DWELLING FIRE SAFETY EVACUATION (DFSE): A SYSTEMATIC REVIEW

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ABSTRACT

Fire is an ignition of heat and smoke materials, which can pose a significant life and property threat. Residential fire in Malaysia has a high percentage of fire cases due to electrical sources, cooking appliances, defective of equipment, careless and negligence. Evacuation during fire is the most critical features in building safety. This includes the utilization of Building Information Modelling (BIM) in developing a good and efficient fire evacuation. This research paper aims to propose and established a conceptual framework of Dwelling Fire Safety Evacuation (DFSE). This paper utilizes the technique of systematic overview from previous research which includes journals, conferences proceedings, reports, framework and guidelines. The outcome of this paper consists the elements of dwelling fire safety evacuation including the element of Fire Scenarios (i.e., Fire characteristic, Building characteristic and Occupant characteristic), Influences Perceived Risk (i.e., Individual-Based, Physical and Social), Survival Strategy (i.e., extinguish, shelter and evacuation) and Safety (i.e., shortest time and awareness) which contributed to the development of the conceptual framework. These findings will assist the extended investigation of DFSE for accidental fire situations.

Keywords: Dwelling fire, Fire evacuation, Fire safety

1. INTRODUCTION

In comparison with other types of disaster, fire poses an crucial threat to life and property in urban and rural areas (Xin & Huang, 2013a).Fatalities caused by an outbreak of fire are mostly high around the world. The statistic shows at the beginning of early 21st, 6300 million people worldwide were killed annually, varying from 7,000 to 80,000 and about 5,000 to 8,000 people were injured by fire (Yenumula, Kolmer, Pan, & Su, 2015). The fluctuating number of fires in Malaysia from 2011 to 2017 is shown in Table 1. Besides that, there are around 6,000 sites annually destroyed by fire and 2,400 sites involve private homes, put between 120 and 150 people die annually in fires (Fire and Rescue Department Malaysia, 2017). This statistic shows an alarming number that there is a lack of fire safety awareness among home dwellers in Malaysia (Fire and Rescue Department Malaysia, 2017; Sulaiman, 2006)

Table 1: Number of Fire cases in Malaysia

Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Number of Fire Cases	28741	29848	33640	54540	40865	49875	29356

In addition, Table 2 shows the statistics of dwelling fires in Malaysia that increases by year. As for Malaysia, faulty electrical sources are at the top of the listing among all the sources of fire risk with 877 cases being reported in the past seven months as well a total of 457 cases out of the 914 electrical accident cases reported are fatal and 15.5% of such cases happened at home(Shefee, 2017).

Table 2: Number of dwelling fires in Malaysia

Year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2016**	**2017**
Number of Dwelling Fire	1840	2781	2968	3063	2998	3341	3261	3011	3696

Fire is an incident of initiating and burning materials that can produce heat and smoke (Kobes, Helsloot, de Vries, & Post, 2010), many causes have been highlighted including electricity, cooking appliances, faulty or misuse of equipment, careless in fire or hot substances(i.e. cigarette disposal by smokers) (Babrauskas, 2013; Crown, 2010; Rahim, 2015). Besides that, caused of fire ignition also include lighting (Andersson, Johansson, & Strömgren, 2015; Quintiere, 2017; Xin & Huang, 2013a), leaking of gas (Tan, Akashah, & Mahyuddin, 2016), candles (Crown, 2017; Holborn, Nolan, & Golt, 2003; Quintiere, 2017), alcohol (Holborn et al., 2003), disregard of safety rules (Xin & Huang, 2013a) and forgotten stove (Andersson et al., 2015).

Dwelling is defined as a shelter which include residence places, house, hotel, dorm or apartment in which people lives (Merriam-Webster, 2017) where accidental fires include incidents where the cause was 'unknown' or 'unspecified' (Crown, 2010). Dweller can determine the design purpose of their constructing though making sure that the elements of design are operated effectively, such as closed the door and maintained alarm system with a suitable plans and practiced to make certain safe evacuation from dwelling during fire event (EOBA, 2017).

Moreover, the most critical feature of safety for building in fire event is evacuation (Kinateder, Kuligowski, Reneke, & Peacock, 2015) or opportunity to safely escape from fire (Kobes et al., 2010). There are three basic activities in the evacuation process, which include: (1) external hazard awareness stimulus;(2) confirmation and reaction to the hazard or danger indicator; and (3) safe travel or refuge (Kobes et al., 2010). Delay in evacuation behaviours may cause occupants to be trapped in a hazardous area (Grindrod, 2014). Meanwhile factors that determine survival strategy of the people in the building during fire include fire characteristic, human characteristics and building characteristics(S. H. Wang, Wang, Wang, & Shih, 2015).

2. RESEARCH METHODOLOGY

The aim of this research is to establish a conceptual framework for DSFE. The method used for this research is by reviewing of literature from internet sources and databases which include Google scholar, SCOPUS, Science Direct, and National Fire Protection Association (NFPA) International Association for Fire Safety (IAFSS) that consists of conferences proceeding, journal, report, framework, and guidelines from year 2001 until year 2018. Besides that, the use of reference management software (i.e., Mendeley) and a set of keywords including "accidental ignition", "dwelling fire", "dwelling fire evacuation", "fire evacuation", "fire emergency evacuation", "evacuation modelling", "fire risk", "fire statistic", "human behaviour in fire", "home fire", "fire fatality", "fire evacuation guideline", "occupant evacuation model" were also considered. This literature search method as shown in Figure 1 has followed the 4 steps for systematic literature review. There were 102 papers which have been reviewed, yet only 44 papers were being selected to be uses in this paper. Besides that, the statistical and government sites in Malaysia with online publication and reports were also being accessed to get a statistic on dwelling fire. The focus of this paper is on emergency evacuation of Accidental Dwelling Fire (ADF).

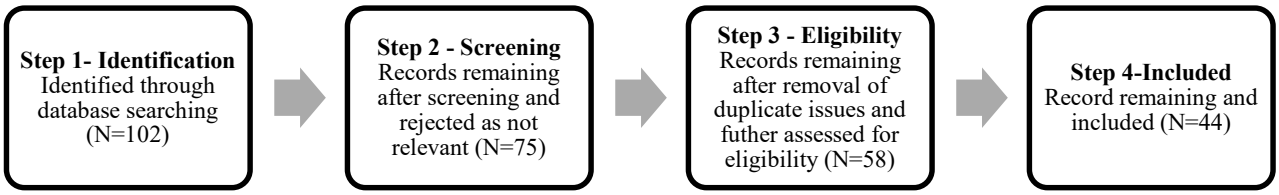

Figure 1. Literature search method

3. LITERATURE FINDING

The results of the existing search of literature revealed several potential variables associated with the evacuation of fire safety in dwelling which consists of fire scenario, influence of perceived risk and safety or survival strategies.

3.1 Fire scenario

Fire is defined as a chemical reaction between three elements which known as "fire triangle" that consists of heat, or an ignition source, fuel and oxygen to be present for the reaction to take place and continue (OSHA, 2018), whereby chronological set of fire that interrelated with success or failure of fire protection systems or actions is defined as fire scenario(Xin & Huang, 2013a). Furthermore, Health and Safety Authority(2019) stated that it is compulsory to remove one of the three elements in the fire triangle in order to stop the fire. Besides that, Fire triangle also needed in understanding the fire sources and also the method of extinguished and prevent fire(OSHA, 2018).Therefore, fire characteristic and fire classification is important in identified for the selection of exact method in extinguish fire(Brady, 1994).

3.1.1 Fire characteristic

Table 3 lists the 11 examples of fire characteristic identified from previous researchers such as nature of fire, fire ignition, flame, fire spread, fire growth, smoke, heat/temperature, flashover, toxicity, location of fire and perceptual features.

Table 3: Characteristic of Fire

Characteristic of Fire	Author
Nature of fire	(Kobes et al., 2010)
Fire ignition	(Andersson et al., 2015)
Flame	(Andersson et al., 2015)
Fire spread	(Andersson et al., 2015; Kobes et al., 2010; Siong, 2017; Xiong et al., 2017; Zhang & Issa, 2015)
Fire growth	(Kobes et al., 2010; S. H. Wang et al., 2015)
Smoke	(Andersson et al., 2015; Kobes et al., 2010; S. H. Wang et al., 2015; Xiong et al., 2017; Zhang & Issa, 2015)
Heat/temperature	(Kobes et al., 2010; S. H. Wang et al., 2015; Xiong et al., 2017)
Flashover (sudden event in fire growth).	(Andersson et al., 2015)
Toxicity	(Kobes et al., 2010; S. H. Wang et al., 2015; Zhang & Issa, 2015)
Location of fire	(Kobes et al., 2010)
Perceptual features (visual, smelling, audible, tangible)	(Kobes et al., 2010)

According to Kobes et al. (2010), the characteristic of fire is refer to fire shape, fire size, fire spread, fire duration and fire emission of smoke. Furthermore, the characteristic of fire will influence the respond and behaviour of building occupant towards fire situation (Crown, 2010). Moreover, the important of fire spread is really needed for seeing the route of evacuation during fire(Babrauskas, 2013).

3.1.2 Fire Classification

The classification of fire can be categorized by the material that cause of fire ignition (OSHA, 2008). The classification of fire that needed in choosing the correct fire extinguisher can be classified in four (4) classes which include Class A, Class B, Class C, Class D and Class K as stated in Table 4.

Table 4: Fire Classification

Class	Material	Example
A	Ordinary solid combustible materials	Paper, wood and textile fibres
B	Flammable liquids and gases	Gasoline, thinners, oil-based paints and propane
C	Energized electrical components	Short circuit, faulty wiring, power cord damages, overcharged devices and overloaded electrical outlet.
D	Combustible metals	Magnesium, sodium, potassium, titanium and aluminium
K	Oils and Fats	Vegetables oils, animal fats

3.1.3 Boundary conditions

Building characteristic and occupant characteristic is the element of building condition that need to be considered during fire breakout. Occupant characteristic (i.e., numbers of floor and floor layout) and building characteristic (i.e., occupant numbers, locations, speed and size) will needed for the simulation of evacuation model(Zhang & Issa, 2015). In addition, the behaviour of building occupant may needed the component of characteristic of fire, characteristic of building and also characteristic of occupants in order to find the interaction between the entire outcome of fire event and the progress of improvement(Proulx, 2001).

3.1.4 Building characteristic (CH)

Building is defined as the structure which individuals live and are in need of fire safety hence the absence of management in facilities and improper instruction presents a fire danger for the evacuees (Yenumula et al., 2015). According to Shi et al.(2009), Building Characteristic (BC) can be classified by the characteristic of architecture, activities of building, and building fire safety features. Furthermore, building is physically enclosed environment in which human are present to carry their activities therefore there are direct impact of BC during fire breakout. Hence, BC is considered as an important element that need to be considered in the design of building fire safety(Wang et al., 2015). Besides that, BC also consists of building information such as indoor space, architectural structure and utilities of emergency which important needed to describes accurately the interaction between object of indoor and analysing an individual's evacuation routes(Kobes et al., 2010).

As for that matter, Table 5 lists the elements of Building Characteristic that were found by previous researchers which are important to be considered in fire evacuation. The characteristics of building include structural layout information, size of building, number of floors fire compartmentation, location of fire started, number of people in building, containment (unit spaces within building), physical distance between units, suppression equipment, emergency utilities, element of rescue in external and internal design of building, types of material uses for the building, architectural structure, engineering, indoor space, ease of finding a way through the building and lastly the maintenance of the building.

Table 5: Characteristic of Building

Characteristic of Building	Author
Structural layout Information	(Kobes et al., 2010; S. H. Wang et al., 2015a; Xiong et al., 2017; Zhang & Issa, 2015)
Size of building	(Kobes et al., 2010)
Number of floors	(Andersson et al., 2015; Zhang & Issa, 2015)
Fire Compartmentation	(Andersson et al., 2015)
Location of fire started	(Andersson et al., 2015; Xiong et al., 2017)
Number of people in building	(Andersson et al., 2015; S. H. Wang et al., 2015a)
Containment (unit or spaces within building)	(Kobes et al., 2010; Siong, 2017; S. H. Wang et al., 2015a)
Physical distance between units	(Siong, 2017)
Suppression equipment (fire extinguishers/fire blankets)	(Siong, 2017)
Emergency Utilities	(Xiong et al., 2017; Zhang & Issa, 2015)
Element of rescue in the external and internal design of building	(Siong, 2017)
Types of material use for the building	(Siong, 2017; S. H. Wang et al., 2015a)
Architectural structure	(S. H. Wang et al., 2015a; Xiong et al., 2017)
Engineering	(Kobes et al., 2010)
Indoor space	(Xiong et al., 2017)
Ease of finding a way through the building	(Kobes et al., 2010; S. H. Wang et al., 2015a)
Maintenance	(Kobes et al., 2010; S. H. Wang et al., 2015a)

3.1.5 Characteristic of occupants (OC)

Occupants need to reach a place of safety during building fire emergencies. Human factor has an important impact on a successful evacuation during fire emergency. In addition, Figure 2 shows the characteristics of building occupants that include personality traits, position and consciousness, knowledge and experience, power of observation and judgement, power of movement, familiarity with layout and social features (Xin & Huang, 2013b).

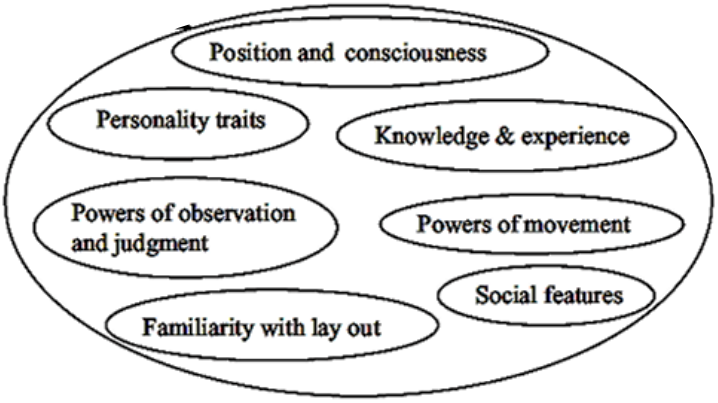

Figure 2: Behaviour scenario of the building occupants
Source : Xin & Huang, 2013a.

In addition, Table 6 shows characteristic of occupants during fire situation that consist of personality, personal behaviour, individual characteristic, demographics, attitude, travel speed, movement types, sizes, observational abilities, responsibility for other evacuees, familiarity with building layout, individual capacities, number of occupants, location of occupants and lastly perceptual features of the occupant.

Table 6: Characteristic of Occupant

Characteristic of Occupant	Author
Personality	(Kobes et al., 2010; Wang et al., 2015)
Personal Behaviour	(Kobes et al., 2010; Liu, Rui; Du,Jing; Issa, 2014; Proulx, 2001; Tan et al., 2016; Xiong et al., 2017; Yenumula et al., 2015)
Individual characteristic	(Kobes et al., 2010)
Demographics	(Andersson et al., 2015)
Attitude	(Shi et al., 2009)
Travel speed	(Kobes et al., 2010; Tan et al., 2016; Zhang & Issa, 2015)
Movement types	(Grindrod, 2014; Kobes et al., 2010; Xiong et al., 2017)
Sizes	(Kobes et al., 2010),(Tan et al., 2016; Zhang & Issa, 2015)
Observational abilities	(Wang et al., 2015)
Responsibility for other evacuees	(Kobes et al., 2010; Wang et al., 2015; Zhang & Issa, 2015)
Familiarity with building layout	(Kobes et al., 2010; Wang et al., 2015)
Individual capacities	(Kobes et al., 2010)
Number of occupants	(Zhang & Issa, 2015)
Location of occupants	(Zhang & Issa, 2015)
Perceptual features (seen, smell, heard)	(Kobes et al., 2010)

According to Kobes, Helsloot, Vries and Post (2010), Speed of building occupant, size, behaviour and movement types are interrelated in identifying route of evacuation. Furthermore, occupant types of movement can be divided into two sections which are horizontal escape (i.e., escape within next storey exit of the floor) and vertical escape (i.e., protected stairwell or building outside) that can be select according to necessary requirement and factors of travel time needed.

Performance of individual responds during fire are related to the direct and influences of human nature that consist of behaviour in term of characteristic of individual (i.e., personal) and characteristic of group (i.e., social and situational)(Kobes et al., 2010).Moreover, fire evacuation guideline have to deal with the building occupant which may have a different types of behaviour that typically absence of coordination strategies(Liu, Rui; Du,Jing; Issa, 2014). Besides that, the most important factor on the success and failure of the evacuation due to human behaviour and reaction are still unpredictable and complex to be predict in forecasting the emergency time and evacuation result(Liu, Rui; Du,Jing; Issa, 2014).

Furthermore, the absence of date given to individuals regarding existing conditions frequently affects the efficiency of an incident emergency reaction (Grindrod, 2014). This is due to the behaviour of occupant's pre-movement(defined as the fast movement of occupant to evacuate when alarm sounding) which assumed to be an important and significant element for the fire survival compared to actual speed of movement(Grindrod, 2014).

3.2 Influence of perceived risk

Risk perception is described as a subjective (conscious and unconscious) evaluation of the likelihood that an imminent undesirable event will affect in a particular scenario and an assessment of the individual's perceived vulnerability and coping capacity (Kinateder et al., 2015). Risk perception is important to be identified and understand due to the influences of fire evacuation transition from pre-evacuation to evacuation behaviour due to the fact that the choice of occupants to evacuate is possibly reliant on risk perception (Kinateder et al., 2015) as individual level of risk taking moderately unpredictable across situations (Nicholson, Soane, Fenton-O'Creevy, & Willman, 2008). According to Zinn (2015), a risk reduction strategy dominates the existing risk analysis, which would prevent and unwanted risk taking. However, this strategy often does not take into account the wider circumstances and risk-taking motives which lead individuals to risk them in danger especially during fire evacuation.

The factor influences perceived risk in dwelling fires can be classified into three factors which include individual based, physical and social. Individual based factors that influence perceived risk is summarised in Table 7

while Physical factors are listed in Table 8.

Table 7: Individual based factors

Individual based factors	Authors
Personnel Behaviour	Crown (2017); Kobes et al. (2010); Zhang & Issa (2015)
Individual Characteristic	Holborn et al. (2003); Kobes et al. (2010); Zhang & Issa (2015)
Psychological States	Holborn et al. (2003); Kobes et al. (2010); Xiong et al. (2017); Zhang & Issa (2015)
Traits of An Individual	Kobes et al. (2010)
Age	Crown (2017); Holborn et al. (2003); Kobes et al. (2010)
Gender	Crown (2017)
Movement Types and Characteristic	Kobes et al. (2010); Xiong et al. (2017)
Sizes	Xiong et al. (2017); Zhang & Issa (2015)
Speed	Xiong et al. (2017); Zhang & Issa (2015)
Pre-Movement Index	Kobes et al. (2010); Zhang & Issa (2015)
Population and Activity Profile/Capacity	Kobes et al. (2010)
Visual Access/Way Finding Design	Kobes et al. (2010)
Perceptible Characteristic *(e.g.: Seen. Smell, Heard)*	Kobes et al. (2010)
Knowledge and Experience	Kobes et al. (2010)
The Power of Observation and Judgement	Kobes et al. (2010)

Table 8: Physical factors

Physical factors	Authors
Environment	Kobes et al. (2010); Zhang & Issa (2015)
Building Information	Kobes et al. (2010); Xiong et al. (2017)
Building Layout	Kobes et al. (2010); Xiong et al. (2017); Zhang & Issa (2015)
Nature of Fire	Kobes et al. (2010); Tan et al. (2016)
Fire Ignition	Holborn et al. (2003); Tan et al. (2016)
Space	Xiong et al. (2017)
Fire Spread	Xiong et al. (2017); Zhang & Issa (2015)
Interaction Among Building Element	Xiong et al. (2017); Zhang & Issa (2015)
Architectural Structure	Kobes et al. (2010); Xiong et al. (2017); Zhang & Issa (2015)
Emergency Utilities	Holborn et al. (2003); Tan et al. (2016); Xiong et al. (2017)
Facilities Management	Kobes et al. (2010)
Material of Building Structure	Kobes et al. (2010); Tan et al. (2016); Zhang & Issa (2015)
Mean of Escape	Kobes et al. (2010); Zhang & Issa (2015)
Size of Building	Kobes et al. (2010)

Table 9: Social factors

Social factors	Authors
Behaviour of others	(Kobes et al., 2010; Zhang & Issa, 2015)
Social Attribution	(Kobes et al., 2010; Xiong et al., 2017; Zhang & Issa, 2015)
Social Deprivation	(Holborn et al., 2003)
Social Economic characteristic	(Tan et al., 2016)

3.3Survival strategies

According to Kobes et al (2010), survival strategy consists of extinguish, shelter and evacuation. Evacuation is defined as the process of rapidly removing building occupant from hazard and treat to a safe place for the needs of save lives (Fire and Rescue NSW, 2018; Yenumula et al., 2015).

3.3.1 Fire Evacuation Plan/Guideline

According to Lujak et al. (2017), the most significant thing in which occupants survive to fire is quickest and effective evacuation. The fire guideline is the element that evacuees must take into consideration in term of emergency evacuation to create a safe and effective evacuation process. Furthermore, an adequate plan and guidelines for fire evacuation can also assists reduce incorrect decisions and hesitations in the event of fire crisis (Pericleous, 2015). However according to Pericleous (2015), only individuals who had examined or participated in emergency drills will be able to behave calmly and save property and life. Yet as stated by Ismail (2018) in the case of a fire or even how to avoid a fire, individuals are still unwilling to respond. Therefore the time for the individual for evacuate in save their life will increase in emergency cases(Lujak et al., 2017).

However it may be possible for additional of exits or extend means of egress and stairs if the model is brought near completion or reaching detailed design phased (Zhang & Issa, 2015). Besides, according to Pericleous (2015) procedure of fire prevention, preparedness, mitigation, respond arrangement and strategy and Emergency Control Organization (ECO) roles and responsibilities are the important elements that need to be include in fire evacuation plan. Hence it is significant o have a sound fire evacuation plan to avoid unnecessary loss of life and property (Stancik, Machacek, & Horak, 2018). In addition, fire evacuation plan must be kept up to date throughout the building life service in order to maintain the effectiveness of the plan (Stancik et al., 2018).

According to Civil Defence Emergency Management (2008),there are 11 phased that need to be considered in developing evacuation model which include selection of authority to plan, gather of planning team, assemble of analysis community, assessment of hazard and risk, defined of planning objective, determine of roles and responsibilities, establish of plan development and the process of evacuation management, arrangement of agreed document, validation of plan, address absences of plan and lastly plan review. These procedure and features are essential in creating an accidental fire evacuation model.

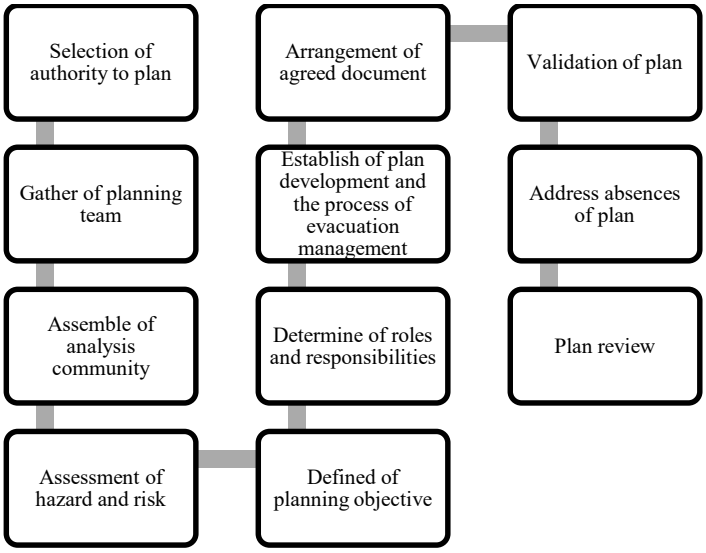

Figure 3: Evacuation Planning Model

In the purpose for minimize evacuation time and to avoid critical condition, evacuation model is needed to find the critical factor which can affect the process of dissimilar condition of fire evacuation. Development of evacuation model need six aspect to be considered which consists of delay in evacuation time(occupant aware on emergency alarm and respond); walking speed of occupant(crowded of horizontal and vertical stairway); occupant

characteristic(differences of occupant action and reaction); action of occupant during evacuation (increase time needed for occupant to evacuate); obstruction effect in evacuation route(egress block or delay) and occupant choice of exit decision(determination of travel path and times) (Shi et al., 2009).

In addition, Building Information Modelling (BIM) has being used wisely as a tools in planning evacuation route due to the effectiveness in visualizing 3D dimension image and also for data information storage to be use for planning, construction and operation or maintenance of building construction project besides facilitate the management of fire safety in building (Wang et al., 2015). According to Ma, Jia and Zhang (2017), the use of BIM technology leads to accurate direct rescue to a more effective evacuation during fire and convenient evacuation drills. Besides that, BIM may also deliver data of 3D geometric for assessment and planning of fire safety (i.e., assessment of evacuation, planning of escape route, and education of safety) towards safety building management by storing of information for property and safety management using equipment of maintenance module in Web Based Environment (S. H. Wang et al., 2015).

Furthermore, geometric data that created by BIM model might be utilized to recognize the potential individuals' area, for example, rooms, passageways and staircases other than used to assess the openness of indoor spaces dependent on the design and space utilization that recovered from BIM model (Li, Becerik-Gerber, Krishnamachari, & Soibelman, 2014). Moreover, fire evacuation model that based on BIM tech ology may also clearly display the location of the safe exit by providing the location and quantity of fire hydrant, fire shutter and other fire equipment's besides giving an accurate information of fire evacuation and emergency rescue (Ma et al., 2017). Besides that, BIM proposed system which can identifies the best route and actives the respective sign blinking with high intensity may enhance the efficiency of signing system by heat sensors that detect fire proposed areas in the building (Yenumula et al., 2015). Additionally, the use of BIM with serious gaming technologies can create an adoptable virtual reality environment to improve fire evacuation plans during the entire life cycle as well as to explore human behaviour during an emergency fire (B. Wang, Li, Rezgui, Bradley, & Ong, 2014).

3.4 Safety

Evacuation in emergency situation intended toward reducing the entire time of evacuation the building's occupant in order to avoid injuries(Liu, Mao, & Fu, 2016). Proulx (2001) also stated that during fire situation, delay in evacuation would result in a building's life risk. Moreover, according to Zhang & Issa (2015) fire safety can be achieved if the required evacuation time is shorter than the available safe evacuation time.

According to Sulaiman (2006) , Malaysian community have a low level of fire safety awareness. Most of the structural fires can be avoided if the fire safety awareness among community is increased (Chew, 2017). It is also found that the key to reduce loss of life, personal injuries and damage from fire disaster is by extensive public awareness and education (National Research Council, 1991). Furthermore, fire safety training can provide fire protection measures such as evacuation plans, training, drill, shelter area and safe lifts to prevent fire from occurring and help to minimize the required time evacuation and encourage occupants to move faster (Xin & Huang, 2013a). In addition, the increasing use of innovative fire safety technologies also may helped in increase fire safety (Quintiere, 2017).

4. PROPOSED CONCEPTUAL RESEARCH FRAMEWORK

Based on the findings from the Systematic Literature Review, this paper proposed a conceptual framework consisting the characteristics and factors that need to be considered to establish emergency evacuation plan for Accidental Dwelling Fire (ADF). Using an analytical tools that has several variations and contexts, a conceptual framework is used to generate conceptual differentiation and perceptions (Yacob, Saruwono, & Ismail, 2017). The suggested conceptual framework consisted of four (4) key elements of DSFE, namely Fire Scenario, Influence Perceived Risk, Survival Strategies and Safety.

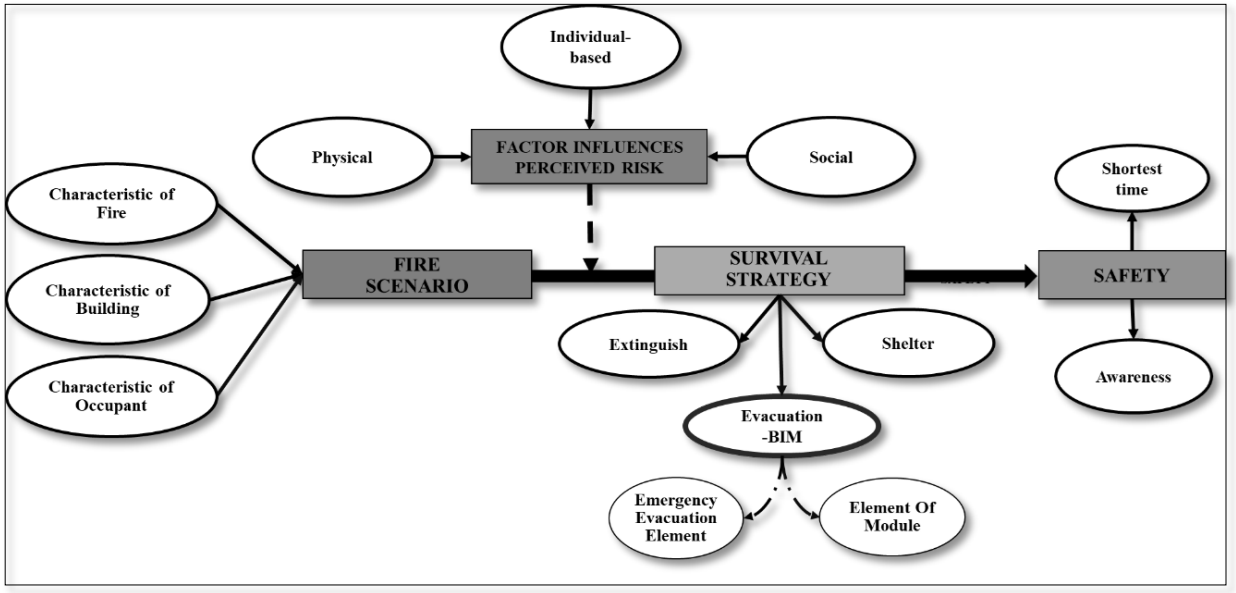

Figure 4: Proposed Conceptual Research Framework

The first component is *Fire Scenarios* which consists of the characteristics of fires, characteristics of building and characteristics of occupants. Fire scenarios is generally determining the degree of fire response performance in the event of fire since characteristics of fire have a direct influence on the degree of fire response performance. Besides that, characteristics of building also has a direct impact due to physically enclosed environment in which occupants exist and activities were carried out. The building environment and evacuation behaviour are key factors for the performance of building evacuation whereby characteristics of occupants has a direct influence on the degree of fire response performance during fire evacuation.

The second component is the *factor influences perceived risk* that include the element of individual-based, physical and social. This component is important to be considered because it may influence the survival strategy taken by occupant during fire in order to achieve safety evacuation. The third component is *Survival Strategy* that consist of extinguish, shelter and evacuation. However, this framework is focusing on the evacuation survival strategy due to the important of evacuation as predominant life safety strategy during fire emergency. Also, in this framework, BIM technology for building evacuation guidance has been included to create an effective and scientific dwelling fire evacuation model. BIM model will help in visualizing building environment by identifying the floor and staircase for escape from the building, store all data and records about fire safety equipment which may increase the effectiveness of maintenance, and helps users to memorize and understand hazardous areas with 3D representation.

Lastly the fourth component is *Safety* that include shortest time and awareness. Fire safety may be improved by having the evacuation activities in shortest time. It is because the longer the time taken for fire evacuation, the higher the risk of fire towards the number of injuries and fatalities. Besides that, increase of fire safety awareness also may reduce the risk of fire breakout in dwelling. This is due to the fact that by having knowledge regarding the fire safety in dwelling, the occupants may be more alert and aware about their surrounding situation which may cause fire occurrences.

In addition, the modelling of evacuation will assist to allow a systematic assessment in a specific evacuation scenario and describe the specific threats that may arise through evacuation phase that related to survival in minimum time taken.

5. CONCLUSION AND RECOMMENDATION

In conclusion, the idea of the study is to provide an overview of safe fire evacuate in dwelling. Therefore, the paper contribution is to fill the gaps of research on Dwelling Fire Safety Evacuation by providing the characteristics of fire scenarios, factors influences perceived risk in fire emergency, evacuation survival strategy with the application of BIM technology and safety in order to improve the survival rate when fire occur as well as reducing fire risk in

dwelling and increases awareness among home dweller. A systematic review of literature research method was employed with the 4 steps process consist of identification, screening, eligibility and included sources for systematic literature review which involve 44 papers of research. This research is conceivable only in literature and previous studies that give valuable inputs for academics and practitioners. The study's concept is relatively new and could be developed further. However, empirical research is suggested to be conducted to reinforce and validate results in order to replicate, analyse and validate the connection between components of the proposed conceptual framework as structural model for statistical analyses. Therefore the potential respondent for the research will be Fire and rescue Department, Ministry of Urban Wellbeing, Housing and Local Government and survival of ADF.

6. ACKNOWLEDGEMENT

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7. REFERENCES

Andersson, P., Johansson, N., & Strömgren, M. (2015). *Characteristics of fatal residential fires in Sweden - SP Report 2015:53*. Sweden: SP Technical Research Institute of Sweden. Retrieved from https://www.brandskyddsforeningen.se/globalassets/brandforsk/bostadsbrander/rapporter/characteristics-of-fatal-residential-fires-in-sweden.pdf

Babrauskas, V. (2013). Some Neglected Areas in Fire Safety Engineering. *Fire Science and Technology*, *32*(1), 35–48. https://doi.org/10.3210/fst.32.35

Brady, J. (1994). Putting out fires. *Revolution (Staten Island, N.Y.)*, *4*(2), 38–39. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/23842066

Chew, R. (2017). Majority of structural avoided res can be. Retrieved December 6, 2018, from http://www.theedgemarkets.com/article/majority-structural-fires-can-be-avoided

Civil Defence Emergency Management. (2008). *Mass Evacuation Planning*. Wellington: Ministry of Civil Defence & Emergency Management. Retrieved from https://www.civildefence.govt.nz/assets/Uploads/publications/dgl-07-08-mass-evacuation-planning.pdf

Crown. (2010). *Fire Statistics in United Kingdom , 2008*. *Department for Communities and Local Government*. London: Crown. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/11746/Fire_Statistics__United_Kingdom_2008.pdf

Crown. (2017). *Detailed analysis of fires attended by fire and rescue services , England , April 2016 to March 2017*. Retrieved from www.nfpa.org

EOBA. (2017). *Framework for Enhancing Fire Safety in Dwellings where concerns arise*. Retrieved from https://www.housing.gov.ie/sites/default/files/publications/files/framework_for_enhancing_fire_safety_in_dwellings.pdf

Fire and Rescue Department Malaysia. (2017). A burning issue. Retrieved November 5, 2018, from https://www.nst.com.my/opinion/leaders/2017/11/304224/burning-issue

Fire and Rescue NSW. (2018). Evacuation. Retrieved January 16, 2019, from https://www.fire.nsw.gov.au/page.php?id=75

Grindrod, S. E. (2014). Information Driven Evacuation System (I . D . E . S .) The University of Edinburgh.

Health & Safety Authority. (2019). Fire Prevention. Retrieved July 18, 2018, from https://www.hsa.ie/eng/Topics/Fire/Fire_Prevention/

Holborn, P. G., Nolan, P. F., & Golt, J. (2003). An analysis of fatal unintentional dwelling fires investigated by London Fire Brigade between 1996 and 2000. *Fire Safety Journal*, *38*(1), 1–42. https://doi.org/10.1016/S0379-7112(02)00049-8

Ismail, Z. (2018). Fire Safety Saves Lives. Retrieved January 16, 2019, from https://www.star2.com/health/2018/01/19/fire-safety-saves-lives/

Kinateder, M. T., Kuligowski, E. D., Reneke, P. A., & Peacock, R. D. (2015). Risk perception in fire evacuation behavior revisited: definitions, related concepts, and empirical evidence. *Fire Science Reviews*, *4*(1), 1. https://doi.org/10.1186/s40038-014-0005-z

Kobes, M., Helsloot, I., de Vries, B., & Post, J. G. (2010). Building safety and human behaviour in fire: A literature review. *Fire Safety Journal*, *45*(1), 1–11. https://doi.org/10.1016/j.firesaf.2009.08.005

Li, N., Becerik-Gerber, B., Krishnamachari, B., & Soibelman, L. (2014). A BIM centered indoor localization algorithm to support building fire emergency response operations. *Automation in Construction*, *42*, 78–89. https://doi.org/10.1016/j.autcon.2014.02.019

Liu, Rui; Du,Jing; Issa, R. R. A. (2014). Human Library for Emergency Evacuation in BIM-Based Serious Game Environment. In *2014 International Conference on Computing in Civil and Building Engineering* (Vol. 3). American Society of Civil Engineers (ASCE). Retrieved from https://ascelibrary.org/doi/10.1061/9780784413616.068

Liu, C., Mao, Z. L., & Fu, Z. M. (2016). Emergency Evacuation Model and Algorithm in the Building with Several Exits. *Procedia Engineering*, *135*, 12–18. https://doi.org/10.1016/j.proeng.2016.01.072

Lujak, M., Billhardt, H., Dunkel, J., Fernández, A., Hermoso, R., & Ossowski, S. (2017). A distributed architecture for real-time evacuation guidance in large smart buildings. *Computer Science and Information Systems*, *14*(1), 257–282. https://doi.org/10.2298/CSIS161014002L

Ma, J., Jia, W., & Zhang, J. (2017). Research of building evacuation path to guide based on BIM. *Proceedings of the 29th Chinese Control and Decision Conference, CCDC 2017*, 1814–1818. https://doi.org/10.1109/CCDC.2017.7978811

Merriam-Webster. (2017). Dwelling Definition. Retrieved July 19, 2018, from https://www.merriam-webster.com/dictionary/dwelling

National Research Council. (1991). *A Safer Future: Reducing the impacts of Natural Disasters*. Washington: National Academy Press. https://doi.org/10.17226/1840

OSHA. (2008). *Guidelines for Emergency Response Planning*. Retrieved from http://osha.gov.tt/Portals/0/Documents/guidelines_for_emergency_response.pdf

OSHA. (2018). Fire Protection and Prevention. Retrieved from https://www.osha.gov/dte/grant_materials/fy09/sh-18796-09/fireprotection.pdf.

Pericleous, A. (2015). How a Fire Evacuation Plan Can Save Lives. Retrieved January 16, 2019, from http://www.firesafeservices.com.au/firesafe/how-a-fire-evacuation-plan-can-save-lives

Proulx, G. (2001). Occupant behaviour and evacuation. *Proceedings of the 9th International Fire Protection Symposium*, 219–232. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.11.202&rep=rep1&type=pdf

Quintiere, J. G. (2017). *Principles of Fire Behavior* (Second Edi). New York: CRC Press Taylor & Francis Group. Retrieved from file:///C:/Users/USER/Downloads/9781498735643_preview.pdf

Rahim, M. S. N. A. (2015). The current trends and challenging situations of fire incident statistics. *Malaysian Journal of Forensic Sciences*, *6*(1), 63–78. Retrieved from http://www.forensics.org.my/pdf/fssmVol.6No.1/Article 09.pdf

Shefee, S. (2017). *Faulty electrical sources top list as cause of fires*. Retrieved from https://www.thestar.com.my/metro/metro-news/2017/12/02/faulty-electrical-sources-top-list-as-cause-of-fires-authorities-warn-against-using-imitation-gadget/

Shi, L., Xie, Q., Cheng, X., Chen, L., Zhou, Y., & Zhang, R. (2009). Developing a database for emergency evacuation model. *Building and Environment*, *44*(8), 1724–1729. https://doi.org/10.1016/j.buildenv.2008.11.008

Siong, C. L. (2017). Is your building a death trap？ Retrieved November 5, 2018, from http://dev.bizedge.com.my/article/your-building-death-trap

Stancik, A., Machacek, R., & Horak, J. (2018). Using BIM model for Fire Emergency Evacuation Plan. In *MATEC Web of Conferences* (Vol. 01012, pp. 1–6). EDP Sciences. https://doi.org/10.1051/matecconf/201814601012

Sulaiman, A. (2006). *Exploring Fire Safety Awareness Among the Malaysian Public*. Retrieved from http://eprints.usm.my/28882/1/EXPLORING_FIRE_SAFETY_AWARENESS_AMONG_THE_MALAYSIAN_PUBLIC.pdf

Tan, Y. R., Akashah, F. W., & Mahyuddin, N. (2016). The analysis of fire losses and characteristics of residential fires based on investigation data in Selangor, 2012-2014. *MATEC Web of Conferences*, *66*, 00109. https://doi.org/10.1051/matecconf/20166600109

Wang, B., Li, H., Rezgui, Y., Bradley, A., & Ong, H. N. (2014). BIM based virtual environment for fire emergency evacuation. *Scientific World Journal*, *2014*, 22. https://doi.org/10.1155/2014/589016

Wang, S. H., Wang, W. C., Wang, K. C., & Shih, S. Y. (2015). Applying building information modeling to support fire safety management. *Automation in Construction*, *59*, 158–167. https://doi.org/10.1016/j.autcon.2015.02.001

Xin, J., & Huang, C. (2013a). Fire risk analysis of residential buildings based on scenario clusters and its application in fire risk management. *Fire Safety Journal*, *62*(PART A), 72–78. https://doi.org/10.1016/j.firesaf.2013.09.022

Xin, J., & Huang, C. F. (2013b). Fire Risk Assessment of Residential Buildings Based on Fire Statistics from China. *Fire Technology*, *50*. https://doi.org/10.1007/s10694-013-0327-8

Xiong, Q., Zhu, Q., Du, Z., Zhu, X., Zhang, Y., Niu, L., … Zhou, Y. (2017). A Dynamic Indoor Field Model for Emergency Evacuation Simulation. *ISPRS International Journal of Geo-Information*, *6*(4), 104. https://doi.org/10.3390/ijgi6040104

Yacob, R., Saruwono, M., & Ismail, Z. (2017). Effects of Uncertainty Factors and Refurbishment Projects Performance in Relation To Leadership Quality of Project Managers. *Journal of Building Performance*, *8*(1), 2180–2106. https://doi.org/http://spaj.ukm.my/jsb/index.php/jbp/article/view/238

Yenumula, K., Kolmer, C., Pan, J., & Su, X. (2015). BIM-Controlled Signage System for Building Evacuation. *Procedia Engineering*, *118*, 284–289. https://doi.org/10.1016/j.proeng.2015.08.428

Zhang, J., & Issa, R. R. A. (2015). Collecting fire evacuation performance data using BIM-based immersive serious games for performance-based fire safety design. *Congress on Computing in Civil Engineering, Proceedings*, *2015-Janua*(January), 612–619. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-84936889791&partnerID=40&md5=6f700c61fad042a3b2face0dee32ffb9