Identification of fire safety indicators for shopping centre buildings in Surabaya

G F Marantika1, M A Rohman1*, F Rachmawati1 and I P A Wiguna1

1 Department of Civil Engineering, Faculty of Civil, Planning and Geo Engineering, Sepuluh Nopember Institute of Technology, Surabaya, East Java, Indonesia.

*Corresponding author's e-mail: arif@ce.its.ac.id

Abstract. The convenience of shopping and getting entertainment at the same time is an advantage which is offered by the shopping centres. But the different functions of building and the crowds of visitors at the shopping centre inflict a greater risk of fire. Therefore, the safety against fire needs to be considered by the shopping centres in order to make users and the building structures more secure. Current fire safety regulation is still dominated by the standards and the codes from NFPA. The lack of conducting researches and knowledge related to fire safety affects the suitability and the application of regulations in Indonesia. This research aimed to identify the fire’s safety criteria according to the current local conditions of shopping centres. A survey was conducted by distributed questionnaires. The variables used in the questionnaire were obtained based on the literature studies and then it was assessed by several experts. According to the experts’ judgment, all variables are relevant with the current local conditions and there were three new variables added in this research. The result showed that the construction practitioners needed to improve their knowledge related to the fire safety in shopping centre starting from the initial stages of design.

1. Introduction
The movement of people from rural areas to urban areas or urbanization is a common phenomenon that is found around us. It triggers the economic growth of a region and the level of community wages positively, and then it will affect the pattern of public consumption. Besides, the industry’s development always presents a variety of goods and services, and also advances science and technology encourage the modern lifestyles to be more consumptive. These phenomena make the retail businesses such as Shopping Centres develop rapidly.

The shopping centre is not only as a place for economic transactions to meet their needs, but it has another purpose such as to get entertainment and to interact socially. Visiting the shopping centre has become a culture that spreads in society regardless of age, economic status, and social status. Based on this phenomenon, the construction practitioner makes a project to build a Shopping Centre to support the market demand. Similar with the other buildings, Shopping Centre needs to suit with the quality of building, this is one of the main keys that need to be considered by the construction practitioner in planning and constructing a building.

The quality of a building is assessed from the structure’s readiness, the functions’ fulfilment, and the reliability’s fulfilment and the feasibility of buildings. These criteria determine that the building has
been suited with the technical standards and the administration of quality buildings. This is confirmed in Undang-Undang Number 28 in 2002 about The Building Construction and also The Minister of Public Works and Public Housing’s Regulation Number 29/PRT/M/2006 in 2006 about The Guidelines on Technical Requirements for Buildings. One of the things which is regulated in these regulations regarding the building structure standards in supporting loads and the ability to dealing with hazards, including fire.

The danger of fire can be defined as any situation that trigger a fire or explosion, and then it can threaten life or property [1]. The building and its system, human activities, and fire establish a complex system that creates the dynamic changes in fire behaviour. In the shopping centre buildings, the different functions of buildings create a greater fire risk to the building itself. The different building functions affect the design of fire response system [2].

The safety guarantees in shopping centre need to be a major concern from the planning stage until the operational stage. Indonesia has regulations that are stated in Minister of Public Works and Public Housing’s Regulation Number 26/PRT/M/2008 about The Technical Requirements for Fire Protection Systems in Buildings and Environments and equipped with normative references such as SNI, that regulates the building planning procedures, fire prevention and fire protection that focus on the main safety controls, namely the physical control of buildings, management control, and human control. Until nowadays, the safety standards for fire still based on National Fire Protection Association (NFPA) 101 Life Safety Code [3]. A few researches had been found according to the local conditions in Indonesia. These researches should become the basis of current regulatory standards.

There are also deficiencies and negligence of the current standards application in Indonesia. According to [4], the gap between regulatory standards and fire protection systems in buildings is based on the lack of knowledge about building management and fire protection standards. Some components are not implemented according to the standards and the regulations. Besides, the shopping centre buildings design that tends to be complex with different functions also allows the building was not designed effectively according to the applicable standards. Based on the statement above, it is necessary to review whether the applicable standards are following the current local conditions and whether there are still deficiencies that need to be added to the existing standards.

2. Literature review

2.1. The concept of fire safety

The fire safety can be defined as a set of practices to prevent fires, manage fire growth, and manage the fire effects either intentionally or unintentionally while keeping the resulting losses at an acceptable level [5]. There are four main goals of fire safety, namely the life safety, the protection of building contents, the protection of building structures, and the minimization of threats to the environment [6]. The fire safety can be achieved through preventive and protective measures [7].

2.2. Fire safety criteria

Safety The safety against fire can be achieved by controlling how the combustible materials such as solids, liquids, and gasses that is available in an environment. When there are cases where a fire ignites, the amount of fire growth can be controlled because flammable materials have a limited amount. The structural stability also has an important role because it can help localize the fire, enable safe rescue operations by the fire fighters, and prevent property loss due to the collapse of entire buildings [5].

The carrying capacity of construction loads and structural elements is very important to be considered by the construction practitioner. One of the burdens that must be able to be ensured by a structure is the accidental events such as fire. If the functions change of a building modifies the life span of the building and it produces the enhancement of incombustible material, then to keep up the structure’s stability, it is
necessary to repair the structural system or the amount of fire exposure needs to be reduced into the original structure stage of building which is able to withstand loading [6].

The fire detectors functions are to detect fire growth that can be a threat to the building users. The detector is a device that will produce a signal that can be captured, used, and forward it to other devices in order to give a warning. The detectors can be categorized according to the type of these devices detection [8], [6]. Furthermore, the signal that is sent will be forwarded to the system control unit, and then it will process the alarm to sound and inform the building user that there is fire [8]. The purpose of fire alarm system is to begin the evacuation process by giving as early notice as possible that fire has been identified [9].

When fire has been detected, then the further efforts are needed to control the fire including controlling the fire, suppressing the fire, and extinguishing the fire. Controlling the fire means limiting the growth of the fire, suppressing the fire means reducing the size of the fire and extinguishing the fire means stopping the fire completely [10]. The sprinkler is an automatic fire suppression tool. While it can use a system of standpipes and hoses manually which allows the water supply to reach outlets on each floor of the building [5].

A smoke management system must be installed to provide the fire safety in large spaces. The smoke exhaust systems can work in keeping smoke at a certain level effectively. The height of smoke exhaust system follows the fire size and the buoyancy generated by fire [6], [11]. Besides the good smoke management, the existence of escape route signs from the room and information about what needs to be done in the event of fire is very important to make sure the safety of building users' lives. Lane markers make it easier for the building users to find the escape routes [6]. Fire safety management is the last thing to be a concern. Fire safety plans must be prepared before, not only by the building manager but also including the designer team at the earliest design stage. There must be a prevention and maintenance plan until the staff training plan [10].

Based on the results of literature identification, it found that there were 18 variables that could be seen in Table 1 below.

| No. | Variable                                                                 | Source                      |
|-----|--------------------------------------------------------------------------|-----------------------------|
| 1.  | Available fuel such as flammable liquid, flammable solids, and flammable gases inside building can be controlled. | [5], [6], [12]             |
| 2.  | Building structure is able to withstand fire.                           | [5], [6]                    |
| 3.  | Fire compartment in building is able to inhibit the spread of fire according to planning time. | [5], [12]                   |
| 4.  | Fire detectors installed in building are able to detect fire.           | [6], [8], [12]             |
| 5.  | Fire alarm systems in building is working properly.                    | [8], [12]                   |
| 6.  | Water source in building are sufficient to extinguish fire.            | [5]                         |
| 7.  | Water tank to extinguish fire in building are separated from daily water tank. | [5]                         |
| 8.  | Automatic fire suppression devices in building such as sprinklers can reduce fire growth. | [6], [8], [10], [13]       |
| 9.  | Manual fire extinguishing devices such as standpipe and fire hose are able to supply water to extinguish fire each floor. | [5]                         |
| 10. | Smoke control system can drain smoke outside the building.            | [6], [11], [14], [15]      |
| 11. | Exit signs inside the building are easily found.                       | [5], [6]                    |
12. Fire escape routes including emergency stairs inside the building are safe from fire. [5], [12]

13. Exit path from the front of the building to the evacuation point free of obstacles. [5], [6], [12]

14. Emergency lighting inside building works well. [12]

15. Special area for parking of fire trucks in building are always available. [5]

16. Fire fighters are involved in fire control in building. [5]

17. Fire protection inspection as an effort to prevent fire in building. [16], [17], [18]

18. Information regarding the procedures for evacuation and emergency contact during fires can be accessed by building users. [6], [8], [16], [19]

2.3. The concept of shopping centre
A Shopping Centre is a group of other retail and commercial businesses that are planned, are developed, and are managed as a single property, that consist of multi-brand commercial rental units and public areas [20]. The rapid population growth in urban areas and the number of people who live alone or independently, for example those who work at home or live in isolated suburbs, it encourages the rise of business places with a variety of products, services, and facilities, such as the building of Shopping Centre [2]. Shopping Centre customers not only buy for certain products but also do another things including getting entertainment [21].

3. Research methodology
After having variables identification from literature review, it was followed by the process of preparing a survey questionnaire. The preparation was done by adjusting the variables that had been known. Then, the variables were modelled in the form of statements to be measured. The chosen method for compiling the questionnaire was Likert scale. Likert scale had four or more questions which were combined in the questionnaire to create a score that represented the individual traits [22]. The measurement scale that was applied to measure the respondents' perceptions of the building safety criteria in shopping centre towards the fire was 1 to 5 scales. Scale 1 reflected an intensely irrelevant assessment while on the contrary, scale 5 was for a highly relevant.

Furthermore, a preliminary survey was conducted by the researchers. This survey was a survey which was conducted by several resource persons (namely: the experts) in order to verify the suitability of the research variables which were obtained from the literature study process according to the current local conditions. From this activity, it was able to be found out whether the existing variables were well-suited or it might need a reduction or addition of a new variable. This survey had been conducted by sending questionnaire and interviews with the experts, which was produced the relevant variables. The experts had been requested to give a variable relevance scale according to the range of the available scale.

The data was obtained from the survey results then were analysed by the researchers. The initial step taken by the researcher was checking the respondents' answers completeness in questionnaires. This activity purposed to check if there were any incomplete or unclear answers. The data was sorted based on the results of checks and was prepared for the data cleaning process. Hereinafter the mean test on the answers of each respondent was collected by the researcher to know the mean score of the test. After that, the mean test results were sorted by rank.

4. Results and analysis
In this research, the preliminary survey results were described to find out the relevance level of several fire safety criteria in shopping centre building. The data analysis was conducted according to the research method.

The results of data analysis from the preliminary survey based on four experts could be seen in Table 2. According to [24], in general, the experts needed to conduct an assessment on a questionnaire tended to
be small. The research conducted by [25], [26], and [27] used two to four experts to participate in the research. Thus, there were four experts in this research were considered able to provide an assessment based on their knowledge and experiences.

The data analysis was begun by calculating the mean and the standard deviation of variables that had been assessed by an expert based on Likert Scale. Scales 1 to 2 were considered irrelevant, while scales 4 to 5 were considered relevant. For scale 3, the assessment weight was quite relevant, so scale 3 was also considered relevant.

**Table 2. The Variable of Fire Safety Criteria in the Shopping Centre Result**

| No. | Variable                                                                 | Rank | Mean | SD  | Conclusion |
|-----|----------------------------------------------------------------------------|------|------|-----|------------|
| 4.  | Fire detectors installed in the building are able to detect fire.          | 1    | 4.75 | 0.50| Relevant   |
| 5.  | Fire alarm systems in the building is working properly.                   | 2    | 4.75 | 0.50| Relevant   |
| 6.  | Water source in the building are sufficient to extinguish fire.            | 3    | 4.75 | 0.50| Relevant   |
| 11. | Exit signs inside the building are easily found.                          | 4    | 4.75 | 0.50| Relevant   |
| 12. | Fire escape routes including emergency stairs inside the building are safe from fire. | 5    | 4.75 | 0.50| Relevant   |
| 13. | Exit path from the front of the building to the evacuation point free of obstacles. | 6    | 4.75 | 0.50| Relevant   |
| 17. | Fire protection inspection as an effort to prevent fire in building.      | 7    | 4.75 | 0.50| Relevant   |
| 2.  | Building structure is able to withstand fire.                            | 8    | 4.50 | 0.58| Relevant   |
| 3.  | Fire compartment in building is able to inhibit the spread of fire according to planning time. | 9    | 4.50 | 0.58| Relevant   |
| 8.  | Automatic fire suppression devices in building such as sprinklers can reduce fire growth. | 10   | 4.50 | 0.58| Relevant   |
| 10. | Smoke control system can drain smoke outside the building.                | 11   | 4.50 | 0.58| Relevant   |
| 14. | Emergency lighting inside building works well.                            | 12   | 4.50 | 0.58| Relevant   |
| 18. | Information regarding the procedures for evacuation and emergency contact during fires can be accessed by building users. | 13   | 4.50 | 0.58| Relevant   |
| 1.  | Available fuel such as flammable liquid, flammable solids, and flammable gases inside building can be controlled. | 14   | 4.25 | 0.96| Relevant   |
| 16. | Fire fighters are involved in fire control in building.                   | 15   | 4.25 | 0.96| Relevant   |
| 7.  | Water tank to extinguish fire in building are separated from daily water tank. | 16   | 4.00 | 0.00| Relevant   |
| 15. | Fire fighters are involved in fire control in building.                   | 17   | 3.75 | 0.96| Relevant   |
| 9.  | Manual fire extinguishing systems such as standpipe and fire hose are able to supply water to extinguish fire each floor. | 18   | 3.50 | 1.00| Relevant   |
Based on the results of preliminary survey analysis which was conducted by the researchers, all variables were relevant. The highest mean of variable was fire detector with a value of 4.75 and the lowest mean of variable was a manual fire extinguishing system with a value of 3.5. There were 16 variables that were most relevant based on the experts with mean score were 4.00 to 4.75. The first variable was the fire detector. This variable was considered to provide safety in the Shopping Centre against fire, but good care was needed in order to make the devices function properly. The same thing applied to the second variable, it was the fire alarm system. The third variable was the water source in the Shopping Centre always might be available with a discharge according to applicable regulations. The fourth to sixth variables were the exit sign, fire escape route, and exit path, these needed to be considered in order to ensure the building user safety. The seventh variable, which was the fire protection inspection, it was needed to be checked routinely so that it could detect more easily whether the protection device was functioning properly or not. The eighth and ninth variables were the structure of buildings and compartments in Shopping Centre should be planned well from the beginning of development. The tenth variable was automatic fire suppression, it would function very well if the placement was adjusted to a combustible material and certain areas were considered to be very vulnerable to fire. The eleventh variable was the smoke control system, it was deemed necessary to be well designed and to pay attention with the air conditioning in the room. The twelfth variable was emergency lighting inside the shopping centre, it was very necessary during the evacuation process; therefore the equipment for emergency lighting must always be ready and functioning properly. The thirteenth variable was the information about how to escape during a fire, it might be available in a place that was visible easily and it might be understood easily, so that this information could be used during the evacuation process. The fourteenth variable was available fuel. It should be considered in quantity and then controlled for their uses so it could be adapted to the fire extinguish equipment. The fifteenth variable was the involvement of fire fighter. It was needed in the process of fire control in according to the main tasks and the purpose of fire fighter. The sixteenth variable was a separate water tank for extinguish the fire. It was needed with the capacity adjusted with applicable regulations.

The experts also provided three new variables that were needed to be added in the existing variables. The first variable was the fire simulation, such as how to use the fire protection equipment, how is the evacuation process, how is the process of extinguishing fire as a preventive measure against fire as well as education for Shopping Centre users. The second variable was the analysis of shopping centre users including the level of knowledge, number of users, users’ experience, users’ gender, diffability, etc. The analysis of users’ behaviour was needed to understand how the behaviour of each individual in dealing with fire. This analysis was considered to be able to support the safety facilities that were available and allowed a fast and independent response from users so it could minimize the loss of lives due to the fire danger. [23] stated that there were three general aspects that affected the fire response model, such as the human aspect, the building aspect, and the fire aspect. The human aspect included individual, social, and situational aspect. The existence of knowledge about human behaviour in facing the fire was very important so the policy be measured could be effective. Furthermore, the last variable was the wide range of entrance and exit access also the wide range of the building perimeter for fire trucks used a ladder. The good design was needed from the start of planning so that the fire trucks could move without obstacles through the entrance and the exit access or around the building.

5. Conclusion and recommendation
Based on the background study and literature review, the researchers obtained that there were 18 variables of shopping centre buildings safety towards the fire danger. In the preliminary survey that was conducted by the researcher, it was found that all variables were relevant to the current local condition and 3 variables were added to complement the existing variables. It is hoped that this research has a contribution to increase the knowledge and it can be a reference research to help the building practitioners and shopping centre managers, also it can help the future research regarding the fire safety.
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