuring and including the intangible factors,
3. limitation in representing interdependencies between different risks and the assumptions that they are independent,
4. and inability to consider both qualitative and non-monetary risk.

The use of this method will fill the skills gap among practitioners in determining the probability and impact values of potential risks in school building projects.

2. METHODOLOGY

The theoretical framework will set the foundation in formulating the research questions to be answered. A mixed method approach will be used in this study to utilize the strengths of both qualitative and quantitative methods. Lee [23] believed that mixed methods are very powerful when carried out correctly for a single research study. The study will first review sources of related literatures that identify and classify various types of risk which are commonly associated in school building projects. Based from these reviews, a classification method will be adopted to arrange risk factors into groups and sub-groups for the purpose of risk identification and modelling as illustrated in Fig. 3.

In this study school building construction risk are divided into two categories: external risks and internal risks and 6 risk factors consisting of sub-risk factors are derived. Based from the presented literatures, risk in a construction projects are generally based from two sources, the external risk which are originated due to the project environment or usually unique to the country while internal risks are initiated inside the project [24, 25, 26, 27, 28].

In the second stage of data collection, selection of group subject matter experts. The group will be defined first according to skills, knowledge and unique qualities and the sample subject matter expert will be selected using a probability sampling process. The subject matter should have undertaken and completed school construction projects for the past 10 years and held administrative position in the institution. The data acquired from this group will play a vital role in the successful application of MC-ANP technique. Therefore, the right people will be selected for best results. Finally, once the group of subject respondents are selected, a survey questionnaire will be administered.

This study will perform pairwise comparisons at every level using the numeric preference of the subject matter expert's judgement as input data from the survey questionnaire. Using Analytic Network Process (ANP) will utilize the derivation of potential relation and the level of riskiness of between potential risks factors as illustrated in Fig. 3 is the proposed risk breakdown network for school building. Assuming the factors are interdependent and there is a feedback loop from elements in level of risk (High, Medium and Low) to factor elements. Judgment consistency ratio (CR) of CI = (λ_{max}- n)/ (n - 1), n is the matrix size with the appropriate value in Table 4. If CR is more than 0.10, the judgment matrix is inconsistent [29].

Table 4 Random consistency index (RI)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	.58	.90	1.12	1.24	1.32	1.41	1.45	1.49

The local priority vectors from pair-wise comparisons on the elements of the cluster and sub-cluster levels will be adopted to achieve a super matrix, which in turn obtain global priorities. After entering the sub-matrices into the super matrix and adjusting its values to achieve column stochastic. The super matrix is raised to limiting powers until weights have converged and remain stable [30, 31, 32]. The proper decomposition of the problem into a network is vital for the successful application of MC-ANP technique.

To address the ambiguity gap that occurs during the judgement of the selected group of subject matter experts in answering the survey questionnaires, this different judgement will be collected to define the probability distributions in order to create the probabilistic pair-wise comparison matrix. Fig. 4 illustrates an example of the proposed probabilistic distribution matrix. Since probabilistic judgment uses random variables the computation of eigenvectors and eigen-values cannot be done in a traditional way, the Monte Carlo simulation technique will be used.

3. RESULTS AND DISCUSSION

3.1 The ANP Model for Risk Assessment

This study proposes a multi-criteria decision model for assessing overall riskiness of school building construction project as shown in Fig. 3.

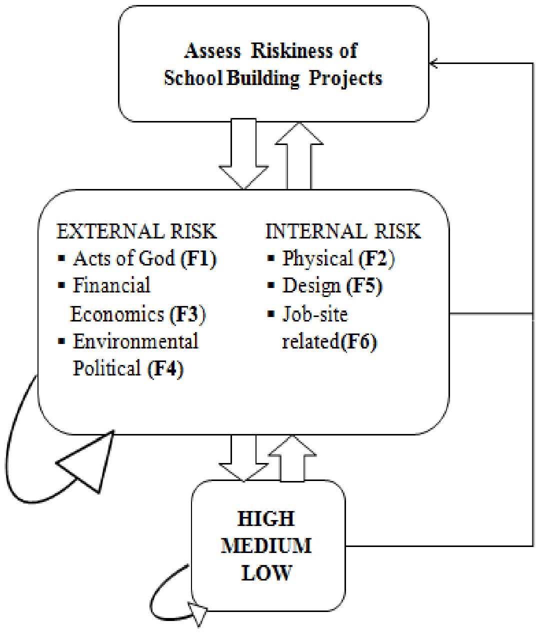

Fig. 3 Risk breakdown network model

The proposed model will evaluate potential risk factors associated in school building projects. There are several conflicting, weighted, and incommensurable risk factors involved besides the interrelationships among these factors such as dependencies and feedbacks. Because of this complicated nature of the problem on hand, it can be modeled as a network and treated with a network based multi criteria decision making approach.

The ANP is a multi-criteria theory of measurement used to determine weights of numeric preference from decision maker's judgements at the same time allows the assumptions of relative influence of higher-level elements from the lower level elements [30]. Saaty [30] proposed ANP approach that can be utilized for examining network model representations. The power of ANP lies in its use of special ratio scales [30] to capture all kinds of interactions between external and internal risk factors for making accurate predictions and better decisions. Because of interactions among criteria, the criteria that are less important individually might turn out to be more important when evaluated collectively in a network [33]. Moreover, two types of interactions are illustrated in the proposed ANP model, the outer dependence which is represented by straight arrows and inner dependence which is represented by loops. Furthermore, the decision problem is characterized by three aspects namely the goal, risk factors and level of impact. Thus, the overall goal of this study is to assess the risk of school building construction projects.

3.2 The probability Distribution Matrix

During the traditional ANP, the pairwise comparisons in the decision clusters and respective elements represented by a_{ij} are deterministic, where a_{ij} indicates how much more important the i^{th} alternative/criteria is than the j^{th} alternative/criteria and this will lead to the construction of the composite priority vector of alternatives' importance. In the MCANP, the a_{ij} values are represented by the p_{ij} probabilistic judgments. The most rigorous and suitable method to select the appropriate distribution of p_{ij} is using the statistical principles. From the central limit theorem, for almost all populations, the sample distribution can be approximated closely by a normal distribution, provided the sample size is sufficiently large [34]. However, it can be difficult to obtain a large sample size of subject-matter experts to perform the pair-wise comparison [35]. Another method can be use according to Banuelas & Antony [35] is the chi-squared goodness-of-fit test to investigate whether an underlying distribution (or population) from which the data have been taken is of a specified form or not. Hauser and Tadikamalla [36] suggest that in the extreme case the decision-makers are not 'n' times. Thus, to quantify variation due to uncertainty of the decision maker's judgements the use of random variable with a uniform probabilistic distribution between 1/9 and 9 in the pair-wise comparison matrix as shown in Table 1.

Rosenbloom [37] recommended the use of Monte Carlo simulation to estimate the composite priority vector from the probabilistic judgment (P_{ij}). Therefore, each replication would be a realization of all the a_{ij}s in the decision hierarchy followed by the standard ANP calculation of eigenvectors and eigen values. Replicating n times will provide estimates of the probabilities associated with the priority vector as shown in Table 2 and Table 3.

The probability distribution function, F(x) is the mathematical equation that describes the probability that a random variable X is less than or equal to x, given by Eq. (1) [21]:

$$F(x) \approx P(X \leq x) \qquad (1)$$

where P (X ≤ x) means the probability of the event X ≤ x. Therefore, in order to meet the Saaty's pairwise comparison scale the probability distribution of the random variable X is equal to or greater than 1/9 and not greater than 9. If X are random variables it follows that final ratings are also random variables. To test the statistical significance of the final ratings the use of Monte Carlo simulation is recommended. Simulation according to Albright [38] is a useful tool for modeling random variables. Thus, constructing a simulation of iterations *n* will provide estimates of the probabilities associated with the vector of priorities [35].

Table 1 Normalized probability distribution matrix

	F1	F2	F3	F4	F5	F6	ω
F1	1	.2	.111	1	.166	.142	.0297
F2	5	1	.125	5	.500	.250	.0951
F3	9	8	1	9	7	4	.5345
F4	1	.2	.111	1	.333	.500	.0420
F5	6	2	.142	3	1	1	.1316
F6	7	4	.250	2	1	1	.1672

λ_{max}= 6.605, CI= 0.12, RI=1.25, CR= 0.097 < 0.10 OK.

Table 2 Simulated priority weights

	HIGH	MED	LOW
F1(0.0297)	0.1692	0.3874	0.4434
F2(0.0951)	0.1311	0.6608	0.2081
F3(0.5345)	0.7928	0.1312	0.0760
F4(0.0420)	0.0890	0.3234	0.5876
F5(0.1316)	0.0881	0.7172	0.1947
F6(0.1672)	0.7626	0.1662	0.0726
Overall Level	0.5840	0.2802	0.1360

Table 3 Overall priority weights

Risk Factors & Levels	Final Ratings
F1	.0451
F2	.0478
F3	.1646
F4	.0300
F5	.0520
F6	.0604
HIGH	.1000
MEDIUM	.0640
LOW	.0400

In the proposed MCANP method compared to traditional approach that assumes precise decisions are provided and there is no venue for statistical interpretation of results on similar or close decisions. MCANP can quantify the error of uncertainty in the judgements through the probabilistic judgements with a confidence level of 95%.

4. CONCLUSION

Classification of all types of potential risks for high-rise school building construction according to probability of occurrence and consequence was suggested. The objective of this classification is to identify the impact of each risk factors on the construction of the school buildings. For example, the total construction cost for structural works in a typical high-rise building is PhP 300M but due to Financial risk factor (F1) as shown in Table 3 the probability of occurrence if not considered during the planning stage is 16.46% and the level of riskiness is HIGH with a possible impact in cost of 10% which translate in a risk value of 1.65% amounting to PhP 4.95M. This cost of risk will be the maximum value of damage according to the impact in percent of the construction cost. Therefore, it is important to determine the potential damage or value of losses of each risk factor in the project. The value of risk is the potential amount of damages when the event occurs. Thus, the method allows to estimate the probable value of losses and the degree of influence in the project.

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