PLANNING MALAYSIA:
Journal of the Malaysian Institute of Planners
VOLUME 19 ISSUE 4 (2021), Page 110 – 120

ANALYSIS OF ELEMENTS INFLUENCING CHILD SAFETY IN HIGH-RISE BUILDINGS USING ANALYTICAL METHOD

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Abstract

Due to the lack of land in densely populated areas in Malaysia, high-rise residential building has become a trend in the recent years. However, in designing and constructing these buildings, safety considerations have not received adequate attention. This study aims to examine the causes of children falling from high-rise buildings, while the nature and frequencies of such accidents were also investigated. The paper is based on the existing literature, as well as feedbacks from questionnaires and interviews. The Analytic Hierarchy Process (AHP) approach within Multi-criteria Decision Analysis was adopted for the analysis undertaken in this study. The outcome reveals that accidents involving child falls can be prevented by establishing appropriate policies and regulations. The strict enforcement of safety laws and regulations will help to avoid untoward accidents and dispel negative thoughts about living in high-rise buildings. The findings elaborate on the ranking of elements that influence child safety in high-rise apartments.

***Keywords**:* Child Safety Element, High-rise Buildings, Analytical Hierarchy Process

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INTRODUCTION

Contemporary building design must protect people and property. Designers should be motivated by the need to address not only threats such as criminals and terrorists, but also natural threats such as earthquakes, hurricanes, floods, and accidents, which could cause a building to collapse. Designing and building accommodation that incorporates enhanced security is a key aspect of the concepts, principles, and processes of new and existing buildings, particularly in multi-storey buildings. Security planners and designers must create ways to incorporate protective measures into multi-storey building designs to ensure the safety of children (Joseph et al., 2004).

Falls from heights are a major problem in urban areas, especially involving children living in multiple-storey and often deteriorating low-income housing (Sieben et al., 1971; Garrettson et al., 1985; Spiegel & Lindaman, 1997). A study done in the United Stated, falls have represented up to 20% of child deaths from unintentional injuries, compared to an average of 1% to 4% nationally (Waller, 1999). The majority of fall-related fatalities among children are associated with falls from heights, mostly from three-storey houses or higher. Falls from one or two storeys are more frequently nonfatal, but second-storey falls may cause serious injuries (Marilyn et al., 2001). Although the average age of patients injured in falls from heights is approximately five years, the age distribution is bimodal; preschool children are more likely to fall from windows than older children (Meller, 1987 & Bull et al., 2001).

ACCIDENTS INVOLVING CHILD FALLS: THE CASE OF HIGH-RISE DWELLINGS

Falls from high places in the home are the main cause of injury among children (Pressley and Barlow, 2005). Children may fall from windows and structures, corridors, balconies, stairs, playground equipment, and even bunk beds (National Action Plan for Child Injury Prevention, 2012). Besides causing the highest number of injuries among children, falls are sometimes fatal. It has been estimated that in the United States, three million children annually need emergency department care for various fall-related injuries (World Report on Child Injury Prevention, 2008). Of the many kinds of impact falling accidents, some may be simple traumatic experiences while others may result in very serious injuries or even death.

Studies have identified various factors related to a high incidence of falls. Research findings have shown that boys fall more frequently than girls; this can be 50 to 300% more, according to different reports. More than two-thirds of all falls happen to children below five years of age, with head injuries and fractures being the most common outcomes. This group of young children also recorded a higher mortality rate from falls (Sieben, Leavitt, & French, 1971).

Depending on the nature of the falls, injuries of varying severities can result. Among the most serious types of falls are the instances where children fall from

a great height, usually from the high-rise buildings where they live. Child falls from tall buildings commonly occur from windows, balconies, or verandas. Unsurprisingly, their injuries can be severe or even fatal. Such accidents are becoming more frequent, especially in urban areas where living in multi-storey apartments is becoming more widespread.

THE MAIN ELEMENT IN CAUSES OF CHILDREN'S FALLS

Although not all falls are fatal, children who fall from height may suffer a range of serious injuries, such as fractures, internal trauma, and brain injuries (Smith, 1975). This is because children tend to topple head first, using their arms and hands to break their fall. A study conducted in the United States showed that 15 out of 70 children who fell from a height of one or more storeys suffered minor soft tissue trauma. Fifty-four per cent suffered head trauma and 33% incurred skeletal trauma. It is highly likely that a child who suffers such an injury will need life-long medical care and assistance (Sherry, 2012, Sahril and Mutalip, 2014).

In Sydney, the Centre for Trauma Care, Prevention, Education and Research and the Kids Health Promotion Unit at the Children's Hospital in Westmead formed a working party in 2009 after the city experienced a dramatic increase in child falls between 1998 and 2006. On average, seven children a year suffered serious falls from windows. Balcony falls also experienced a rise, increasing from an average of six between 1998 and 2006 to 11 in 2007 (Sherry, 2012). Unfortunately, centralised hospital records on children's falls were not maintained, making it difficult to determine the exact number of children treated in various hospitals for injuries due to window and balcony falls in Sydney (Sherry, 2012). The same situation has been happened in Malaysia, especially in urban areas. However, accurate statistics cannot be identified because the incidence of children falling from multi-storey dwellings in Malaysia has been recorded in sudden death category. The issue does not entirely relate to the action taken by adult but also the building design.

It is vital that parents with young children living in high-rise buildings are educated on child safety. Hence, there is no substitute for vigilant adult supervision. Children may fall from windows, balconies, or verandas, which are the main areas of potential hazards. Injuries can be minimised or deaths avoided altogether through proactive measures (Miller, 2011).

Installing window guards is one of the most effective ways of preventing a potential fall, regardless of parenting skills, income, or education. After such a measure was made mandatory in New York, there was a 50% reduction in falls in the two-year period from 1973 to 1975 (Sherry, 2012). This shows that the mandatory provision of physical barriers is the most effective means of reducing the number of child fall injuries or even saving lives. Studies have shown that the risk of a child's injury associated with housing is independent of other risk factors (Shenassa, 2004). Hence, mandatory preventive measures that ensure children do

not fall from height would certainly reduce, if not eliminate, the possibility of fall-related injuries among children living in high-rise homes.

In Malaysia, the Uniform Building By-Laws (UBBL) 1984 enacted under the Street Drainage and Building Act 1974 stipulate that all new buildings require submission of plans for approvals prior to construction by a principal submitting person (PSP), such as a Professional Architect and Professional Engineer. The UBBL 1984 stipulates the building's structural requirements related to the design and specifications of materials, loadings, foundation and superstructure; which govern the design, specifications and construction of walls, floor and building structure. The UBBL 1984 also stipulated the construction requirements and fire requirements of a building. However, for multi-storey residential buildings, the standards set are comprehensive and more focused on design for safety in the event of fire.

While the standards and guideline issued by the Ministry of Housing and Local Government for window, balcony, corridor and stair design are comprehensive. The window height limit was in line with international standards. The heights above 1100mm for windows are a safe distance for children. However, the standards issued was only emphasize the height limit of window. The window opening limit itself is not set in the checklist provided. This window opening limit is important since active children will act to pick up objects as a tool to climb towards the window and can cause the child to fall. With a limit on window openings, this risk can be reduced. The standards for balcony were focused more to the disabled and the area of the horizontal space. No specific standard is described regarding the height of the balustrade for children. In addition, barrier type standards and barrier openings are also not specified for child safety.

METHODOLOGY

The Analytic Hierarchy Process (AHP) approach within Multicriteria Decision Analysis (MCDA) was adopted for the analyses undertaken in this study. MCDA is a form of data analysis used to identify related criteria based on previous research. Determining the principal criterion/element that explained the incidence of child falls from high-rise buildings was divided into two hierarchical levels, with the goal at the higher level, followed by the explanatory criteria (Figure 1). Those elements were based on extracting input derived from a systematic literature review. Each criterion (element) in the hierarchical level was compared pair-wise with another element to determine which was preferable in achieving the goal at the higher level. The selection of the goal and the criteria contributing to the goal were based on reports contained in the literature, feedback from questionnaires, as well as interviews with high-rise residents and experts in the field. This study involved 435 survey respondents and 7 experts involving Department of Director General of Lands & Mines, Department Of Town and Country Planning and Fire and Rescue Department to strengthen the results of the study.

MCDA is one of the most widely used decision-making methodologies in science and engineering research. In the field of engineering, MCDA has been applied to flexible manufacturing systems, layout design, and integrated manufacturing systems, as well as in evaluating technology investment options (Priyabrata et al., 2013). Essentially, MCDA facilitates a selection from the choices available by grouping possible alternatives to rank them and then determining how well the best choice meets the selection criteria. This approach helps researchers focus on what is important, logical and consistent (Ferreira et al., 2011).

One difficulty frequently encountered when employing MCDA is ranking various possible decision options (attributes, decision criteria, or objectives) that are characterised differently in relative or absolute importance but must be considered concurrently (Gbanie et al., 2013). To meet this challenge, MCDA divides the decision into smaller parts that are easier to understand. To that end, the AHP was applied to determine the relative importance of the factors at each hierarchical level that influenced the final selection of the principal factor. The AHP technique assigns weightage systematically to each element to determine its relative contribution to a decision (David et al., 2014). The subsequent integration of the parts produces the decision solution. Interested parties have the opportunity to evaluate the strengths and weaknesses of the alternative solutions available, as well as offer adjustments and trade-offs, before arriving at the final decision.

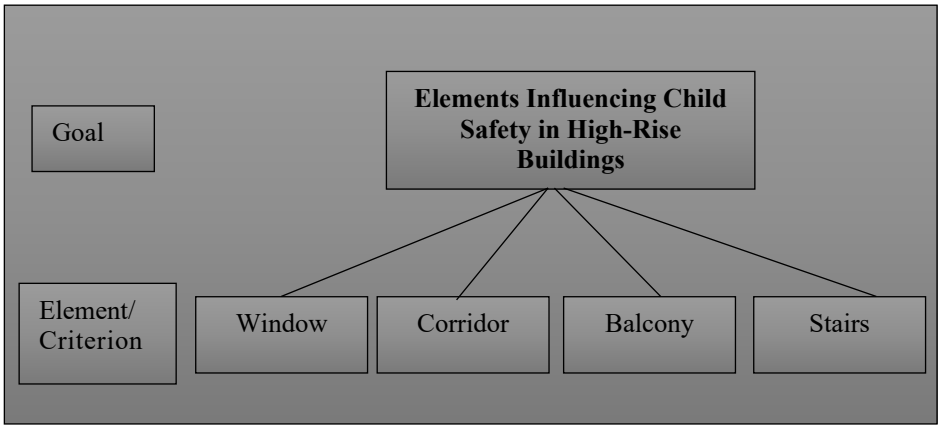

Figure 1: Hierarchical levels of relationships between the overall goal, the interests (Criteria) seen as important to the decision

ANALYSIS AND DISCUSSION

Since this study was conducted based on locally and internationally established literature, pair-wise comparisons were used to determine the weights applicable to the factors/criteria for the AHP. Each evaluation criterion or element was assigned a weight, with the criterion scoring the higher weight being deemed the

more important factor. Using the Microsoft Excel spreadsheet, an overall score was then assigned to each criterion based on the sum of the pair-wise comparison scores obtained. As the criteria selected for the MCDA were of unequal importance, the results of the weighted comparisons reflected the relative importance of each element and its contribution to the goal. The relative importance of the eight criteria that influenced the incidence of child falls from high-rise buildings is presented in the pair-wise comparison matrix in Table 1.

Table 1 : Pair-wise comparison matrix (PCM)

Corridor	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	Window
Corridor	9	8	7	6	5	4	3	2	1	2	3	4	5	**6**	7	8	9	Balcony
Corridor	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	Stairs
Balcony	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	Balcony
Balcony	9	8	**7**	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Stairs
Window	9	8	7	**6**	5	4	3	2	1	2	3	4	5	6	7	8	9	Stairs

Table 2: Pair-wise Comparisons for Criteria

Pair-wise Comparisons for Criteria				
Criteria	**Corridor**	**Balcony**	**Window**	**Stairs**
Corridor	1	0.1667	0.3333	5
Balcony	6	1	2	8
Window	3	0.5	1	6
Stairs	0.25	0.125	0.1667	1

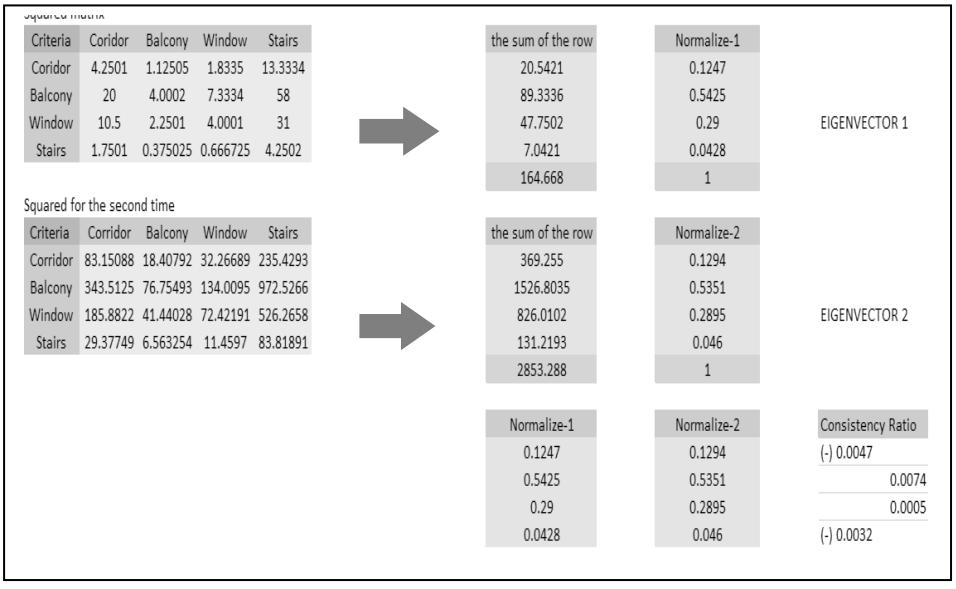

Figure 2: Computation of priority of criteria/elements using the AHP and MCDA

Four elements, *viz.* balcony, window, corridor, and stairs, were selected as the possible contributing factors to the occurrence of child falls from high-rise buildings. These elements were selected based on residents' responses in questionnaires, case studies, the literature, and interviews with experts. The pair-wise comparison matrix (PCM) was used to determine the weightage for each element by row-column normalisation to obtain the eigenvectors, as shown in Figure 2. The ranking of the elements in Table 3 indicates that the presence of a balcony (eigenvector value = 0.5351) was the most important element in terms of explaining why children fall from tall buildings. This was followed by windows in high-rise apartments (eigenvector = 0.2895), and corridors (eigenvector = 0.1642). The fourth element, stairs, appeared to be of less importance (eigenvector = 0.046).

Table 3: Ranking of the selection criteria as determined by eigenvectors

Eigenvector	Ranking	Element
0.1294	3	corridor
0.5351	1	Balcony
0.2895	2	Window
0.046	4	Stair

The weightage assigned to each element/criterion was based on the records of cases of child falls from multi-storey buildings in Malaysia from 2000 to 2014. The victims fell most frequently from balconies compared to the other elements, i.e., windows, corridors, or stairs (Table 4). From the cases examined in the present study, from the questionnaire responses, and in the opinions of experts, falls from a balcony were often linked to an apartment's furniture arrangement, in particular, the furniture location relative to the balcony. The balcony space and the view from it were also factors that influenced the behaviour of victims. Children are inclined to climb balconies to reach for objects, e.g., to retrieve an object lying outside the balcony. In these circumstances, children might slip, lose their balance, and fall. Furniture and domestic appliances on the balcony, such as washing machines, are often used by children as climbing aids.

A spacious balcony is an attractive playing space for children, increasing the likelihood of them falling from there. This is especially dangerous in cases where adult supervision is lacking. Exacerbating the problem is poor balcony design in terms of child safety. In urban settings, falls from balconies have been recognised as a significant cause of injuries and deaths. Case studies and expert opinions suggest that in the majority of such cases, children climb and fall over the balcony railings, or they fall from between the railings.

In cases where children fall from high-rise windows (the second most important element in this study), the window design has an important bearing.

Protective grills and screens, as well as child-proof latches, would help reduce untoward incidents. While adult supervision would obviously make a major difference, the fact remains that a parent had been in the home/apartment when most of these accidents occurred. Therefore, parental perceptions that window screens are effective fall barriers might give a false sense of confidence, leading to them being less vigilant. Household furniture placed on balconies or close to windows contributed to almost one-fourth of the falls from high-rise apartments. Many parents did not realise that furniture and appliances helped their children gain access to a window opening.

Table 4: Fatal child falls from high-rise buildings

No	Years	Victim	Place	The cause of the accident
1.	2015	Male (5 years)	Eighth floor of an apartment in Taman Nirwana, Ampang	Fatal fall from the balcony of the eighth floor of an apartment in Taman Nirwana, Ampang
2.	2015	Male (3 years)	Ninth-floor apartment in Teluk Air Tawar	Climbing stacked boxes before falling out of the window
3.	2014	Male (8 years)	15th Floor of a Housing Flat in Ulu Pudu, Cheras, Kuala Lumpur.	Playing at fifteenth level before falling off the porch / balcony building
4.	2014	Male (2 years)	Apartment Elite Level 4, Putra Perdana, Sepang	Climbing the balcony before falling
5.	2014	9 years	Ninth-floor flat Taman Bukit Angkasa, Pantai Dalam, Kuala Lumpur	Slipped after climbing the balcony
6.	2014	8 years	Corridor fifth-floor apartment, Amazing Height, Sungai Udang Klang	The child tried to take the rubber ring on the fifth-floor corridor of his apartment ledge backfired as he slipped before falling to the ground floor
7.	2010	Male (6 years)	Falling from the 12th floor of an apartment in Selayang	The victim had fallen from the balcony of the 12th floor of a 20-storey building while left alone
8.	2004	Female (3 years)	14th Floor, Flat Pelangi Damansara, Kuala Lumpur.	Fell while playing on a bicycle leaning against the wall of the corridor

9.	2004	Male (6 years)	Fourth Floor, Flat Bijangga, Dungun, Kuala Terengganu, Terengganu.	Fell from windows because of emulating a superhero
10.	2003	Male (6 years)	Level 7, The Condominium Putramas, Puchong	Fell while playing on the balcony
11.	2002	Female (3 years)	Ninth Floor, Apartments Sri Panglima A, Bukit Saujana, Johor Baharu, Johor.	Climbed and fell out from window
12.	2001	Male (3 years)	Level 31, Condominium Sri Smart, Jalan Putra, Kuala Lumpur.	Climbed up and opened the window of the room before falling from the window
13.	2001	Male (3 years)	Level 18, Kinta Heights, Ipoh, Perak	Climbed a washing machine placed on a balcony

Sources: Adapted from National House Buyers Association (2015) and Releases Report (2001-2015).

CONCLUSION

In high-rise buildings, the absence of safety and preventative designs are causing more deaths and serious injuries from falls from such buildings. Young children falling from high buildings has been recognised as one of the most common causes of injuries and deaths. Falls from the balconies, windows, corridors, and stairs of apartments are less likely to result in death. Regulations are an important element of child safety and accident prevention. Many successful injury prevention interventions directly involve or are dependent on regulations and standards. Regulations can influence behaviour, products, or the environment in which children find themselves. Hence, building codes and standards in high-rise buildings should be continually improved and updated. The introduction of municipal standards for child safety in high-rise buildings must be considered. With careful planning and attention to detail, it is possible to incorporate many such principles into a building or development to improve child safety in high-rise buildings.

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Received: 19th August 2021. Accepted: 10th November 2021

