A Study on the development of fire safety educational project for occupants of multi-story residential building

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A study on the development of fire safety educational project for occupants of multi-story residential building

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Chapter 1. Prologue

1.1. Background

In many countries of the world, because of the urban population is expanding very fast. To address the urban population housing issue in the limited land, the high-rise residential building with high people density is the best choice. On the other hands, for each real estate enterprise, to build a high-rise residential building with high floor area ratio on the precious urban land is in their own interest as well. Such as almost all the newly built residence in China is high-rise residential building in recent years.

However, the high-rise residential building fire happened frequently all over the world. Especially the exterior fire that represented by the Grenfell Tower fire has become a new threat to the high-rise residential building. Many overseas high-rise buildings adopted thermal insulations that do not have vertical and horizontal compartmentations as the exterior wall materials. Once the insulation material is ignited, there is a high risk that the fire would easily spread both vertically and horizontally inside the panel with an updraft. Because of its characteristic that with high spread speed, the conventional compartmentation method could not function properly, and fire extinguishing activities are difficult as well. Similar fire spread mechanisms have caused significant economic and life loss in the UAE, China, Britain, and South Korea.

On the contrary, in some countries like Japan, the exterior thermal insulation method has not been adopted by most of the high-rise buildings, such fires have not occurred yet, so although there are some fire prevention officials who have been paid attention to it, from the reaction of the legislature and academia, society has not paid enough attention to it. From Professor Kyoichi Kobayashi's research, the current Building Standards Act has no request on the exterior material's incombustibility, the prevention of exterior fires only relies on the "voluntary standards" of construction companies are not reliable. Including commercial buildings, there is no possibility that such fires will not occur in Japan in the future.[1)]

Besides, with the signing of the Paris Agreement, many countries made their promise to decrease greenhouse gas emissions. For achieving this target, the zero-emission building is the key to the whole emission reduction system. Based on the experience of China, before China government signed the Paris Agreement, an energy-saving measure called Three-step Energy-saving has been implemented for several years. The content of the Three-step Energy-saving policy requested the buildings that were constructed in 1991-1999 should save 30% less energy than the building before 1991 as the first step, the buildings that were constructed in 2000-2004 should save 50% less energy than the building before 1991 as the second step, the buildings that were constructed after 2005

should save 65% less energy than the building before 1991 as the third step.[2] The key of this policy is strengthening the thermal insulation ability of the building's exterior wall. The thermal insulation material is made of polyurethane or polystyrene, this kind of foamed plastics' characteristic is that after gets heated for a period or lighted by fire, it could burn in the air. In the recent decades, several high-rise building fires that spread through exterior thermal insulation material occurred. Such as Beijing Television Cultural Center fire in 2009, Shanghai high-rise residential building fire in 2010 (58 deaths). This type of fire has been one of the focuses of fire safety work in China. After the signing of the Paris Agreement, the energy-saving measure has been a signatory policy for fulfilling the promise of emission peak and carbon neutrality in many countries. Such as in Japan, for achieving the goal, Japan government had made a promise that decreases 26% greenhouse gas emissions by 2030 compared to 2013. For achieving this target, Japanese government has established an energy-saving policy with three pillars of renewable energy, electric vehicles, and zero-carbon emission house.[3] However, according to expert estimates, even all the newly completed houses are zero-emission houses, the target of Paris Agreement still could not achieve. Therefore, the renovation of the existing residential building is necessary.[4] Based on the experience of Britain and China, the work of the existing residential building's renovation is adding additional thermal insulation layer to the exterior wall of the building. However, because of the characteristics of thermal insulation, the same issue like China has been happened several times in the world, such as Dubai the Marina Torch fire in 2017 and 2019, London Grenfell Tower in 2017 (71 deaths). Ulsan high-rise residential building fire in 2020 (93 injured). Although this type of fire still occupied small rates in home-structure fire, with the popularization of building thermal insulation measures, this type of fire and the countries that catch this type of fire may increase in the future. Considered the difficulty of firefighting and human rescue in the high-rise residential building, this type of fire has to be concerned from the aspect of fire prevention and fire rescue seriously.

To address such issues, the countermeasure proposed by each country's government could be summarized into two aspects, the aspect of the hard factor and the soft factor. The hard factor is to improve the technical ability in the field of fire prevention and fire rescue such as revise the code of architectural designing, develop new building material, or equip the device with the latest technology. The soft factor is to improve the management system, or people's awareness of fire safety through fire safety education or drill. For the high-rise residents of the residential buildings, because the evacuation in a high-rise residential building is much more difficult than any other residential building and the evacuation equipment that could evacuate residents fast could not popularize very soon by the economical or the technical factor. Therefore, fire safety

education is the most realistic way to improve the residents' ability to fire evacuation so far. The conventional method of fire safety education is mainly focused on improving people's knowledge of fire prevention and evacuation, the latest research of fire safety education has been focused improve the residents' ability of emergency response in the fire, or so-called "attitude response" in the fire.

1.2. Previous studies

1.2.1. OHNISHI Kazuyoshi's research[5)]

In OHNISHI Kazuyoshi's research, it based on the current situation of the elderly facility included the related law, designing, the behaviors of the staff in the elderly facilities, and combined with the case study of the elderly facilities' fire, to propose a new method of the fire education that called FIRE IMAGE GAME (short as FIG) for the elderly facility. It mainly focuses on the staff's decision-making ability when the fire occurs, the training covers the whole process that from initial firefighting to personnel statistics after evacuation. After the FIG training, the trainee could increase their knowledge or altitude or emergency response ability through group discussion.

Besides, as a supplementary method of FIG, the research prepared a fire safety knowledge supplement mini game in the form of SUGOROKU, to complete and enhance trainee's fire safety knowledge system before FIG.

As table 1-1 shows, the main body of the FIG for multi-story residential building's object and the preset scene is different from the FIG for the elderly facility. Based on the research on the fire safety awareness of the staff of the elderly facility, because of the objective conditions such as the installation of the fire safety equipment or fire safety management system is different from the residential building, the fire safety issue that the people focusing on is different as well.[6)] Besides, because of the real environment (Coronavirus pandemic). The proceed method would be completely different. Therefore, the research would be based on the ideology and methodology of FIG's development process for the elderly facility and combined with the principle of FIRE AND LIFE SAFETY EDUCATOR (short as FLSE) that published by the International Fire Service Training Association (IFSTA), OODA theory (Observation Orientation Decision and Action) and the characteristics of high-rise residential buildings and their residents, to develop a FIG for the high-rise residential building.

1.2.2. Hisaisha seikatsu saiken card (Victim's life reconstruction card)[7)]

This education game was developed by a lawyer, Nagano Kai. It mainly provides the knowledge of life reconstruction-related law and regulation. The game form is a sort of desk game. The cards are divided into "live reconstruction card" and "lifestyle card". 4-6 participants of the workshop would follow the procession of reconstruction, with the

Table 1-1 The difference between the FIG for the elderly facility and the FIG for the multi-story residential building.

Educational Program			Ohnishi's research	Ma's research
Object			The staff of the elderly facility	The occupants of the residential building
Characteristic of object	Hard factor	Evacuation route	Long and complicated in the horizon direction, Short in the vertical direction . (In general)	Short and in the horizon direction, Long in the vertical direction . (In general)
		Relate equipment's installation	Have obligation to install sprinkler (stricter)	The installation of sprinklers is a relaxation clause (loose)
	Soft factor	The management	Have obligation to conduct fire management (stricter)	Have fire management theoretically (loose)
		The related education experience	Have obligation to obtain professional fire education	No professional fire education
Preset Scenario	Scenario		The night fire of the elderly facility	The night fire of the residential building
	Content		Staff assist residents of elderly facility to evacuate together	The occupants evacuate by their own or with their family
Proceeding method			Workshop	Automatic remote control via smartphone

guidance of the coordinator who is familiar with the situation of the disaster area and related law system, to put the card into a checkerboard. Finally, the participants reproduce a process of the victim's life reconstruction through the card game. According to the workshop, trainees gather and discuss all sorts of possibilities in life reconstruction after a disaster such as an earthquake or tsunami.

Based on FIRE AND LIFE SAFETY EDUCATION (FLSE)'s definition of education, it is a program which includes information that increases knowledge and skills and encourages behavioral changes.[8)] From the participants' feedback, the method that simplified complex laws and regulations into graphics is proper for sending information to the participants. As a serious game, from the aspect of gaming, it lacks sufficient entertainment attributes. However, from the content of the education, it sent information about the post-disaster compensation to the participants, money-related content is good enough for motivating the participants' interest. Compared with this program, fire safety knowledge-related content is much more boring. For motivating the participants' interest, considering a game method that has much more playability is necessary.

1.2.3. Sonaeru Karuta (The Karuta of “get ready”)[9)]

This education game was developed by MITSUBISHI Estate Residence company. It mainly provides the knowledge of evacuation and disaster-prevention shelter management to the common residents and the manager of municipality. The game form is a sort of Japanese card game, Karuta. The cards are divided into ten types for confronting different issues in the process of evacuation in the disaster and life of the disaster-prevention shelter. This game covers the whole process from evacuation to life in the shelter. The participants could conduct a self-check of their preparation’s level for the disaster through cards’ Q & A program. One participant asks the question provided by the card, and another participant answers the question based on the current condition of their living place or awareness of the disaster. After the game, the participants would make a disaster-prevention plan through discussion or any other methods.

Sonaeru Karuta could implement its function that reminds the participants to prepare for the disaster. However, as an educational game, its playability is weak, and the content couldn’t motivate the participants’ interests in disaster prevention or mitigation. And the lack of amusement weakened the game’s function that could extend the audience.

1.2.4. Otsuki’s research[10)]

For strengthening the residents’ awareness of disaster mitigation from the dimensions of self-help and mutual aid in the community, the research developed a serious game called “R-DiSa”, and for expanding the education’s audience that includes kids and the elderly, the researcher chose SUGOROKU as the form of this serious game. And from the participants’ feedback, such form of the game could achieve the purpose that the researcher designed for.

From the research’s result, choosing serious games as an educational method is quite rare in the current domain of disaster mitigation or fire safety education. To achieve the purpose that extending the education’s audience, choosing an easy-to-play and amusement game is necessary like SUGOROKU. Besides, the evaluation method that is according to make comparison the attitude of the participants before and after the educational game is consistent with the concept of impact evaluation prescribed by FLSE. Therefore, the evaluation method of educational programs’ effectiveness has value to reference as well.

1.2.5. Disaster Imagination Game (Short as DIG)[11)]

DIG is a disaster-prevention training program developed by KOMURA Takashi, it mainly trains people that the emergency response ability when a disaster occurred. The operation method is that laying a vinyl sheet on the map, writing down the damage situation if the disaster occurred, the participants get together and discuss the countermeasure. Compared with the conventional training program, it could be able to

visualize problems and much easier to operate. Besides, it could be helpful to discuss the issues from the regional disaster prevention to specific drills base on the level of participants.

The FIG's development was inspired by DIG as well. However, the DIG was developed for large-scale disasters, many factors like personnel flow, material deployment, or the traffic condition in a wide area should be considered and addressed by the people from the municipality manager to specific residents. FIG was developed for a fire case that occurred in one specific building such as an elderly facility or residential building. Although the scale of the scenario is much smaller than a disaster, the condition and environment's changing is much faster, the related personnel should make the decision much faster with high stress, it requests them to have a better ability of information acquisition and judgment. With the limit of the venue's scale, after appropriate information's judgment, the option for issue-addressing is much simpler than the people who confront disaster. Therefore, compared with DIG, FIG needs its participants to pay more attention to information acquisition and judgment ability.

1.3. Method

For achieving the purpose, the research proposed a new fire safety educational program, the program aims to strengthen occupants of multi-story residential buildings' fire safety ability from the level of attitude and emergency response. The educational plan includes two parts, FIG and SUGOROKU. For developing the FIG, the researcher determined the content and form of the educational program through literature review and comparative research. And determined the current situation of the fire spreading pattern, residential building's floor plan, and human behavior through cases study, comparative research, and analysis. Then reference the methodology of Ohnishi's research, to design a preset scenario for FIG from both hard factor and soft factors. Because of the Corona pandemic, to avoid close contact and ensure the effect, the research changed the proceeding method of the FIG, to develop a program that could be operated on a personal terminal through the internet.

For strengthening the effect of FIG, the participants need to warming-up and supplement the related knowledge before the formal training begins. For extending the education's audience, the game method chose boardgame that with the attribute of easy-to-play and amusement. And combined with typical fire cases that occurred in recent years to propose a fire safety game.

The educational program was tested in China, it was posted on a questionnaire platform, WJX.cn, and evaluated the effect of the program through questionnaires.

1.4. The structure of the research

The structure of the research as figure1-1 shows.

At first, the research determined the FIG's content and form according to reference the FLSE's definition and classification, and comparative research between the United States, China and Japan's current situation of the fire safety education. It like a constitution of the whole educational program, the advancement of the design should be carried out in accordance with this framework.

The content of the FIG could be separated into two big categories, the hard factor category and soft factor category.

Hard factor category includes the analysis of fire spreading pattern, the code or law of the architecture's fire safety designing, and the floor plan of high-rise residential buildings. The hard factor is the main basis of FIG's scenario designing.

The soft factor category includes the analysis of human behaviors of multi-story residential building fire. The soft factor is the basis of the SUGOROKU and FIG's form and specific decision-making option's setting.

After hard factor and softer factor's research, the research would propose a new educational program, it includes fire safety SUGOROKU and the FIG for the multi-story residential building, and evaluate the effectiveness of the whole fire safety program through questionnaire research.

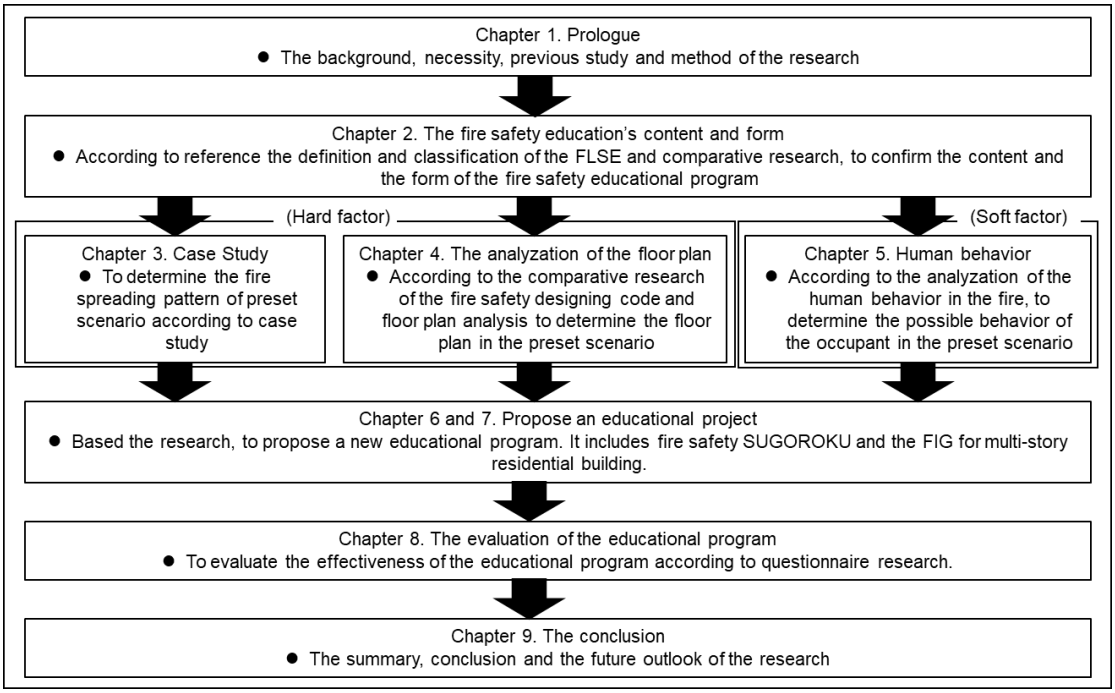

Figure 1-1. The structure of the research

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Chapter 2. The form of FIG

2.1. Introduction

In this episode, the research would introduce the fire safety education system of China, the United States, Japan from the aspect of the law system and the education system through comparative research. Then these contents would lead to the description of the FIG form's setting.

2.2. The development of the fire safety education

2.2.1. The United States

In the early 1970s the United States government estimated that approximately 12,000 citizens were being killed annually in fires.[1)] This number had exceeded the number of soldiers who died in the Vietnam war.

By 1972, under the direction of President Nixon, the federal government had studied America's fire problem and produced a landmark report entitled America Burning. The report called for an integrated approach to fire prevention using a combination of preventive interventions.[2)] It made many recommendations. Among them were the following:

Place greater emphasis on fire prevention.

Provide better training for fire fighters.

Educate the American public about fire safety.

Improve the safety of living environments through design and materials.

Improve the fire protection features of buildings.

Enhance research into how and why fires occur.

Through these milestone recommendations, the United States Fire Administration (USFA) and the National Fire Academy (NFA) were created. Building codes, standards, and built-in fire protection began to improve. Fire experience research was enhanced dramatically and eventually led to the development of the National Fire Incident Reporting System.[3)]

After the report was published, the US government published the FEDERAL FIRE PREVENTION AND CONTROL ACT OF 1974 so that support fire safety education from a legal perspective.

By the end of 1970s, the USFA and the NFA were offering a number of advanced training programs on how to reduce fire risk in the community. NFPA established a professional qualification standard for fire prevention education officers, and the International Fire Service Training Association (IFSTA) published the manual IFSTA 606, Public Fire education in 1979.[4)]

It took until the mid-1980s for residential fire deaths to fall to an annual occurrence of between 4000 and 6000. According to the USFA, 3320 civilians lost their lives as the result of fire in 2008.

While this manual is titled Fire and Life Safety Educator (F.L.S.E), its content promotes using a broad spectrum of integrated strategies to prevent or mitigate community risk through public education, technology, and leadership.[5)]

2.2.2. China

The first document that fire safety education was involved in was published by the state council in 1957. It pointed out that it is necessary to deliver extensive fire safety education work for the public, raise the fire safety vigilance of the public, and popularize fire safety knowledge. At that time, the job of fire safety education tended to focus on "prevention", the method of education is post fire protection slogans and banners.[5)] It could be seen as beginning of fire safety education.

Until the 1980s, with the development of the economy, the local government and society paid more and more attention to fire safety education. It became an important part of fire departments' daily work. Besides, with the development of technology, the method of fire safety education was extended to the radio, television, newspaper, and magazine. The content was no longer limited to "prevention", the "firefighting" was included.[5)]

By 1998, the Fire Control Law was enacted and promulgated by the National People's Representative Meeting. It clarifies the responsibilities and obligations of governments at all levels and relevant authorities in fire safety publicity and education. [5)] The fire safety education had support from a legal perspective.

In 2002, China's government published Fire Safety Management Regulation for departments, parties, enterprises, and public institutions. It requests all these units have obliged that provide fire safety education to their staff, and residents management organizations have obliged to provide fire safety education to their residents. In Public Space, the related administrators have obliged to publicize fire safety knowledge. It emphasized the specific unit's obligation in fire safety education.

2.2.3. Japan

After World War II, with the order of GHQ (General Headquarters), the fire department was rebuilt in 1946. In 1947, at the request of GHQ, fire department dispatched a large number of firefighters to prevent and guard against fires in buildings related to the expeditionary forces. The GHQ gave the dispatched staff strong authority over fire prevention measures. From this event, the related department have accumulated experiences for shifting from passive firefighting, which used to only extinguish fires, to active firefighting with administrative authority and focusing on fire

prevention. This became the cornerstone for the subsequent establishment of preventive administration.[6)]

In 1948, the Fire service act was published, as an important part of fire prevention, the certificated fire managers of related buildings have obliged to making and operating the fire safety plan. As a part of the fire safety plan. Based on the eighth article of fire service law, the fire manager has an obligation that provide fire safety education to the personnel of the buildings.

2.3. The law support of fire safety education

2.3.1. Introduction

This chapter mainly introduced the specific content about law support to the fire safety education in the United States, China and Japan. For the obligation to provide fire safety education, these three countries have related request.

2.3.2. The specific article related to fire safety education

2.3.2.1. United States

In the FEDERAL FIRE PREVENTION AND CONTROL ACT OF 1974, section 6.

The Administrator is authorized to take such steps as the Administrator considers appropriate to educate the public and overcome public indifference as to fire, fire prevention, and individual preparedness. Such steps may include, but are not limited to, publications, audiovisual presentations, and demonstrations. Such public education efforts shall include programs to provide specialized information for those groups of individuals who are particularly vulnerable to fire hazards, such as the young and the elderly. The Administrator shall sponsor and encourage research, testing, and experimentation to determine the most effective means of such public education.[7)]

This section briefly describes the method, purpose and target population of fire safety education as well.

2.3.2.2. China

In the Fire Control Law, Chapter one, Article six.

Each level of people's government should organize and deliver regular fire safety publicity and education to improve citizens' awareness of fire safety. Departments, organizations, enterprises, public institutions, and any other units should strengthen the fire safety publicity and education of their own personnel.[8)]

2.3.2.3. Japan

In Fire Service Act, Article 8.

In school, hospital, factory, business place, entertainment Place, department store, multiple-use fire prevention object and many other objects which have exit, work, or reside functions in the fire prevention object specified by a Cabinet Order, a fire manager

is determined from those who have the qualifications stipulated by a Cabinet Order. The fire manager should formulate a fire safety plan, all the necessary works in fire management should follow the fire safety plan such as fire extinguishing, the training of report and evacuation……other work necessary for fire prevention management must be performed.[9)]

From the content of each countries' fire safety-related law, all these three countries' basic laws prescribe the related personnel has the obligation that provides fire safety education to the public. Besides, in the United States, it has an extra request about workload and content for the educators according to NFPA 1035 standard. Considered when each state adopted the standard, it would have equal status with the law. Therefore, those requests for the educator are mandatory. The comparative content as the table 2-1 shows.

Table 2-1 The comparison of fire safety education's law support

Country	The obligation of fire safety education provision	The certification of fire safety educator
The United States	FPCA 1974	NFPA 1035
China	Fire law	NONE
Japan	Fire service act	NONE

2.4. The executive body of fire safety education

2.4.1. Introduction

The executive body of fire safety education means the organization or personnel who operate the fire safety education. As table 2-2 shows, this part would introduce the executive body of fire safety education.

2.4.2. United States

In the United States, the executive body of fire safety education is not only fire service personnel who work in the fire department, but also any fire safety-related organization or institution that could provide fire safety education, the educator should be certificated by the standard NFPA 1035. Such a system could ensure the quality or workload of fire safety education and the fire safety educator's teaching ability.

2.4.3. China

In China, the executive body of fire safety education is the local fire department or enterprise-owned fire department. The fire departments' firefighter provides fire safety education to the public or government-sponsored institutions (hospital, school, etc.). The

job occupation-related fire safety education was provided by their enterprise-owned fire safety department.

2.4.4. Japan

In Japan, the executive body of fire safety education is not only fire service personnel who work in the fire department, but also any fire safety-related organization or institution that could provide fire safety education like a Non-profit organization or university. However, both China and Japan have no certification system to ensure the quality or quantity of fire safety education, and the situation that fire safety educators' teaching ability could not be ensured as well.

Table 2-2 The comparison of fire safety education's executive body

Country	Executor	Certification
The US	Fire related institution and department	Certificated*
China	Fire department	Uncertificated
Japan	Fire department, NPO, University, etc.	Uncertificated

2.5. The proceeding method of fire safety education

Based on FLSE's definition, the method of fire safety education could be divided into two types, formal educational methods and nonformal educational methods. The formal educational methods include:

1. Lecture. In a lecture, the educator talks, explains, and tells. Whiles this can be an effective means of sending information to the audience, there is only one-way communication. That is, there is no real opportunity for feedback or a means for measuring understanding. Lectures can be uninteresting and a barrier to effective communication. Lectures are useful with large groups and can be effective for providing factual information.

2. Discussion. Unlike the lecture method, discussion allows for the audience and the educator to interact. The educator is able to exchange views and opinions with the audience/students. The educator is able to ask and answer questions, provide examples, and measure understanding. The discussion method is ideal when the target audience already has some basic knowledge about the subject.

3. Illustration. The illustration method is useful either with the lecture method or the discussion method. The educator shows something to the audience. With illustration, the educator simply shows the item or a picture of an item; no behavior is performed or demonstrated.

4. Demonstration. Demonstration is used when teaching the audience a skill. The educator actually performs the task step-by-step for the audience and then allows the audience to perform the task.

5. Team teaching, Team teaching is where a group of educators work together in a presentation for a single educational objective. Team teaching is appropriate where the material is perhaps too broad for one instructor or when more than one perspective is needed. Team teaching is also a way of building relationship with other organizations, agencies begin to work together on programs and projects.

6. Web-based/ interactive. No discussion of educational techniques would be complete without at least touching on the use of Web-based or computer-interactive instruction. This is certainly a viable form of instruction and one that is definitely on the increase in many different arenas.[10)]

The nonformal educational methods include:

1. Role play. Participants take turns acting out a prepared situation.

2. Case study. A detailed story about a situation.

3. Brainstorming. Participants speak out with any sudden idea, no matter how impractical.

4. Sharing. Participants freely exchange knowledge, ideas, and opinions on a subject.

5. Problem solving. Participants do a particular task that should lead to a desired result.

6. Small group discussion. Participants divide into smaller groups to discuss or perform a particular task. The group comes back together for a large group discussion.[11)]

In the process of fire safety education, nonformal educational methods are widely used in conjunction with formal education methods to enhance effectiveness.

2.6. The content of fire safety education

2.6.1. Introduction

Based on fire safety education's purpose, the content of fire safety education could be divided into three levels. As the figure 2-1 shows. (Figure 2-1)

The first level is the most basic level, for sending the related information to the public, the first step is drawing the public's attention to be aware of the importance of fire safety. Therefore, inspiring the public's interests or concern the fire safety through telling them the risk of fire or any other methods that could draw the public's attention is the first step of fire safety education. It always is the initiation stage of one group's (from a community to a country) fire safety education. And this stage keeps in a continuous state in daily life in order to affect more groups of people.

Figure 2-1 The pyramid of fire safety education's content level

After drawing the public's attention to fire safety, then comes to the second level, sending the knowledge of fire safety, the knowledge includes:

1. Fire prevention. Fire management and habits in daily life.

2. Firefighting. The measure of the initial fire's extinguished, the method of firefighting equipment's operation.

3. Evacuation. The method of evacuation in the fire. Basic knowledge of situation judgment.

This level is the core of most countries' current fire safety education. And most countries' current fire safety education stops on this level.

After the public has mastered considerable fire safety knowledge, they started to confront with one issue, when and where did they use this knowledge. This issue is on the third level of fire safety education content, attitude and response. This level is the most difficult for the public, they should combine the fire safety knowledge and the experience of their daily life, to judge what can be done to prevent the fire occur, or save themselves in the fire.

Then the content about which level of fire safety education was achieved by the United States, China and Japan would be introduced in the next part.

2.6.2. The United States

For the current situation of fire safety education in the United States, In the first and second levels, the United States government has a mature system to promote fire safety education. It has various textbooks to teach the fire safety educator step-by-step for how to design a fire safety education project, the process includes from planning to execution

to evaluating the whole project finally. The educator could even select content from multiple sets of textbooks and combine their own circumstances to form a set of their own fire safety educational project.

In the first level, National Fire Protection Association (NFPA) create the cartoon character Sparky the Fire DOG in 1954, and through this cartoon character to launch a series of publicity about fire safety until now. The fire departments in various regions also cooperate with the media like television, radio or newspaper, or movie stars on specific days and hold a series of activities to promote fire safety through various methods, such as Fire Chief for a Day.

In the second level, different fire safety-related organizations or institutes have developed multiple sets of fire safety education programs for front-line educators to choose from. Such as NPFA's "Remember when" program, USFA's "Fire Safe Seniors" program, American Burn Association's "Fire safety for older adults", IFSTA's "Fire and life safety educator". These textbooks told educators each detail in the process of fire safety education even including the method of lecture environment's construction like table and chair placement.

In the third level, there is no textbook to tell educators how to establish fire education project in terms of attitude and emergency response. The related education method and content are still in explore, from the description of discussion and brainstorm in FLSE, it would be an appropriate method for this level's education method.

2.6.3. China

China has no systematic guidance documents or materials for fire safety education like the United States. Whatever the first level or the second level, the education method and specific designing of one fire safety education project completely depend on the experience and talents of the fire department's staff or firefighters. There is no doubt that they are experts in the field of fire safety. However, from the aspect of education, their teaching level and content is uneven and could not be guaranteed because of the lack of a standard or syllabus.

In the first level, the main methods are publicity and lecture, the publicity as mentioned in the previous background introduction, as an initial stage of fire safety education in the 1950s, China inspired the public's interest and concern the fire safety through various publicity methods like banners, slogans and posters. After the 1980s, the fire department also actively cooperates with the media department to publicize the importance of fire safety to the public in various multi-media ways. Besides, the Ministry of Public Security established November 9 as National Fire Day in the 1990s. The fire department would prepare some special campaigns on that day to publicity the knowledge or conduct interactive games with the public. For the children or elderly, the

fire department would adopt some mild method to inspire their concern about fire safety. For the adult, the fire department uses a unique tactic to inspire their concern to fire safety in a lecture, the tactic is according to demonstrate the shocking photographs where are taken in the fire to warn the audience aware of the risk of the fire. This tactic was called the “shock and awe” tactic by the author. This technique is also widely used in the United States’ congress report, America burning. From the result, it is quite effective to the audience whatever the publicity or congressman.

In the second level, the main method is lecture, the Fire Control Law prescribes the obligation of fire safety education’ s provides. The adults take fire safety education lecture held by their workplace, the elderly take fire safety education lecture held by community management organization or the elderly facility, the children take fire safety education lecture held by their school or kindergarten. Some education projects include the training of fire equipment’s operation. Besides, the adults would get a fire safety manual that is published by their workplace like the petrochemical corporation, the main content is not only safety production precautions, but also have some introduction of fire safety knowledge in daily life.

In the third level, the method and the content of fire safety education are still under exploration. Such as Tianjin Fire Research Institute proposed a fire safety education project that combined with VR technology, to train the people’s emergency response in the fire. This project is a VR serious game, it produces an immersive experience for the participant by simulating the scene of the fire and the interactive operation. Thus, making an impact on the participant’s attitude’s change.

2.6.4. Japan

Japan’s current situation is similar to China. Japan has no systematic guidance documents or materials for fire safety education like the United States. Whatever the first level or the second level, the education method and specific designing of one fire safety education project completely depend on the experience and talents of fire-related personnel or firefighters. There is no doubt that they are experts in the field of fire safety. However, from the aspect of education, their teaching level and content is uneven and could not be guaranteed because of the lack of a standard or syllabus.

In the first level, the main method is publicity. The fire departments cooperate with the media department to publicize the importance of fire safety to the public. Some fire departments created their own comic characters or mascots, to draw the public’s attention to fire safety. The fire department also held a campaign in the memorial days or combined Japan’s traditional culture to hold Dezomeshiki (Assembly ceremony) or Kasaiyoboushuukan (Fire prevention week), to draw the public’s attention or send fire safety knowledge through cultural performance or fire safety exhibition.

In the second level, because the fire service act prescripts the staff of fire safety object have obligation to take fire safety education. The related unit would invite the firefighter, or the experts from the university or any other fire-related institute to deliver fire safety education through various types include lectures and fire safety workshops.

In the third level, the method and the content of fire safety education are still under exploration. Such as the Fire Image Game for the elderly facility is a fire safety education project that developed for the staff of the elderly facility. The FIG simulated a fire scenario in a conceived elderly facility, the staff based their own fire safety knowledge and experience, make a trial to evacuate the residents of the elderly and themselves. After that, the participants would exchange their thoughts and opinion to change their attitude and improve their emergency-response ability.

2.7. The evaluation of fire safety education

Based on FLSE's definition, the evaluation method of fire safety education could be divided into three types, process evaluation, impact evaluation, and outcome evaluation. The evaluation method would be introduced as the follow shows.

1. Process evaluation occurs during the development and delivery of the program. Through process evaluation, the following can be accomplished:

- Community outreach can be measured; that is, how many people have been reached and through what media.
- Program materials and activities can be described and assessed.
- The effectiveness of instructors in program delivery can be measured.
- The quantity and quality of programs delivered are evaluated to determine if changes are needed, additional funds are required, or remedial training for instructors should be provided.
- The program's implementation and progress is measured, not its effectiveness.

2. Impact evaluation identifies the effectiveness of the presentation on the audience, or the impact the program has made on the target population. Impact evaluation accomplishes the following:

- Measures changes in knowledge, skills, attitudes, behavior, and environmental modifications.
- Studies the immediate or direct effect of the presentation on the followers.
- Requires that baseline data be obtained before the beginning of the program or presentation and then that same data be compared to the information obtained after delivery of the program or presentation. While process evaluation produces immediate results, impact evaluation may occur over a period of time.
- Measures knowledge or educational gains with pretests and posttests.

- Evaluates changes in behavior through observation or observational studies.
- Assesses environmental changes through mail or telephone surveys, home inspections, or by asking residents about their households.[12)]

The most common evaluation methods include:

- Pretests/posttests
- Skills tests
- Surveys
- Inspections
- Direct observation[13)]

3. Outcome evaluation, the most comprehensive level of evaluation is outcome evaluation. Outcome evaluation tracks statistical information and other evidence over a period of time and may take 5 to 10 years to complete. It is, however, the strongest evidence that a program is working, because it uses verifiable data to show a decrease in the occurrence of incidents, injuries, and loss of life. Outcome evaluation looks at all aspects of the risk-reduction program, from the presentations being made in the community, environmental changes being initiated, and any legislative actions being enforced. Outcome evaluation will determine if the objectives of the overall community risk-reduction initiative are being met: if lives are being saved, injuries and fires are prevented, and property is saved. Outcome evaluation methods include monitoring data to determine if there is a reduction in injuries or deaths and collecting anecdotal information or stories to provide evidence of program impact.[14)]

As table 2-3 shows, the content about the evaluation system for fire safety education's current situation in the United States, China and Japan would be introduced in next part.

2.7.1. The United States

In the United States, the local fire departments could choose one or more fire safety education program that is published by various fire-related organization or institute as the material of their own fire safety education in the process of fire safety education project's plan and design. There are not all fire safety education programs have the content of evaluation. Therefore, not all educational programs need to be evaluated. However, if the fire department thought it has necessary to evaluate the effectiveness of an education project. They have detailed content for reference. For the method of evaluation, because of outcome evaluation is too costly. Most of the education project chose impact evaluation as the evaluation method.

2.7.2. China

China has no systematic guidance documents or materials for fire safety education like the United States. And there are no strict rules for assessing education's

effectiveness. China's fire safety education has no evaluation measure to evaluate its effectiveness.

2.7.3. Japan

Japan has no systematic guidance documents or materials for fire safety education like the United States. And there are no strict rules for assessing education's effectiveness. However, in some fire safety workshops, the lecturer that comes from a fire-related institute or university would use a questionnaire survey to verify the effectiveness of fire safety education's method or content that they designed or created. Although there is no detailed content for reference, their evaluation method is similar to the impact evaluation that the FLSE defined.

Table 2-3 The comparison of evaluation system of fire safety education

Country	Evaluation (Have/None)	Method
The United States	Have (Impact evaluation is much common)	● Process evaluation ● Impact evaluation ● Outcome evaluation
China	None	
Japan	Have (Similar to impact evaluation)	Impact evaluation

2.7.4. Summary

For the law support of fire safety education, the United States, China, and Japan's fire-related law prescript related personnel (the fire department, fire manager or any other administrators in relevant departments) have obligation to provide fire safety education to their employees or residents. Only the United States have a certification system and standard to ensure the fire safety educator have enough workload, thus ensure the quality of education for the audiences.

For the executive body of fire safety education, compared with the United States, both China and Japan have no certification system to ensure the quality or quantity of fire safety education. For the educators, there is no doubt that they are experts in the field of fire safety. However, from the aspect of education, their teaching level and content is uneven and could not be guaranteed because of the lack of a standard or syllabus.

For the content and method of the fire safety education, in the third level that training the public from the aspect of attitude and emergency response, the United States, China, and Japan have begun research and exploration on this with a different method. Both in the first and second level, these three countries' method is quite the same. However, the United States has systematic guidance documents or materials for fire safety education,

the educator has detailed content for reference in the process of planning and designing a fire safety education. For the evaluation of fire safety education, the United States and Japan's fire safety education has evaluation procedures but it is not required. The evaluation procedure's planning and designing have the same issue, the United States has systematic guidance documents or materials for fire safety education, the educator has detailed content for reference in the process of planning and designing a fire safety education, but Japan does not.

2.8. The form of the FIG

This part would combine the three-level fire safety education content system and the educational method as introduced before. To introduce the designing purpose and the form of the Fire Image Game.

2.8.1. The designing purpose of Fire Image Game

The main purpose of Fire Image Game is to strengthen the participants' emergency response abilities. The participants should understand the emergency response that the related people should take priority in the event of a fire at night. It is positioned as an educational tool for the purpose of "strengthening" and as a method of planning fire prevention and evacuation drills that involve action.[15)]

Another major purpose of FIG. is to make participants aware that there is a time limit for evacuation behavior in the event of a fire and to understand the necessity that the residents' decision-making process should be finished within the evacuation time limit.

2.8.2. The form of the FIG

Based on the three-level fire safety education content as introduced before, the content could be summarized as the third level fire safety education content. Based on the FLSE's definition, the method of Fire Image Game's implementation is "discussion" and "illustration" in the category of formal education methods, and the all the nonformal educational methods (role play, case study, brainstorming, sharing, problem solving, and small group discussion). The brief process is as follows.

- The organizer would prepare the illustration of the floor plan first, it is generally a typical high-rise residential building's floor plan in the area.
- According to the real fire event, design a scenario with a conceived time and place.
- The participants are divided into groups based on family and play corresponding roles.
- The participants would follow the development of the scenario to make decisions and try to lead their families to escape safely.
- In the process of evacuation, there will be emergencies occurred, participants should take corresponding countermeasures to ensure the safety of evacuation.

- After the FIG training, the participants would share their thoughts and opinions through small group discussions.

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Chapter 3. Case Study

3.1. Introduction

The research would choose four fire cases that happened in Japan, China, and Britain as the entry point, conclude the characteristic of high-rise residential building fire according to case study. And the result of research would be a part of the designing basis of FIG's scenario. The four fire cases are Hiroshima Motomachi high-rise residential building fire (Japan), Skycity Minamisuna high-rise residential building fire (Japan), Shanghai Jingan high-rise residential building fire (China), and London Grenfell tower fire (Britain). These four fire cases' information sources come from the official report or related paper.

3.2. Hiroshima Motomachi high-rise residential building fire (20 floors' building)[1)]

The fire was occurred on October 28th, 1996, about 14:27. The cause of the fire is unknown. The fire caused 83 households damaged and 2 people injured.

3.2.1. Process of fire spreading

The initial fire broke out in room 965 at 14:27. After 7min, the flame in the balcony of room 965 break into the room. After 14 minutes, the fire spread to the 10th floor, the fire lighted the flammable stuff in room 1065's balcony. After 16.5min, the flame breaks into the room through the screen window. After 20 minutes, the fire spread to the 11th floor, the fire lighted the flammable stuff in room 1165's balcony. Then this process repeats and repeats until the rooftop after 23minutes. After 25.5minutes from the fire broke out, the fire spread along the horizon direction. The record shows that fire broke into the room 1566, 1966 and 2066 after 50minutes. Then the fire broke into the room 1565 and 1866 after 1 hour 14 minutes. After 1 hour 51 minutes, the fire broke into the room 1765, 1965, 1966 and 2066. The committee of fire case investigation focuses on the flammability of the acrylic decoration board set on the balcony. After plenty of experimentation, the flammability of acrylic was proved. However, except the acrylic decoration board, the flammable stuff such as gasoline that was stored in the balcony by the residents was also involved in the spread of fire and it played a main role in it. All the spread pattern in each floor is the flame lighted the flammable stuff first, then lighted acrylic decoration board. At last, the flame break into the room through the window.

Although the opening balcony in this high-rise residential building slow down the speed of fire spreading and the damage was not very serious, after few decades, such kind of fire spreading pattern would happen more frequently with the popularization of thermal insulation.

3.3. Skycity Minamisuna high-rise residential building fire (28 floors' building)

This fire case occurred on August 24th, 1989, about 16:00. The cause of the fire and fire spreading process is unknown. The characteristic of the fire case is that because the residents did not close the door after evacuation, the strong wind pressure of high floors made the front hall's fire door open, the smoke spread into the stair-room caused one of the evacuation routes cannot be used. It hindered the evacuation of residents.

In conventional fire cases, the stair-room failed because the invasion of the smoke that caused by the reliability of the smoke exhausting system failed was quite common. Although the human and economic loss was not heavy in this fire case, such kind of smoke spreading pattern that has a physical relationship with the high floors environmental condition needs to be paid attention with.

3.4. Shanghai Jingan high-rise residential building fire (28 floors' building)[2)]

The fire was occurred on November 15th, 2011, about 14:14. The cause of the fire is the spark of welding lighted the thermal insulation material. The fire caused the whole building damaged, 58 died, 71 injured.

3.4.1. Process of fire spreading

At that time, the construction worker was working on the building's energy-saving reforming construction. Their job is that laying the thermal insulation on the exterior wall, then laying the concrete above the thermal insulation. At about 14:14, the welding spark in the 10th floor dropped to the 9th floor's scaffold. Then the spark ignited the piled Polyurethane board. The worker tried to put out the fire immediately. After the initial firefighting action failed. The flame spread along with the nylon net covering the scaffold in vertical and horizontal directions. Besides, the flame ignited the thermal insulation. The thermal insulation that was not covered by concrete was ignited as well. During this process, the flame break into the room through the windows and started spread inside the building. At this time, the fire that spread along both exterior and interior routes has become "Liti Huozai" which was called by the official fire investigation report, could be translated as "Stereoscopic fire" in English. And the fire was out of control. In 14:40, the flame had been spread to the whole building through two routes.

Based on the survivors' description, because it happened at about 14:00, some elderly residents were taking a nap at that time, which caused them to miss evacuation timing. And the situation that smoke exhausting system in the stair-room was malfunctioning caused the evacuation of residents to become critical. The stereoscopic fire caused the firefighters' rescue action to become much more difficult whatever inside the building or outside the building as well. Shanghai fire department tried to rescue residents from the

roof by helicopter. However, the action was failed due to the harsh external environment. Because of people's lack such experience that confronts with the high-rise residential building fire, it caused the heavy human and economic loss. After that, China government strengthened its investment in the updating of firefighting technical equipment and public fire safety education. The new fire safety designing code was published in 2015, many contents were revised after summarizing the experience of the Shanghai fire, especially in the field of thermal insulation material. Shanghai Jingan high-rise residential building fire was the first exterior fire that caused heavy losses. Besides, the fire mainly spread along with the nylon net in this case, although the thermal insulation was not fully involved in the spread of fire, the fire case that exterior fire occurs in the process of construction needs to be paid attention with as well.

3.5. London Grenfell tower fire (24 floors' building)

The fire was occurred on June 14th, 2017, about 00:50. The cause of the fire is an aged fridge-freezer caught fire. The fire caused the whole building damaged, 72 died, more than 70 were injured.

3.5.1. Process of fire spreading

The initial fire is an aged fridge-freezer, it caught fire at 00:50 a.m. in the 4th floor's flat 16 that located in the northeast corner. At 00:54, the 999-emergency call got a phone call that reported his room caught fire. At 00:55, London Fire Brigade (short as LFB) was mobilized and arrived at the point at 00:59. The fire made the uPVC window frame melt, deformed, and mechanically failed. Then the fire broke through the window, escaped from the fire location, and spread to the cladding system of the thermal insulation panel. At 1:15 a.m. the smoke was discovered in the 5th floor's room, above the room that caught fire. Then the flames spread up along the northeast corner at a "terrifying rate", said the witness. The fire on the eastern exterior spread sideways and the flame break into the internal of the building. After 15minitus from the flame started spreading, a rising column of flames had reached the roof and the fire was out of control. In 1:42, the fire reached the north side. In 1:52, the fire started spreading toward to south side in the horizon direction on the east side. Then the flame kept spreading through the thermal insulation. At 3:08 a.m. the fire met another flame that came from the east-south route at the west side.

With the process of fire spread along the exterior of the building, the smoke spread in the interior of the building as early as around 01:20 based on the survivors' oral testimony. It means, as the basis of the "Stay put" strategy, the function of compartmentation had been lost. According to the description of the report,

The principle of the design known as "compartmentation" lies at the heart of these

safety features. In essence it involves creating within the building a series of self-contained living spaces (usually individual flats) which are separated from all other similar spaces and from the common parts by fire-resisting barriers (walls, floor and ceiling), so that if a fire breaks out within one space it can be contained within that space for long enough to enable the fire and rescue service to extinguish it before it spreads to other parts of the building.[3)]

For the "Stay put" strategy, LFB's opinion said:

The concept of compartmentation, combined with other supporting fire safety provisions, has given rise to the "stay put" strategy, under which, in the event of a fire elsewhere in the building, the occupants are advised to remain within their own flats unless they are directly affected by fire, heat or smoke. This safety strategy reflects the assumption that where traditional construction methods are used, a fire in such a building will usually be contained within the flat of origin and that it is safer for the occupants of other flats to remain where they are rather than leave the building. [3)]

Therefore, ensure the integrity of the compartmentation function, the "Stay put" strategy could be effective. However, based on the fire investigation report, because of the heat, the window glazing, window frame, or kitchen extractor fans failed in the fire and the smoke and flame breakthrough these places entered the interior of the building. Thus, the specific compartmentation was breached. Besides, the report believed that the evacuation activities of the occupants or maintenance factor of the flat door caused the door to keep opening. It caused the smoke to spread in the horizontal direction of the interior of the building. firefighters forced the fire door of the stair room to open due to fire extinguishing and rescue activities, as well as the evacuation of occupants caused smoke to enter the stairwell. And the smoke spread in the vertical direction of the interior of the building through the smoke control system (based on the description of the occupants). Besides, because the smoke spreading inside the high floors of the building is from the stair-room to the lobby, then breach into the household through the gap of the front door, based on the oral testimony of the survivors, the smoke detector did not activate in time. This situation has an impact on occupants' evacuation timing as well. And in the late period (between 02.30 and the extinguishing of the fire), it was called "the untenable stage" by Professor Torero who attend the fire investigation, in the report.

He noted that in that phase of the fire a very large number of flats had been affected by the external fire, compartmentation had been breached at many floors and the scale of the fire exceeded the firefighters' capacity to contain and extinguish it.[4)]

Although the occupants still had chance to evacuate successfully if they "got the right window", the condition still threatened occupants' life or be perceived by occupants to be

life-threatening.

In the process of fire spreading, the fire made the uPVC-made window frame or kitchen extractor fans failed, the compartmentations were breached. With the condition that a number of key fire protection measures, both active and passive, failed to operate as effectively as could reasonably have been expected 5). LFB's "Stay put" strategy's basis did not exist anymore, plenty of residents missed the timing of evacuation, in the follow-up investigation, the appropriateness of the "Stay put" strategy became the focus of controversy between Parliament and LFB. After the fire lost control, the evacuation order was published by the fire department. However, at this time, the environmental condition with high temperature and low visibility hindered people's evacuation behavior physically and psychologically. At last, the fire caused 72 died, more than 70 were injured.

3.6. Summary

Four cases would be summarized by the time of the fire occurred, the cause of the fire, and the fire spreading pattern.

3.6.1. The time of the fire occurred

Both Hiroshima Motomachi and Shanghai Jingan high-rise residential building fire occurred in mid-noon. However, in the case of Shanghai, according to news reports, most residents were taking a lunch break at that time, which have an impact on their perception of the fire and missed the timing of evacuation, and caused heavy casualties.

The time of London's case occurred at night. Almost all the residents had fallen asleep, which delayed their perception of the fire and missed the timing of evacuation, and caused heavy casualties as well. Consider the people's behavior (taking a break and fall asleep) at the time and environment condition. The scene and situation that the occupants were confronted with in London's case are similar to China's case.

Skycity Minamisuna's case occurred in afternoon, the occupants' behaviors were active. Compared with Shanghai and London, the occupants' reaction is faster when they were confronted with the fire.

3.6.2. The cause of the fire

In both Japan's fire cases, the cause of the fire was unknown.

In China's case, the cause of the fire was the sparks of welding work. For the most of the people, the fire that caused by construction project is quite rare in daily life, considered the current situation of the low-emission residential building's stock and the urgency of dealing with environmental changes, such fires would increase with the growth of such construction projects. This situation has value for consideration.

In Britain's case, the cause of the fire was an aged fridge-freezer. The household appliance fire or kitchen fire is quite common in the causes of fires in various countries.

3.6.3. The fire spreading pattern

For the flame spread patterns of Japan's case, the medium of fire spread is the acrylic decoration board and the flammable stuff that piled on the balcony. Among them, the flammable stuff accounted for a large proportion. The flame spread route is that the flame spread along with the balcony's acrylic decoration board, flammable stuff that piled on the balcony, the upper floor's acrylic decoration board, and looped.

For the flame spread patterns of China's case, the medium of flame spread is the nylon net that covered the scaffold, and the PU board of thermal insulation which had not been covered by the concrete. The flame spread in two routes, external route, the nylon net and PU board and internal route, the fire breach into the building and spread. Therefore, this kind of fire was called "Liti Huozai" which was called by the official fire investigation report, could be translated as "Stereoscopic fire" in English.

For the flame spread patterns of Britain's case, the medium of flame spread is the PE material of the thermal insulation system. The flame spread route is similar to China's case, external route, the thermal insulation system, and the internal route (after the compartmentation was compromised). The fire became a "Stereoscopic fire" at last as well.

For the fire spread patterns of these three cases (Skycity Minamisuna's fire spreading situation was unknown), although the material of fire spread is different, the main fire spread route was the external side. The fires' type could be concluded as "exterior fire".

3.6.4. The particularity of the exterior fire

From the experience of various countries' residential building fire, conventional fire is the fire that occurred in a single source and spread inside the building. With the fire spreading, the area affected by flames or smoke continues to expand. In this case, occupants far away from the fire source have plenty of time to react. With help of the building's fire safety design, fire equipment, or the firefighters, they do not even need to evacuate.

However, in exterior fire, the fire would spread along the thermal insulation layer in a short time. From the angle of the occupants, the fire far more likes occurred in multi-source in a short time. They need to react based on the current situation instead of judging the situation based on the experience or stereotypes. For example, in Grenfell tower inquiry report, it recorded the survivor Naomi Li and Lydia Liao's process of evacuation. At first, after they got the information about the fire that occurred, they decided to evacuate immediately. Then they found the route was blocked by the flow of people. They move to the neighbor's flat temporarily. However, after they got the information that the fire source is on the 4th floor, they refused the leaving advice from the neighbor, slow down their pace of evacuation, and decide to stay at the flat. Finally,

until the situation turned critical, they left the building with the help of the firefighters. Therefore, when the occupants are confronted with such kind of situation, they should abandon their reliance on past experience as much as possible, judge the situation through a certain methodology, and then react. That is one of the purposes of Fire Image Game as well.

3.7. The design of the pre-set scenario for FIG

In these four fire investigation reports, although the report of Hiroshima Motomachi high-rise residential building fire could be classified as an exterior fire, as a material of fire education program, this fire's scenario could not leave a deep impression to the participants, and compared with the exterior fire that occurred in recent years, the scenario is not typical enough.

The report of Tokyo Skycity Minamisuna high-rise residential building fire, although this case has no relationship with exterior fire, as a material of Fire safety Sugoroku or the reason of horizontal and vertical compartmentation's function failure in FIG training, the example that the flat door opening caused the compartmentation was compromised has value to remind the participants paying attention to flat door issue in the process of evacuation.

The report of the Shanghai Jingan high-rise residential building fire is a typical exterior fire case that has a relationship with thermal insulation, and as a material of fire education program, the heavy casualty and economical loss could leave a deep impression on the participants and enhance the persuasiveness about the importance of fire safety education. However, this report's main purpose is to determine the responsible personnel or group in the fire, the process of fire spreading and occupants' evacuation does not describe clearly. As a scenario of FIG training, the lack of detailed situation description, could not provide an imageable space for the participants, which may have an impact on the effectiveness of FIG training. However, some detail of fire spreading or occupants' evacuation activity have value to be referenced as a material of fire safety Sugoroku.

The report of London Grenfell tower fire is a typical exterior fire case that has a relationship with thermal insulation, and as a material of fire education program, the heavy casualty and economical loss could leave a deep impression on the participants and enhance the persuasiveness about the importance of fire safety education. This fire investigation report provides a detailed description of the fire and smoke spreading process, the process and reasons for the compromise of the compartmentation, and the entire process of survivors' escape. It would be helpful for the construction of a scenario of FIG that with a full process from the occurrence of the fire to the fire breach into the

interior of the building.

The scenario of FIG as the table shows, for increasing the difficulty and challenge of the training, the time of the fire occur is the midnight when the occupants' perception of fire is weakest, the place of the participants' living is 12 or higher floors that cannot be reached by ordinary fire trucks. For the cause of the fire, based on the survivors' oral testimony, because the fire occurred on the other floor, almost all the occupants did not understand the cause of the fire at that time, the signal that initiated their evacuation procedure is that the fire-related sign such as the smell of smoke, the phone call from a neighbor, friend, or family member, people's shouting, or any other signs. Therefore, the setting for the cause of fire is meaningless for the participants of FIG. The flame spread pattern is after the fire breaks out, the flame spread along the building's external, the medium is the thermal insulation, then the fire breach into the interior of the room through windows or kitchen extractor fan, the fire and smoke spread along both exterior route and interior route. Based on the survivors' oral testimony, the occupants in the fire have no possibility that watching a panoramic view of the fire, they just could judge the situation and take action based on what they saw in the fire. Therefore, in FIG training, the participants judged and considered the emergency response method based on the description of a specific scene of the fire spreading process in this scenario. A detailed description of the fire spreading process would be introduced in the chapter on human behavior analysis of the fire.

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3) Grenfell Tower Inquiry, GRENFELL TOWER INQUIRY: PHASE 1 REPORT, Volume 1, P27, 2019.10
4) Grenfell Tower Inquiry, GRENFELL TOWER INQUIRY: PHASE 1 REPORT, Volume 2, pp. 564-565, 2019.10
5) Grenfell Tower Inquiry, GRENFELL TOWER INQUIRY: PHASE 1 REPORT, Volume 2, P568, 2019.10

Chapter 4. The analyzation of the floor plan

4.1 Introduction

The research would be according to consult the China's <Code for fire protection design for buildings>, <Residential building Code>, Japan's < Building Standards Act> and the United States' <International Fire Code>, <International Building Code>, and take China's code as the main body to make a comparative research between China, Japan, and the United Stats' related codes or laws and the changes of new code for fire protection design for buildings, to determine the improvement, advantages, and disadvantages of related codes in law system and relevant content about fire safety design (especially passive fire prevention).

Then through comparative research, to analyze the floor plan of China's high-rise residential building. Especially the evacuation route's change of China's high-rise residential building.

4.2 The research of China's new code for fire protection design of buildings

4.2.1 China's fire safety law system

After Reforming and opening, China started to construct law system of each industry. China's first basic law of fire safety industry was published in 1998. And after about twenty years of development, China's fire law has become a complete system with its own characteristics.

From the content, China's law system could be categorized into two large parts, administrative clause, and technical standard. And the administrative clause could be categorized into fire prevention law, fire prevention or administration regulation, and local regulation.

From the judicature, China's law system could be separated into two parts, legal validity part, and non-legal validity part. In legal validity part, the fire prevention law has the highest position in this system because it was approved by National People's Congress (short as NPC) of People's Republic of China, the highest legislature. The fire prevention or administration regulation was drafted and published by the relevant department of State Council, it has the second position in this system. The local regulation was approved by local NPC, the position was in accordance with the local government's administrative level. All this law and regulations has mandatory. On the contrary, technical standards have no legal validity, it was published by relevant ministry. such as the code for fire prevention design for the building was published by Ministry of Housing and Urban-Rural Development, it just provides a basis for fire safety design to the designer and a supervision standard for the relevant department. It has no

mandatory. For ensuring related employees could comply with these codes. Fire prevention law authorized the fire department to inspect and supervise the drawings of fire safety design. Just all the drawings compliance the requests of code, the process of design could step into next stage.

4.2.2 Comparative Research with Japan and United States

Japan's fire safety law structure is quite simple, fire prevention administrative clause and technical standard are included in Fire Service Act and Building Standard Act. For legal validity, because of these two laws was approved by Japan's highest legislature. These two laws have the highest position in fire safety law structure. Below these two laws, cabinet ordinance and ministry ordinance refine the related clause such as operation method. Local regulations as similar to China, their position is in accordance with local government's administrative level.

Because of all these laws and regulation was approved by the central government or legislatures, it has mandatory. For inspection and supervision, from 1999, the adamant of Building Standard Act allows the third-party agency that was authorized by relevant departments could inspect and supervise the drawing of fire safety design. The basis for fire safety design to the designer and the supervision standard for the third-party agency comes from the Fire Service Act, Building Standard Act, and local regulations.

The United States' law system structure is in between. At first, the technical standards were drafted and published by relevant association or institute, it would be updated every three years, and it has no legal validity and mandatory. However, the local government according to parliament' vote to choose one technical standard as their designate standard, it started has legal validity and mandatory. For inspection and

Table 4-1 The comparison of the content of fire safety law system

Fire safety and evacuation related content		**China**	**Japan**	**The United States**
Technical standard	Fire safety design	・Fire prevention design code	・Building Standard Act	・Building code ・Fire code
			・Fire Service Act ・Building Standard Act	
	The oblige of fire safety equipment setting	・Any other professional code ・Fire prevention design code	・Fire Service Act ・Building Standard Act	・Fire code
Administrative clause	Fire safety design's inspection and supervision	・Fire Prevention Law. ・Fire Prevention regulations in each level government	・Fire Service Act ・Building Standard Act	・Fire Prevention Law and regulations in each state
	The administrative clause about fire safety management		・Fire Service Act	

supervision, it is quite similar to China, the fire laws and regulations authorized fire department to inspect and supervise the drawing of fire safety design. (Table 4-1)

4.2.3 Evaluation

For China's law system structure, from the designer, the content of technical standard and the administrative clause was separated is much more convenient to use. Because most of the administrative clause has no relationship with fire safety design. And drawing of fire safety design. The basis for fire safety the technical standard was separated based on its professional scope is convenient to reference, and content's extension in the future. If put all these content gets together in one or two laws just like Japan, the content is too massive to use easily4), and if the content was extended in the future, the content may cause confusing the users. However, authorizing the third-party agency to execute inspection and supervision could be a trend in the tide of "Small government". And in Shanghai, let the third-party agency execute inspection and supervision to the architectural plan is in the test. It has a possibility that the fire safety designs inspect and supervise by the third-party agency in the future as well.

On the contrary, codes lack of legal validity and mandatory may cause the issues in law enforcement. It may cause the designer lack of enough awareness of fire safety in the fire safety design. And then, it may cause peril risk in the fire safety. The whole process just relies on the fire department's inspection and supervision is unreliable. To improve the codes' legal validity and mandatory in fire safety law system is necessary like the United States.

4.3 The specific content of <Code for fire protection design for buildings>

In this part, the research would combine the change of new code, according to make comparative research with Japan and the United States' code and take residential buildings' fire safety design as the main body, to evaluate the advantages and disadvantages of related content.

4.3.1 Fire resistance class's classification

In new code, the classification of the building was separated into three categories only has accordance with the building's heights. The heights took twenty-seven meters and fifty-four meters as the limit, the residential building that the heights over fifty-four meters was defined as Type one building, the residential building that the heights over twenty-seven meters and no more than fifty-four meters was defined as Type two building, the residential building that the heights no more than twenty-seven meters was defined as single/multi-story residential building. This is a great difference from the former codes that the building's classification has two types, story type, and height type. Then, the fire resistance class was defined based on the buildings' type. It has four

classes that from high to low. The code prescribed that the fire resistance class of Type one building is Class one, the fire resistance class of Type two building was no less than Class two, the multi-story building's fire resistance class was Class three, and based on the <Code for residential building>, the fire resistance class of the residential building with no more than three stories was Class four (Because of <Code for residential building>'s new version has not published, it is still classification the buildings through the story of the building).

4.3.1.1 Comparative research

Compared with Japan's or the United States' classification of buildings, Japan's <Building Standard Act> classification method is according to building's story, the law prescribed the calculation from the top floor, the main structure's fire resistance rate of the building that has four stories is one hour, the main structure's fire resistance rate of the building that has five to fourteen stories is two hours, the main structure's fire resistance rate of the building that has fifteen to eighteen stories and basement is three hours. And in these building, the standard's difference would exist in accordance with the buildings' usage, rank, and scale. (Figure 4-1) Compared with the United States, take the <International Building Code> (short as IBC) 2015 version as an example, the classification of the building would be different in accordance with building's usage, the buildings were separated into ten groups. In these group, the residential building was defined as R Group. The high-rise residential building in China's definition belongs R-2 Group in IBC. Correspond to this classification, these buildings' heights or the number of stories was limited and fire prevention request was defined as Construction Type I to V, this request is similar to China's code. (Figure 4-2)

4.3.1.2 Evaluation

Compared with Japan and the United States, China's classification more like from the aspect of fire extinguishing and rescue's difficult, to classify the building's type and define the importance of buildings. From the classification method, China's method was similar to Japan's method much more, both countries' method is according to buildings' vertical indicators. However, because of classification by the number of stories may exist the possibility that designer or real estate seeks to profit by using the height of each floor to avoid relevant requests. the building's total height is an objective data, there is no operation space for related personnel. Compared to Japan's method, China's method is much more efficient, objective and scientific. And decrease the chance that let the real estate avail themselves of loopholes.

4.3.2 The fire resistance rate of building structures' components

In the new code, most of the building element's fire resistance rate did not change, the classification and indicator still use the old code that inherited from the Soviet Union's

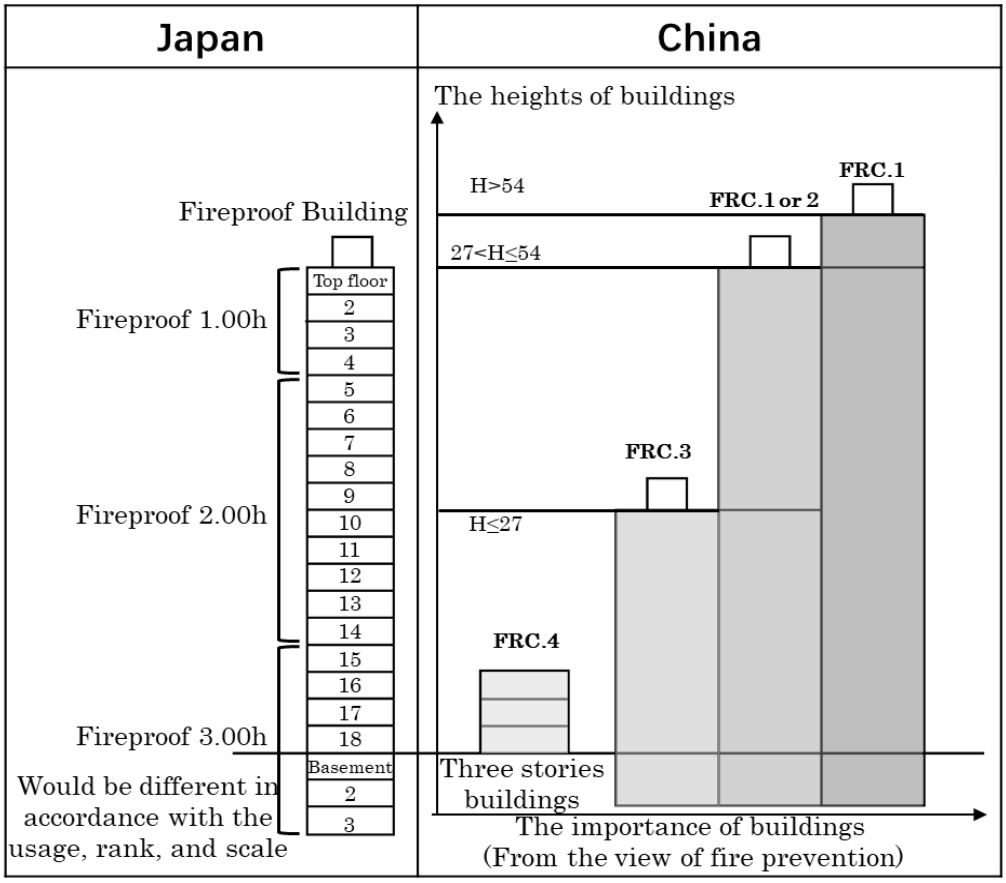


Figure 4-1 The classification of the building (Japan and China)

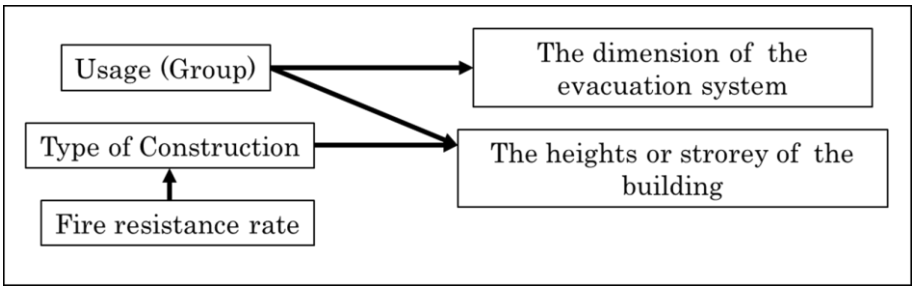


Figure 4-2 The classification pattern of the building in the United States' code

code. The floor slab's fire resistance rate of the buildings that the heights over one-hundred meters were increased from 1.5 hours to 2.5 hours. Because the high-rise residential buildings that the heights over one hundred meters are quite rare, the research still concentrate on the Class one residential building, Class two residential building, and single/multi-story residential building.

The fire resistance rate of the building's element as the table shows, in the non-bearing wall parts, the building element was classified further in accordance with its usage. And the classifications and some indicators quite as similar to the Soviet Union. Therefore,

it may have a relationship with learning from the code of the Soviet Union in the past. All the members based on their chemical property was defined as incombustibility, flame retardance, and flammability. (Table 4-2)

Table 4-2 The fire resistance rate of China and Japan

China's fire resistance hour					
Component		Fire Resistance Class			
		Class 1	Class 2	Class 3	Class 4
Wall	Firewall	3.00h	3.00h	3.00h	3.00h
	Bearing wall	3.00h	2.50h	2.00h	0.50h
	Nonbearing wall (Outer)	1.00h	1.00h	0.50h	0.00h
	·The wall of stairs-room and front-room ·The wall of elevator shaft ·The splitting wall for the residential unit and household	2.00h	2.00h	1.50h	0.50h
	The wall of corridor	1.00h	1.00h	0.50h	0.25h
	Room partition wall	0.75h	0.50h	0.50h	0.25h
Column		3.00h	2.50h	2.00h	0.50h
Beam		2.00h	1.50h	1.00h	0.50h
Floor slab		1.50h	1.00h	0.50h	0.00h
Roof load-bearing member		1.50h	1.00h	0.50h	0.00h
Stairs		1.50h	1.00h	0.50h	0.00h

Japan's fire resistance hour					
Component			Floor (From the top floor)		
			Over 15	5~14	1~4
Wall	Partition wall	Bearing wall	2.00h		1.00h
		Nonbearing wall	2.00h		1.00h
	Outer wall	Bearing wall	2.00h		1.00h
		Nonbearing wall	2.00h		1.00h
Column			3.00h	2.00h	1.00h
Beam			3.00h	2.00h	1.00h
Floor slab			2.00h		1.00h
Roof load-bearing member			0.50h		
Stairs			0.50h		

4.3.2.1 Comparative research

The comparative research chooses the building elements those were defined as primary structural frame by IBC. It means column and any other parts that having direct connecting with columns including beam, floor, roof. Because high-rise residential buildings with bearing walls occupy a large ratio in China, the bearing wall was added into the comparative research as well.

In IBC, the definition process is opposite from China and Japan, the code confirms the building's usage and fire resistance rate first, then prescribed the building's height. In Type I, with the situation that installed the sprinkler system, the residential building (R-2 Group) has no heights or number of stories' limit. According to making a comparison, the research determined that the United States' code is stricter than China's and Japan's, and if considered with America's code has no heights or number of floors' limit; such request cannot say overkill. In addition, although the fire wall's fire resistance rate is not listed in the table, based on the content of SECTION 706, its fire resistance rate in R-1 and R-2 group is three hours. It is as similar as China's code. China's request as strict as Japan's, if considered with China's bearing wall type's high-rise residential building's ratio, the request of China's code is stricter than Japan's. The comparative as the table shows. (Table 4-3)

Table 4-3 The comparison of fire resistance rate in China, Soviet Union, Japan, and the United States

	China		Soviet Union[1)]		Japan			America
Building Element	Fire Resistance Class		Fire Resistance Class		Floor (From the top floor)			Type of construction
	Class 1	Class 2	Class 1	Class 2	Over 15	5~14	1~4	Type 1
Bearing wall	3.00h	2.50h	3.00h	2.50h	2.00h		1.00h	3.00h
Column	3.00h	2.50h	3.00h	2.50h	3.00h	2.00h	1.00h	3.00h
Beam	2.00h	1.50h	2.00h	1.50h	3.00h	2.00h	1.00h	3.00h
Floor	1.50h	1.00h	1.50h	1.00h	2.00h		1.00h	3.00h
Roof	1.50h	1.00h	0.50h	0.25h	0.50h			3.00h

4.3.2.2 Evaluation

Through the comparative research, China's high-rise residential building's relevant request is equivalent to Japan. Especially the bearing wall type high-rise residential building's request is stricter. However, compared with America, some of China's indicators that inherited from the Soviet Union may need to be strengthened based on experience from the fire cases and practice.

4.3.3 Fire separation distance

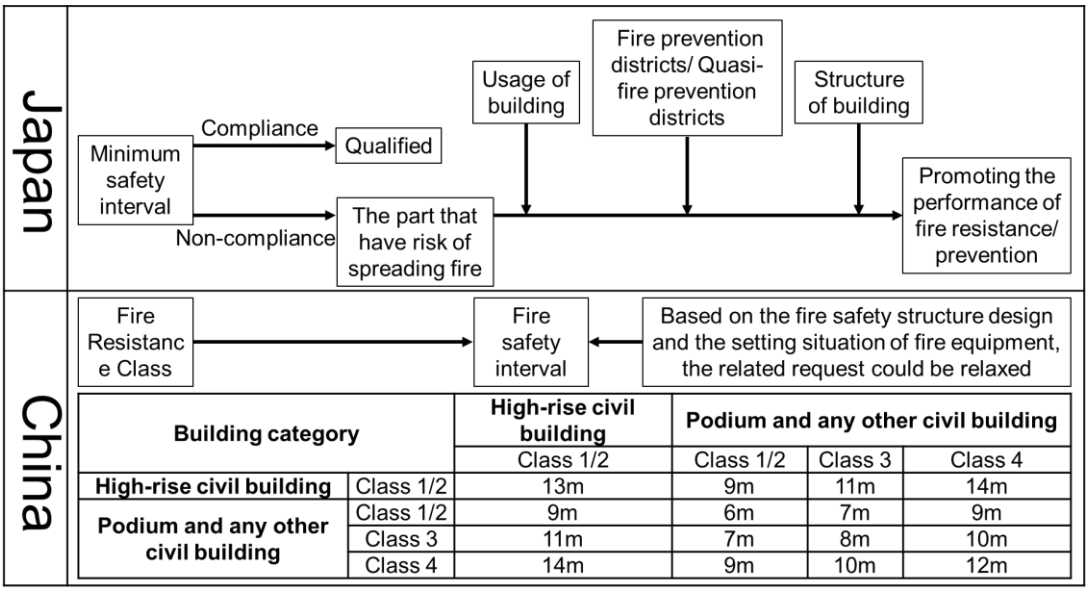
In new code, the fire separation distance used the old content. The fire separation distance's purpose is to prevent the fire from spreading among the buildings. Based on the building's fire resistance class and the classification rules the distance between the buildings. However, if the building has additional structure design or fire equipment, based on the determination conditions, the request could be arranged.

4.3.3.1 Comparative research

Compared with Japan, because of some objective conditions, Japan has not enough space for setting fire separation distance. Japan's building standard act prescribes that if the distance between two buildings could not meet the request, the relevant part would be designated as fire spreading risk existed part and be strengthened based on the building's usage, structure, or any other conditions to promote the performance of fire spreading prevention. (Table 4-4)

Compared with the United States, the IBC prescribes that the fire resistance rate of the exterior wall (non-bearing wall) depends on the fire separation distance. From the specific, with the situation that the exterior wall' fire resistance rate is the same (one hour), the request of fire separation distance in IBC is shorter than China. However, if

Table 4-4 The fire separation distance of China and Japan



Building category		High-rise civil building	Podium and any other civil building		
		Class 1/2	Class 1/2	Class 3	Class 4
High-rise civil building	Class 1/2	13m	9m	11m	14m
Podium and any other civil building	Class 1/2	9m	6m	7m	9m
	Class 3	11m	7m	8m	10m
	Class 4	14m	9m	10m	12m

Table 4-5 The fire separation distance of the United States

The fire resistance rate of exterior wall (Non-bearing wall)		
Fire separation distance	Type of construction	Occupancy Group R (R for residence)
X<1.524m	ALL	1h
1.524m≤X<3.048m	IA, Others	1h
3.048m≤X<9.144m	IA, IB	1h
X≥9.144m	ALL	0h

considered with China's arrangement clause, China' request is equivalent to the United States. (Table 4-5)

4.3.3.2 Evaluation

For the purpose of fire spreading prevention, increase the fire separation distance like China would be much more effective and simpler. However, from the actual practice, it is not economical because of wasting the space of using. From the objective condition, Japan just relies on promoting the fire prevention performance because it has no such wide space for arranging buildings on a site like China. Therefore, combined the performance of single building's fire prevention and ensure the fire separation distance like America would be a much more effective method in normal condition.

4.3.4 Fire Compartmentations

In new code, the relevant request did not change. Fire compartmentations' purpose is that quarantine the ignition source, prevent the fire from spreading in the building. The relevant request as the table shows. For the unit type's residential building, the fire compartmentations are in accordance with the unit. For the corridor type's residential building, the fire compartmentations still follow the request in the table. (Table 4-6)

4.3.4.1 Comparative research

In Japan, the fire compartmentation's requirement over the 11th floor becomes much stricter than the lower floor, for the interior that does not use non-combustible material or flame-retardance material, the compartmentation area should be below 100m^2. If use

Table 4-6 The fire compartmentation of China

Maximum allowed floor area for fire compartmentation			
	Fire resistance class	**Maximum allowed floor area（m^2）**	**Separation method**
Single/Multi-story civil building	Class 1/2	2500m^2	• Fire wall • Sprinkler • Fire roller shutter • Fire resist water curtain • Fire door • Fire window
	Class 3	1200m^2	
	Class 4	600m^2	
High-rise civil building	Class 1/2	1500m^2	
<Code for fire protection design for buildings> 5.3.1: For residential buildings, fire separation is mainly based on units. Generally, the building area of one floor is not larger than the allowable building area of a fire compartment.			

Table 4-7 The fire compartmentation of Japan

Specified designated building		**Compartment area**	**Structural standard**
The main structure of building is fireproof construction or semi-fireproof building		Below 1500m^2	・Semi-fireproof structure 1.00h ・Specific fire prevention equipment
The related buildings compliance the 27th clause, 62nd clause and 67th clause's 2nd item of Building Standards Act		Below 1000m^2	
The part that over 11th floor	General (The interior using neither flame retardance material nor non-combustible material)	Below 100m^2	・Fireproof structure ・Fire prevention equipment
	The interior using flame retardance material	Below 200m^2	・Fireproof structure ・Specific fire prevention equipment
	The interior using non-combustible material	Below 500m^2	

non-combustible material or flame-retardance material, the request could be relaxed appropriately, those are 500 m^2 and 200 m^2 respectively. For the residential building, there are no applicable provisions for dwelling units like China or the United States. The area of one unit residence should be adapted to the requirements of fire compartmentation as well. Therefore, from the aspect of application, it is not as flexible as China and the United States' codes. Besides, the corresponding fire equipment's installation or non-combustible material's application could be relaxation conditions that extend the fire compartmentation's area. This part is as same as China. (Table 4-7)

In the United States, the separation method of residential building (Group R-1, R-2, R-3, and R-4) is quite the same, walls separating dwelling units in the same building shall be constructed as fire compartmentations wall.[2)]

4.3.4.2 Evaluation

According to comparative research, the principle of fire Compartmentations for residential building in China and the United States is quite the same, the separation wall for dwelling units constructed as fire Compartmentations is the most effective and economical choice in current condition. Compared with China and the United States, Japan's code lacks some flexibility. However, from a practical perspective, the figure required by the code is similar to that of China.

4.3.5. Evacuation

In new code, for high-rise residential building, a new request was added that the building should set a room that could be used for refuge room when the height of the residential building is over fifty-four meters. And the request for scissor stairways was improved further as well, the pressurized air supply system of the stair-room should be installed independence as far as possible. If there is no room for two more pressurized air supply systems, the blower and pipe could be shared use, the terminal should be installed independently. The front room of the scissor stairways should not be shared, if shared, the area of the front-room should be over six square meters. The stair-room and the elevator shouldn't share same front room, if shared, the area should be over twelve square meters and the length of the short side should be over 2.4 meters. (Figure 4-3) (Figure 4-4)

For the evacuation method of residential building, based on the request of code, China's idea is much more like Japan's two-way evacuation route type. All the building with the relevant condition should set more than two separately safety exit, one safety exit corresponds to one evacuation route. In some condition, the designer should ensure more than one way of evacuation through designing the rooftop evacuation route or scissor staircase. (Table 4-8)

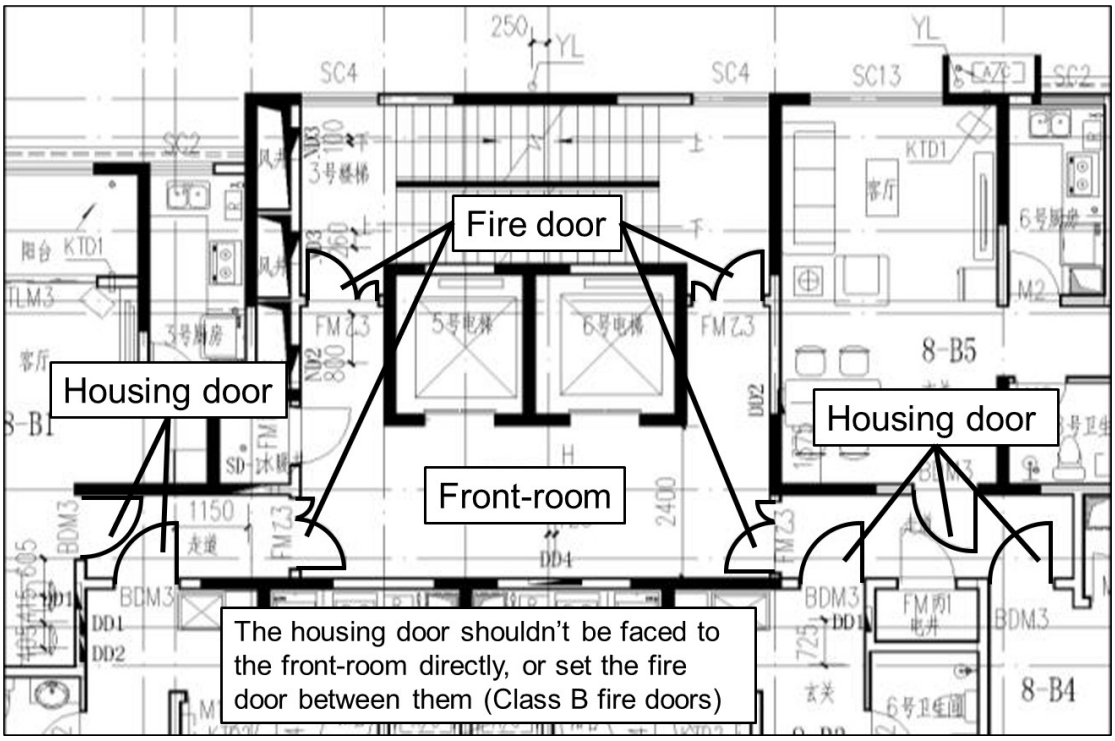


Figure 4-3 The floor plan of high-rise residential building's transportation core (Designed based on old designing code)[7)]

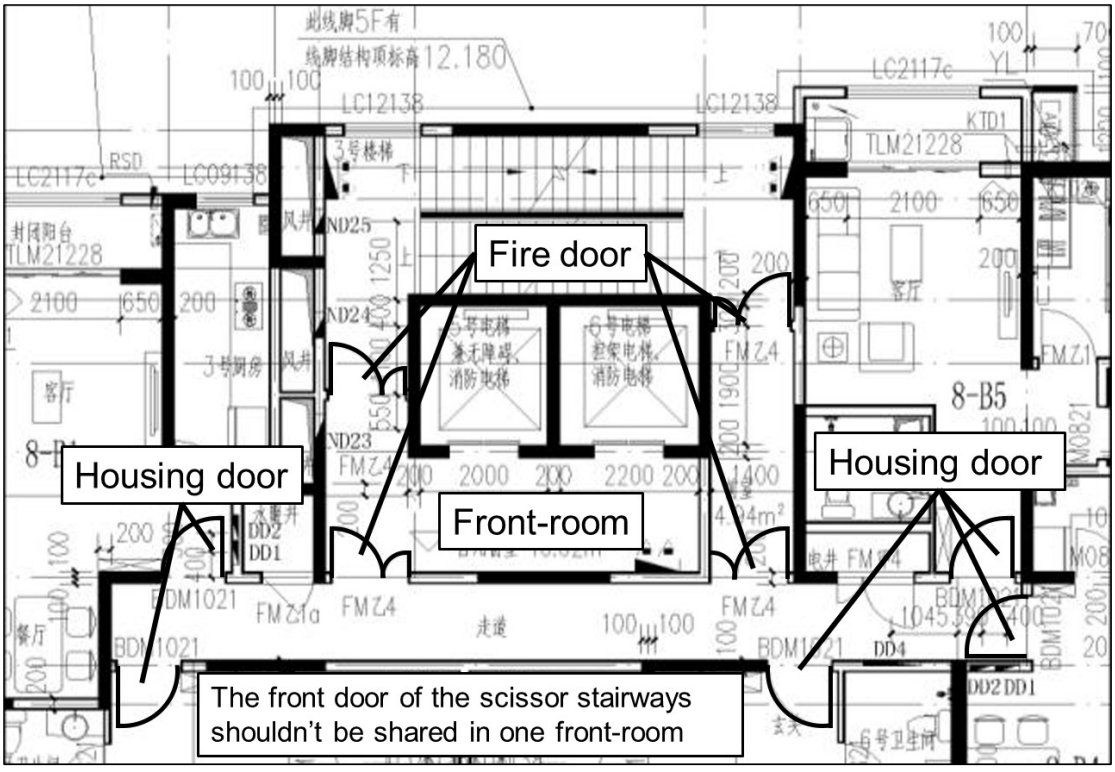


Figure 4-4 The floor plan of high-rise residential building's transportation core (Designed based on new designing code)[7)]

Table 4-8 The number of the exit in China's code

Height (H)	Condition	Safety exit (N)	Remarks
H≤27	• The floor area of one floor in each unit over 650m^2 • The distance between any door and the nearest safety exit over 15m	N≥2	• The distance between two safety exits (side by side) should be over 5m. • If it has difficulty in setting evacuation stairs separately, and The distance between any door and the nearest safety exit below 10m. The scissor staircase could be used.
27<H≤54	• The floor area of one floor in each unit over 650m^2 • The distance between any door and the nearest safety exit over 10m	N≥2	
	• The floor area of one floor in each unit below 650m^2 • The distance between any door and the nearest safety exit below 10m	When one evacuation stairs are set in each unit, the stairs should be connected to the rooftop, and each evacuation stairs could be connected to each other through the rooftop.	
H>54	—	N≥2	

Table 4-9 The width of the passage in China's code

The width of passage		
Object (Just for residential building)	The minimum width (W)	Remark
Door	W≥0.9m	Still need calculation based on the evacuation time and the flow of people
Safety exit		
Evacuation passage	W≥1.1m	
Evacuation Stairs		
The safety exit on the first floor		

Table 4-10 The number of the exitin the United States' code

OCCUPANT LOAD PER STORY	MINIMUM NUMBER OF EXITS OR ACCESS TO EXITS FROM STORY
1-500	2
501-1,000	3
More than 1,000	4

Table 4-11 The number of the exit in Japan's code

Evacuation type	Characteristic
Two way evacuation route type	For providing one more safety evacuation route to the residents, this type should ensure two different routes for evacuation to the evacuation floor or ground (included the balcony that could be used for evacuation effectively)
Open type	Because of the main entrance faced to opening passage or opening stairs, the smoke could be exhausted in the fire
Two way evacuation route and open type	Have both two characteristics
The other	The type without both two characteristics

The evacuation distance means the distance between any room's door and safety exit. It is in accordant with building's height, floor plan, and fire resistance class, the evacuation distance is different. And the width of the passage as the table shows.

These requests are quite general because it is the minimum request, the specific number need calculation based on the evacuation time and the flow of people. (Table 4-9)

4.3.5.1 Comparative research

Through making a comparison with <International Fire Code> 2015 version (short as IFC) and Japan's < Building Standard Act >, for the number of exits, IFC's request is based on the occupant load per story, to prescribe the number of exits. Considered with the residential building, the occupant load per story should at the level of "1-500", the number's request of the exits is similar to China's code. Japan's request is much more complicated and systematic than China and the United States, it provides four types of the evacuation design methods, the residential building should meet the relevant request of evacuation type that it chooses. (Table 4-10) (Table 4-11)

For the evacuation distance, in IFC, the request is in accordance with the passage's form, the sprinkler's installed situation. The evacuation distance's form has two types, common path, and dead-end. It is as same as China's code. In addition, it prescribed the total distance as well. For the specific indicators, the IFC's request is stricter than China's code. Compared with China's code, Japan's request is quite meticulous. The distance is different in accordant with the room's function, the story of the building, interior material, and structure's type or material. For the specific figures, both two countries are quite the same. (Table 4-12) (Table 4-13)

Table 4-12 The comparison of the evacuation distance
(China and the United States)

The evacuation distance							
	Building category	**The door between two safety exits**			**The door at the sides or end of a dead-end**		
		Class 1/2	Class 3	Class 4	Class 1/2	Class 3	Class 4
China	Single/ Multi-storey civil buildings	40m	35m	25m	22m	20m	15m
	High-rise civil building	40m	—	—	20m	—	—
	OCCUPANCY	**COMMON PATH LIMIT**		**DEAD-END LIMIT**		**TRAVEL DISTANCE LIMIT**	
America		Unsprinklered	Sprinklered	Unsprinklered	Sprinklered	Unsprinklered	Sprinklered
	Group R-2 (Apartments)	22m	38m	15m	15m	61m	76m

Table 4-13 The comparison of the evacuation distance (China and Japan)

China							Japan			
Building category	The door between two safety exits			The door at the sides or end of a dead-end			Room category		Using semi-fireproof structure or incombustibility material (Main structure)	The others
	Class 1/2	Class 3	Class 4	Class 1/2	Class 3	Class 4				
Single/ Multi-story civil buildings	40m	35m	25m	22m	20m	15m	The room below the 14th floor	Windowless room in the lighting definition	Below 30m	Below 30m
								The main room of the hospital, hotel, dormitory, and apartment house, etc.	Below 50m	Below 30m
								Any other rooms	Below 50m	Below 40m
								The rooms and evacuation routes interior using flame retardant material① (Only limited to the part over 1.2m from wall and floor slab)	Below 1:30+10=40m 2:50+10=60m 3:50+10=60m	—
High-rise civil building	40m	—	—	20m	—	—	The room over the 15th floor	As same as ①	Below 1:30-10=20m 2:50-10=40m 3:50-10=40m	—
								As same as ① (Only limited to the part over 1.2m from wall and floor slab)	Below 1:30m 2:50m 3:50m	—

For the width of passage and exit. In common condition, in IFC, the passage's width is 44 inches (equals 1.12 m), with the condition's change, the width could be decreased. The stairway's width is not less than 44 inches (equals 1.12 m). The width of exit is as same as the request of door's size is 32 inches (equals 0.81m). From the indicators, the IFC's request is as same as China's code. In Japan's < Building Standard Act >, its relevant request has a relationship with the function of the building, the function of the passage, and the floor plan. From the specific figures, Japan's width of passage is wider than China's. China's width of stairways is wider than Japan's. (Table 4-14) (Table 4-15)

4.3.5.2 Evaluation

Through the changing of the code, the request for scissor stair-room that the most common in China's residential buildings becomes much stricter than old code, especially from the aspect of smoke spreading prevention.

Through comparative research, in the field of High-rise buildings evacuation system's design, although the form of China's request is quite different from America's code, the other specific indicators of two countries' code about the same except the evacuation distance, it is stricter than China's code.

4.4 Conclusion

According to make comparative with China's <Code for fire protection design for buildings>, Japan's <Building Standard Act>, the United States <International Building Code> and <International Fire Code> in the field of fire safety law system and high-rise residential building's fire safety structural design (the general layout and the floor plan),

Table 4-14 The comparison of the evacuation route's width
(China and the United States)

	Object	Minimum Width (W)	Remark
China	Door	W≥0.9m	Still need calculation based on the evacuation time and the flow of people
	Exit		
	Corridor	W≥1.1m	
	Stairways		
	The exit in the 1st floor		
The United States	Door	W≥32inch（≈0.81m）	
	Exit		
	Corridor	W≥44inch（≈1.12m）	In the following situations, the passageway shall be not less than 36 inches (914 mm) in width. ・occupant load of less than 50
	Stairways		

Table 4-15 The comparison of the evacuation route's width (China and Japan)

China			Japan			
Object (Just for residential building)	The width of passage (W)	Remark	Applicable Object	The usage of passage	The width of passage (W)	
					Central corridor type	The other type
Door	W≥0.9m	Still need calculation based on the evacuation time and the flow of people	One of the following: 1. Special building in Law Appendix 1 (イ) Column (1)~(4) 2. The building has over three floors 3. The floor have windowless room in the lighting definition 4. The building's total area over 1000m²	(1) For the patients in the hospital (2) The area of shared space over 100m² in an apartment (3) Ground floor: the area of room over 200m² (4) Basement: the area of room over 100m²	W≥1.6m	W≥1.2 m
Safety exit						
Evacuation passage	W≥1.1m					
Evacuation Stairs						
The safety exit on the first floor			Apartment Housing	Evacuation Stairs	W≥0.75m	

the research determined the fire safety system and specific request' s advantage, disadvantage, and made an evaluation for each part.

4.4.1 Fire safety law system

Compared with Japan's and the United States' fire safety law system, the separation of China's technical standard and the administrative clause is convenient for the user

and good for extending in the future. However, China's technical standard lack of legal validity and mandatory. although the Fire prevention law ensures the technical standard could be executed effectively through authorized the fire department to inspect and supervise the fire design drawing, for the designers, it is unhelpful to establish a fire safety awareness in their mind. In addition, from the experience of Japan, in the tide of "small government", it has a possibility that the drawing's inspection and supervision could be executed by the third-party agency in the future.

4.4.2 The specific content for fire safety design

The research makes a comparison with Japan and America's technical standard about the request of fire safety structural design, the content includes the building's classification, fire resistance rate of the main structure, fire separation distance, fire Compartmentations and evacuation system. All this content is the most important process in a building's design and the main component of passive fire safety system.

For the building's classification, China's classification method adopts building's heights as the standard, the building's total height is an objective data, there is no operation space for related personnel. And compared with Japan, building's height is much more efficient, objective and scientific.

For the fire resistance rate of the main structure, China's high-rise residential building's request is equivalent to Japan, especially the bearing wall type high-rise residential building's request is stricter. However, compared with America, China's content that inherited from the code of the Soviet Union needs update based on the latest experience of the experiment and practice.

For fire separation distance, China tends to increase the distance of buildings to prevent the fire spread. Japan tends to improve the performance of the single building to prevent the fire spread. America tends to combine both methods to prevent the fire spread. However, considered with China's arranged clause, China's request is equivalent to America.

For fire Compartmentations, in the field of residential building, China and America's requests are quite the same, using the separation wall for dwelling units constructed as fire compartmentation is the most effective and economical choice in current condition. Japan has no provisions for dwelling units. From the specific requirement figures, it is as similar as China. For evacuation system design, the content includes the number of exits, evacuation distance, and dimension of passage. According to make the comparison with IFC, some request of China's Code is not lower than international advanced level.

However, there is still have room for improvement, such as improve the determination condition for each specific request, transfer the experiment and practice experience to actual request timelier and efficiently.

4.5 The application of floor plan in preset scenario

Because the test would proceed in China, the floor plan would adopt China's residential building's floor plan. To choose a typical floor plan for a preset scenario is necessary.

In the 1980s, Hong Kong real estate giant Li Ka-shing proposed the concept of communal area. The communal area includes elevator shafts, pipeline shafts, stairwells, garbage passages, substation rooms, equipment rooms, public halls, corridors, guardrooms, etc. These areas are averaged into the purchase housing area of the buyer. In 1995, this concept entered the mainland of China for the first time.

After entering the 21st century, real estate was commoditized under the influence of neoliberalism. This conception started to have an impact on the public. The public tends to purchase housing with a smaller communal area. In this case, the stair-room type becomes popular because it has the smallest communal area.

Therefore, the most common residential building's floor plan in China is the stair-room type. The stair-room type is that the housings are arranged around the stairwell. Based on the comparison of the floor plan before and after the building designing code's revise that was introduced before. Both two types of floor plan characteristics could be determined. For the old type of floor plan, if the compartmentation was compromised because of any reason. The smoke would invade the front room, and because two evacuation routes share the front room, it would cause both two evacuation routes to lose their function. Although the stair-room has a pressurized exhaust system, from the experience of Shanghai high-rise residential building fire, the reliability of fire equipment should be taken into consideration. Therefore, if the fire occurred in this condition, the situation of the occupants will become extremely unfavorable. For the adoption of the floor plan for the preset scenario, consider the huge stock of the old type floor plan, and the training needs to create the most unfavorable condition for the participants to obtain a better training effect. The preset scenario would adopt the floor plan that was designed based on the building designing code before the code's revision.

Reference

1) SNiP 2.08.01-85, 1985 (In Russian)
2) INTERNATIONAL CODE CONCIL, International Fire CODE, 2015, P94
3) Ji Cong, The research of transportation core design of high-rise residential based on the fire protection code in a new building, Xi'an University of Architecture and Technology, 2017.05(In Chinese)

Chapter 5. The analysis and summary of human behavior in the fire

5.1. Introduction

As the basis of FIG's scenario's design, in addition to the floor plan's analysis from the aspect of hard factor, it is necessary to analyze the human behavior from the aspect of soft factor as well. This episode would base on the survivor's oral testimony that was recorded in Grenfell Tower Inquiry, and combined with the O.O.D.A theory that proposed by John Boyd, the former Colonel of the United States Air Force, to analyzed the human behavior in the fire.

5.2. Dynamics of human behavior

The FLSE conclude six dynamics of human behavior:

- Past experience with the fire will cause an individual to make certain assumptions and expectations about the fire that may not always hold true.
- A lack of information or perhaps erroneous information will lengthen the decision-making process. With effective education, cues and decisions can be made in advance.
- Culture may influence role expectations, such as male versus female, and parent versus child. Culture may also influence the perception of the seriousness of the fire.
- Physical environment of the residence, including the size, familiarity, and layout may influence the cues and behaviors of the occupants.
- An individual's physical condition will influence the decision-making process. As well, those individuals with physical challenges or impairments may have limited options.
- Distractions may influence those in the building or residence. For example, if there are small children in the house, this may distract the parent or caregiver from making the proper decision.

Besides, based on the current research, FLSE conclude eleven behaviors that are common in residential fire.

- Notifying other that the house is on fire.
- Searching for the fire in the residence.
- Calling the fire department from inside the home.
- Getting dressed.
- Leaving the house.
- Getting the family together and preparing to leave together.
- Fighting with the fire.

- Leaving the area of the fire and retreating to another part of the structure.
- Doing nothing.
- Having someone else call the fire department.
- Gathering personal property.[1)]

However, based on the latest research, whatever the dynamic or the reason of the human behavior in the fire, the "panic" factor is not included. In FLSE, it was introduced as follows.

In early studies, "Panic" was defined as a sudden and excessive feeling of alarm of fear that leads to extravagant and injudicious efforts to secure safety. However, more recent studies define panic as a behavior that is fear-induced, that is nonrational, nan adaptive, and nonsocial, leading to reduced possibilities for a group to escape. Then, studies on human behavior during fires have found that irrational or illogical response was not present, and individuals were quick to help others, often at great personal risk.

During a fire, individuals will develop a feeling of stress. The intensity of this stress is dependent on information available and the success of decisions already chosen. In fact, people are often lethargic in response to a fire alarm, ignoring or delaying their response to the initial cues of an emergency. While an individual receiving ambiguous and incomplete cues about a fire will experience an increase in the level of stress, panic in the form of irrational behavior is rare during fires.

This increased level of stress during an incident's development is not abnormal or negative; in fact, it is often what spurs an individual to action. Decision-making during stress can lead to a narrowing of attention and a reduced number of options. Therefore, an evacuation plan that has been well-rehearsed and practiced is easier to apply.

Fire and life safety educators must remember that strategies or behaviors chosen in fire situation that are unsuccessful are not necessarily irrational or illogical to the individual involved. Individuals who do not have sufficient information about the proper actions to take will make choices based upon the information they have. It is the job of the fire and life safety educator to make sure that individuals involved in a fire have all information they need to make the proper choices before they are confronted with this emergency.[2)]

From the latest research, people's irrational or illogical behavior blames insufficient information under stressful conditions, not the panic factor. And the acquisition of information obtaining and analysis's ability mainly depends on the fire safety knowledge delivery at the second level of the fire safety knowledge system that was introduced before. Therefore, in the research of human behavior or designing a fire safety education project, the "panic" factor should not be considered any more.

5.3. About O.O.D.A theory

From the description of panic, a human behavior model in the fire that is people make decisions from the information they got, then act accordingly could be summarized. Because the people could not evacuate through only one process, the “Information-Decision-Action” process would loop under the stress condition until evacuate successfully. However, from the aspect of the analysis of the human behavior and design of fire training tools, mere "information" cannot well reflect the process of residents before making a decision. If the “information” is divided into two actions, obtaining information and analyzing information. It would more precisely describe the actions before the decision is made. However, a resident’s behavior would not have a clear boundary in information’s obtaining and analyzing. Therefore, FLSE as a fire safety education textbook of the second level knowledge system, the mere “information” cannot be said “inaccurate”. (Figure 5-1)

After structured the word "information", the model changed into “Information Obtaining-Information Analyzing-Decision-Action” model, it became to fit with the O.O.D.A theory. O.O.D.A theory was proposed by the United States Air Force Colonel, John Boyd. This theory aims to improve the O.O.D.A loop of one’s own side through technical and tactical means, and reduce the speed of the opponent’s OODA loop, so as to achieve victory in air combat. It is the theoretical basis for the development of modern command and control systems and electronic countermeasures systems as well. In the business field, this theory is also widely used in the formulation of business strategies like Toyota Motor Corporation. (Figure 5-2)

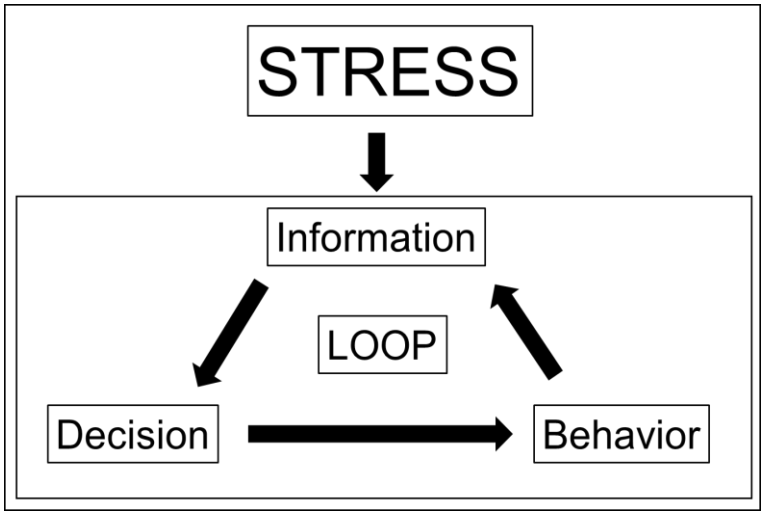


Figure 5-1 The model of the human behavior

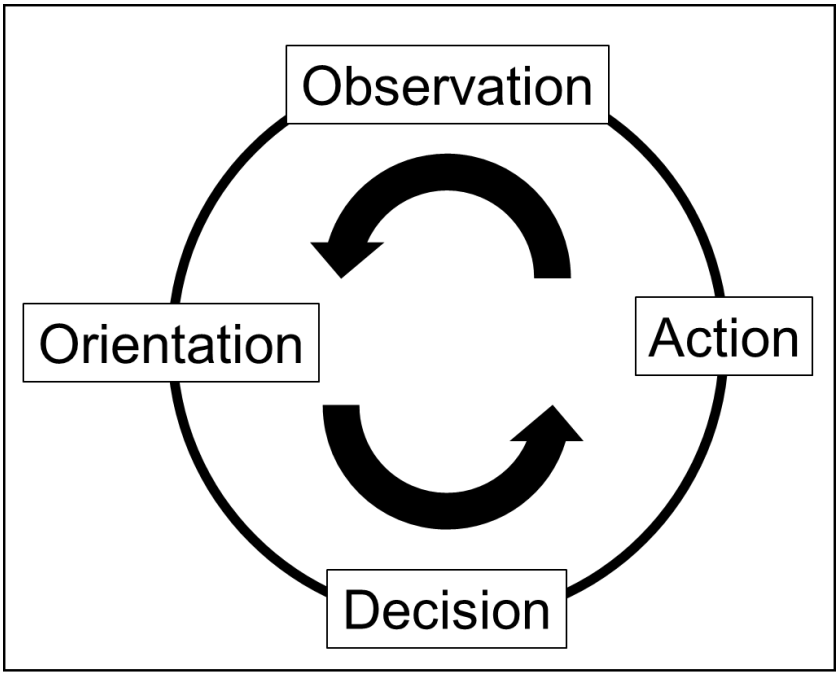


Figure 5-2 O.O.D.A loop

The four letters of OODA stand for:

- Observation, the information obtained by means of the senses.
- Orientation, the analysis of data to form one's determination.
- Decision, Embody the course of action based on one's determination.
- Action, the physical playing-out based on decisions.

However, in the fire site, fire is objective stuff. Its spread follows the general objective law. It would not actively reduce the speed of the residents' OODA loop. Therefore, the residents should unilaterally increase their own OODA loop speed to achieve the purpose of safe evacuation. Combined with the practice of fire safety evacuation, it could be concluded as:

- Observation, the ability to recognize or understand danger signs.
- Orientation, the ability to interpret the signs of danger (the ability to analyze various information on the fire site).
- Decision, the ability to make decisive decisions (the ability to make choices on the rich information on the spot and make proper action decisions in a short time)
- Action, Improve the ability to respond to various situations.

In the Grenfell Tower event, the "Observation" includes the occupants' sense of hearing, sight, and smell. And they got the information from the firefighters, 999 emergency calls, or any other source. The human behavior in the fire would be analyzed from the above four aspects.

5.4. The analyzation of the human behavior

5.4.1. The information resources of analyzation

The information resources of human behavior analysis come from GRENFELL TOWER INQUIRY: PHASE 1 REPORT, the report recorded 28 occupants' oral testimony, and all the oral testimonies have side proof from the testimony of 999 emergency center and London fire Brigade. The content of the oral testimony mainly recorded the occupants' scene that they saw at that time and their reaction to the scene. Be cautious, the occupants' description of the scene is subjective, not the reality scene. Therefore, there may be contradictions in describing the same scene by different people at the same time. Because the occupants' decisions and actions were made based on their observation and orientation, the difference of the scene that they observed has no impact on the analysis.

5.4.2. The summarization of environment's condition of the fire site

For ease of description, based on the description of the oral testimony, the situation of the fire site's environment was summarized into three zones.

- Green Zone (safe), no sign of flame, no smoke, but smoke could be smelled.
- Yellow Zone (danger), the light of flame could be seen, white or grey smoke could be seen (light smoke), could not feel the heat of the fire.
- Red Zone (critical), flame break into the interior, dark grey or black smoke (thick smoke), Low visibility (about 1-1.5 meters), could feel the heat of the fire.

5.4.3. The description and analysis of the occupants' human behaviors

The description and analysis of the occupants' human behaviors as the figure shows. (Figure 5-3) (Figure 5-4) (Figure 5-5) (Figure 5-6) (Figure 5-7) (Figure 5-8) (Figure 5-9)

Case1, Zoe Dainton & David Benjamin

The environment is "Green Zone", they were notified by the neighborhood about the fire, then they followed the "stay put" advice and stay at their flat. They open the door and confirm the situation, they found the environment turned to a "Yellow Zone". Then the environment turned to a "Red Zone", they had a conversation about the fire with a neighbor through a phone. Finally, they decided to leave and evacuated through the stair room, they are safe.

At first, they got the notice from the neighbor, and the "stay put" advice. This process could be classified as "Observation". The "stay put" advice had been introduced in the "Case study" episode before, the advice misled their "Orientation" process and interfered with their decision-making process. This is one of the reasons why the Commission of Inquiry believes that the London Fire Brigade should be responsible for the heavy casualties. Then, they decided to stay at the flat and was acting as the decision. This is the end of the first O.O.D.A loop, and from they open the door and check the situation,

the second O.O.D.A loop started. They found the situation turned from green to yellow, then turned to red. They obtained information through communication with the neighbor and their own observation as the “Observation” process, and they finished "Orientation" at the same time. Finally, they decided evacuation and was acting as the decision. The second O.O.D.A loop ended and they evacuated safely.

The occupants of Case 1 finish the evacuation process successfully through two O.O.D.A loops. The execution of loops is smooth except for the mislead of “Stay put” advice, it extends the interval between two loops

Case 2, Jose and Carmen Vieiro

The situation is “Green Zone”, they caught a phone call about the fire from a friend, and they got dressed. After a while, they found the light of the flame outside the building, the situation turned to “Yellow Zone”, they opened the front door again and moved to the lobby for checking the situation but found nothing inside the building. After the situation turned to “Red Zone” that the flame and smoke break into the flat though the exhaust fan, they decided to leave, locked the door after they left. After that, the man came back to his flat with a firefighter, they check the situation again. Finally, after they confirm the situation is “there is nothing we can do with this”, [3)] he took his property and left again, he left the building with his family through a lift.

At first, they were notified by his friends as the “Observation” part of the first O.O.D.A loop. They decided and get dressed and start to alert. Then they found the light of the flame, they decided to check the situation further again. However, because of the characteristic of the exterior fire, they found nothing inside the building, this is the second O.O.D.A loop. After a while, they observed the flame and smoke break into the flat through the exhaust fan, they decided to leave the building and lock the door, this is the third loop. However, after they leave the flat, the man of this family came back and check the situation again, he took his property and left again. This is the fourth loop.

From this family’s reaction in this case, after they got the sign of the fire, they actively obtain information and their OODA loop is smooth. In the second loop, they found nothing inside the building, their “waiting” decision is blameless. However, because the man’s action that took his property put him in danger again. Although he observed the situation with the firefighter, the last loop is meaningless and unnecessary.

Case 3, William Thompson

The situation is “Green Zone”, he was notified by the neighbor and got the “Stay put” advice as “Observation” part of the first loop, and he decided to follow the advice and was acting as the decision. After a while, he checked the lobby again, and found the black smoke came from the elevator shaft and filled the lobby, the situation turned to “Red Zone”, he decided to leave and was acting as the decision. Finally, he left the building

and notified the other neighbor.

This case is quite similar to Case 1, he was misled by the “Stay put” advice and delayed the process of entering the second O.O.D.A loop. However, with his actively obtaining information by observation, he found the situation turned to “Red Zone”. The second loop started immediately and finished smoothly. Finally, he evacuated safely.

Case 4, Salah Chebiouni and Hanan Wahabi

He smelled the smoke and check the kitchen, and found the light of the frame, the situation is “Yellow Zone”. He woke up his family immediately. Then they checked each room of their flat twice until the situation turned to “Red Zone” that they could feel the heat of the flame. Then they left the building through the stair-room and evacuate safely.

In the first O.O.D.A loop. From the “Observation” that the man found the fire, to the “Action” that he woke up his family, the process is smooth. However, in the second loop, they checked the situation twice instead of making the decision to evacuate under the situation that they have known the fire occurs. This incomplete loop stuck on the “Observation” and “Orientation”, it wasted the opportunity that evacuates in a better condition. Until the situation worsened to the “Red Zone”, they started the third loop and decided to leave the building. From the observed “Red Zone” situation to leave the building, the third loop is smooth.

Case 5, Hoang Khanh Quang and Van Quang Ho

The woman woke up by the smelling of the smoke and check the kitchen, she found the light of the flame, the situation is “Yellow Zone” at this time. After one minute, when she checked the hallway, she found full of black smoke, the situation turned to “Red Zone”. Then they decided to leave the flat, the environment of the lobby is better than their flat, the situation turned to “Yellow Zone”. Finally, they left the building through the stair-room.

Because there is just one minute between her checking the kitchen and hallway of her flat, these two processes should be seen as one “Observation” process, and after she found the situation worsened to “Red Zone”. They decided to leave the flat immediately and was acting as the decision. They evacuate from the flat in one loop, and the loop is smooth.

Case 6, Adam Supareogsanond & Ann Chance

She was woken up by the noise and smelt the smoke, then she found the smoke spread into the room from the front door, the situation of the flat is “Yellow Zone”. She dialed 999 and report the situation. She checked the lobby and found the situation of the lobby is “Red Zone”, she dialed 999 again and got “Stay put” advice. With the situation of the flat worsened to “Red Zone”, they dialed 999 eight times and followed 999’s advice like blocking the door or cooling down with a wet towel. In the last five times of 999 calls, they were advised to leave the flat, but they refused. In this process, they tried to leave

the flat three times but failed. Finally, the fire fighter reached the flat and take the family out from the flat.

Because the timing of aware of the fire is too late, they had been lost the opportunity that evacuates in a good condition. They didn't have too much choice. From a general point of view, their loops that from get advice from 999 to execution is smooth. And the advice helped them persist in the fire until rescue came.

Case 7, Jafari family

At first, the situation of the flat is "Green Zone", the younger daughter of the family is aware the fire occurred and woke up her family. The mother and younger daughter left the flat at first, the elder daughter and father stayed in the bedroom. The father had a physical problem. Then the daughter found the flame break into the kitchen, the situation of the flat turned to "Red Zone". The daughter closed the door of the kitchen and checked the situation. After she went back to the flat. She tried to put out the fire but failed, then they decided to leave the flat. In the process of evacuation, they notified the neighbor of the fire. Finally, they left the building through the elevator.

In the first loop, the younger daughter is aware the fire occurred and woke up the family immediately. This loop is smooth and decisive. And considering the family's physical condition, the "Decision" is reasonable. Then after the situation of the flat turned to "Red Zone", although, from the result, her firefighting decision is unnecessary, her second and third loops are smooth and decisive as well.

Case 8, Natasha Elcock

She was notified by the neighbor and checked the lobby. She found the thin smoke. The situation turned to "Yellow Zone". She dialed 999 to report and was told "Stay put" order. She stayed at her flat until the smoke became thicker that the situation turned to "Red Zone". She dialed 999 to report and was told "Stay put" order. However, she ignored the order and tried to leave the flat, but she failed because of the heavy smoke. After that, she repeated this loop eight times, in this process, the front door deformed and the smoke poured into the flat, she asked 999 for firefighters five times. Finally, the firefighter got to her flat and take her out of the fire site.

At first, the same issue appeared again like Case 1 and 3, it caused the occupants to lose the opportunity that evacuate in a good condition. After the situation worsened to "Red Zone", she still got the "Stay put" advice, she judged the situation and choose to ignore the advice. However, her eight O.O.D.A loops stuck on the "Action" part, she judged the situation and made the proper decision, she could not leave the flat in "Red Zone" condition. It makes her loop worse and worse. This is the shortcoming of her evacuation process. Finally, she was taken by the firefighter luckily.

Case 9, Youssef Khalloud

The situation is “Green Zone”, he was notified by the neighbor about the fire, he left the flat and checked until the 4th floor, then he came back, but find nothing. After a period of time, he was notified by his friend about the fire and found the black smoke filled with the lobby. The visibility was about one or two meters. He decided to leave the flat with his family and met the firefighters in the stair-room.

Considered the man had been fully observed the environment and found nothing, although he was notified by the neighbor about the fire, the fire’s scale was not be told, his judgment and decision were not wrong. It is reasonable to have a long interval between the two loops. After he found the situation turned to “Red Zone”, the second loop started, he made the decision immediately and was acting as the decision until they met the firefighters. The whole loop is smooth.

Case 10, Roy Smith and Katarzyna Dabrowska

The man smelled the smoke and checked the situation, but he found nothing, he went back to the bed. The situation is “Green Zone” at this time. After a period of time, they smelt the smoke became stronger, and got up again. They check the lobby several times and found the smoke. The situation turned to “Yellow Zone”. Then they dialed 999 to report the situation and they got the “Stay put” advice, they decided to follow the advice and wait for firefighters. After that, they repeat this process twice, and the situation worsened in this process. When the process repeated the third time, the situation turned to “Red Zone”. After that, the firefighters got to their flat and took them out.

The main issue is concentrated in the last five loops, they observed the situation frequently but followed 999’s advice caused losing the opportunity to evacuate in a good condition. The reason is that they have made a mistake in their own "Orientation" process. They overestimated the danger of what they observe. It made their loops worse and worse.

Case 11, Denis Murphy

He was woken up by the smell of the smoke, he checked the lobby and found the smoke, the situation turned to “Yellow Zone” at this time. Then he dialed 999 and report, he got “Stay put” advice and he decided to follow it. The situation was worsened, the smoke poured in and filled with the room. The situation turned to “Red Zone”. He dialed 999 again and was told the firefighter was coming. He decided to wait for the firefighters. The firefighter took him out of the flat and left him in the lobby. Then the firefighter found the stair-room filled with the smoke, he moves him to his neighbor’s flat. Finally, when he evacuated with his neighbors, he was left behind and lost his live in the fire.

From the aspect of O.O.D.A loop, the front two loops’ issue is “Stay put” advice’s misleading caused him to lose the opportunity that evacuates in a good condition.

However, after two loops, the firefighter met him, following the firefighters' order in the fire is a basic principle. His behavior that followed the firefighter's order could not be applicable to OODA theory. And in his process that evacuating with his neighbors has no record, it could not be analyzed with OODA theory.

Case 12, Hamid Wahbi

At first, He heard a crackling sound in the kitchen and check it, he found the smoke and flame break into the room. The situation is "Red Zone" at this time. He decided to leave. He dressed up, left the flat and get into the stair-room, the situation in the lobby and stair-room is "Green Zone". However, after he went to the 14th floor, he went back to the 16th floor. He collected stuff included his passport, and left the building with his neighbor.

This man evacuated in one O.O.D.A loop. And the "Observation", "Orientation", and "Decision" process is smooth. However, in his "Action" process, the behavior that get back to the flat and collected the stuff put him in danger again. This action is unnecessary from the aspect of a fire evacuation.

Case 13, Corinne Jones

She was woken up by smell of the smoke. She checked and found nothing. So, she slept again. The situation is "Green Zone" at this time. Then, she was woken by her son and she checked the situation again. She found the light of the flame, the situation turned to "Yellow Zone", She got dressed and decided to leave. Finally, she left the building with her family through the stair-room.

In the first loop, she observed and found nothing, and decided to keep sleeping. After her son woke her up, the second started, she found the light of the flame and decided to leave. The whole loops are smooth and decisive. It made her evacuate safely.

Case 14, Shah and Sayeda Ahmed

He was woken up by the alarm and checked the kitchen, he found the light of the flame. The situation turned to "Yellow Zone". He dialed the 999 but didn't communicate with it. He decided to leave the flat and was acting as the decision. The women notified the neighbor about the fire and left the building with his husband.

They evacuated from the building in only one loop, the whole process of the loop is smooth and decisive.

Case 15, Rabia Yahya

The situation is "Green Zone" at this time, she was awakened by the noise outside and dialed 999. She was advised to stay put. However, she woke up the kids and get ready for leaving. She checked the window and found the smoke at a lower floor of the tower. She was notified by the neighbor about the fire. The situation of her flat is still "Green Zone", she decided to stay put. She dialed 999 again and report the situation and was

advised to keep staying put. The firefighters got to her flat and told her they would take everyone on floor 18 out together. Then she was advised to keep stay put by the firefighter. After a while, the flame break into the room, the situation turned to “Red Zone”. She went to the neighbor’s flat with her son. The situation of the neighbor’s flat is “Green Zone”. She dialed 999 to report again. She was advised to leave the building, but the situation outside didn’t allow her to leave. After a while, she dialed 999 again. She decided to leave this time. After fully prepared, she left the building with any other neighbors.

In the first three loops, she was misled by stay put and lost the opportunity that leaving the building in a good condition. After the situation turned to “Red Zone”, she moved to neighbor’s flat immediately in the fourth loop, this loop is smooth and decisive. In the fifth loop, she got the leaving advice from 999, her “Orientation” process made her choose to stay. As the time goes, after she got the leaving advice again from 999, she left the building with the neighbors in the sixth loop. The sixth loop is smooth as well.

Case 16, Paulos Tekle and Genet Shawo

They were awakened by the noise. Then they found the smoke in the lobby. The situation inside the room is “Green Zone”. They notified their friends who lived in the tower about the fire and communicated with neighbors. They checked the front door again. The lobby’s smoke became thinker. The neighbors came to their flat for avoiding the smoke and fire. Then the firefighters came in and communicated with them, advising them to stay at their flat. Their friend phoned them and advised them to leave, but they decided to follow the firefighter’s advice. After a while, the smoke came in through the window, the situation turned to “Yellow Zone”. They dialed 999 and reported the situation, they were advised to leave the flat. They started to make preparation for leaving the building. Because of one neighbor opened the front door, the smoke poured into the room, the situation turned to “Red Zone”. After the finished preparation work, they left the building with their neighbors. However, they lost their elder son in the evacuation process.

In the first loop, they actively obtained the information through various means. And because the situation inside kept “Green Zone” at the beginning. Their “Orientation” and “Decision” processes are appropriate. In the second loop, because their situation still is “Green Zone”, and the neighbors gathered in their flat. Leaving the building without full preparation may have more issues than following the stay-put advice from the firefighters. Therefore, they chose to stay is reasonable. In the third loop, after the situation turned to “Yellow Zone”, they started to make preparation immediately. In the fourth loop, because of one neighbor’s miss, the situation turned to “Red Zone”, they left the building immediately when they finished the preparation job. In the last two loops,

their process is smooth and decisive, although they lost their elder son because of carelessness, their evacuation process was great.

Case 17, Amal Ahmedin

At first, the situation is “Green Zone”, she was notified by the neighbor about the fire in the lobby. She ran back to her flat and check the situation. She found the sign of the fire, the situation turned to “Yellow Zone”. Then she took her kids to the neighbor’s flat that in the upper floor. In the neighbor’s flat, they found the fire came to their flat. They tried to stop the flame and smoke come into the flat, but failed. The flame and smoke break into the room through the front door and the window, the situation turned to “Red Zone”. She decided to leave the flat with her kids and was acting as the decision. However, their bodies were found in the lobby after the event.

In the first loop, her process of the loop is smooth. However, in the second loop, her “Orientation” made her go to the neighbor’s flat instead of evacuating in “Yellow Zone” condition. Although her third and fourth loop is smooth, she lost the opportunity that evacuate before she was in a dangerous situation.

Case 18, Marcio Gomes and his family

He was awakened by the neighbor and notified about the fire. At the same time, he checked the situation and found the smoke in the lobby. The situation is “Yellow Zone”. 10 or 15 mins later, they started to prepare for evacuation. Then he found the dark grey smoke spread into the room through the side and underneath the bottom of the front door. He blocked the gap of the front door with wet towels, it made the situation do not worsen. He contacted his friend and he was advised to stay put. However, he ignored the advice and tried a few times to come out, but was not able to do so, because his wife was pregnant. He got the advice of leaving the flat from the firefighter or 999 and he tried, but failed. After tried three times, he decided to wait for rescue. After a period of time, the flame break into the room, the situation turned to “Red Zone”. They decided to leave the flat. They covered themselves with wet towels and left the flat. Finally, they met the firefighters at the eighth floor and left the building.

In the first two loops, after he found the fire signs, he made preparation for evacuation and tried to stop the smoke spread into the room immediately. The loop is smooth and decisive. Then in several loops, he avoided the misleading from the stay-put advice, made trials of leaving the flat. However, because his wife was pregnant, the trials were failed. After the trial, he decided to wait for rescue. His family’s physical condition has an impact on his “Decision” process. Then, due to the delay of the firefighters and the situation was worsened to “Red Zone”, they decide to leave the flat. After their full preparation, they left the flat. The last loop is smooth and decisive. From a general point of view, his “Action” process made his loop extend, and lost the opportunity that evacuate

in an early stage. However, because of his family's physical condition, each loop is reasonable.

Case 19 Naomi Li and Lydia Liao

At first, the situation is "Green Zone", they smelt the smoke and check the situation. They dialed 999 to report the situation and got stay-put advice. Then they got information from the neighbor, they decided to leave. In the stair-room, they found the route was blocked by the flow of people. They decided to go back to their flat. In the process of going back to their flat, they were invited by the neighbor and they went to the neighbor's flat. They dialed 999 again and got the stay-put advice. After they got to know about the fire that occurred on the 4th floor, they decided to follow the advice. After a while, they got leaving advice from the neighbor, they decided to follow the stay-put advice and refused the neighbor's advice. Then they found the smoke spread into the room, the situation turned to "Yellow Zone". They block the gap and dialed 999 again. After they got the leaving advice, they decided to leave. However, the smoke inside the flat became thicker, the situation turned to "Red Zone" at this time. Finally, they left the building with the help of the firefighters.

In the first loop, although they spent a lot of time on actively obtaining the information through communication with the neighbor or dialing 999, they didn't pay attention to dealing with the "Decision" process. In the stair-room, their "Orientation" made them lose the opportunity that evacuate in good condition. In the period of staying in the neighbor's flat, they were misled by "Stay put" advice and lose the opportunity again. Finally, until the situation worsened to "Red Zone" and they got the leaving advice from the 999, they left the building with difficulty and made their risk in the fire much bigger.

Case 20, Nicholas Burton

He was awakened by the sound of knocking on the door. He opened the door found no one but the black smoke. The situation of the lobby is "Red Zone". He thought the firefighters would deal with it in a short time, he stayed at home. Then the smoke spread into the flat, the situation of the flat is "Yellow Zone". He blocked the gap of the front door and woke up his family. Then his friend notified him about the fire and urged him to leave the flat. He considered the situation and his wife have dementia, he decided to stay. He dialed 999 and got "Stay put" advice. He found a safe place in his flat, he took his family to stay there and waited for rescue. He dialed 999 again and was told the firefighters are coming. Finally, his family was rescued by the firefighters.

Considered his family's physical condition (dementia) and the lobby's situation, although his "Orientation" is not in line with reality. His "Decision" is reasonable. After the situation of the flat became "Yellow Zone", his "Decision" (Stopping the smoke spread, refuse his friend's advice and taking his family to safe place) is proper. From a general

point of view, his loops are proper and smooth.

Case 21, Yehualashet Enyew

At first, the situation of his flat is “Green Zone”, he was notified by his friend about fire, then he checked the lobby and the stair-room, found the situation of the lobby is “Red Zone”. He decided to go to the neighbor’s flat. He met the firefighter in the neighbor’s flat and was told to stay in the flat. He followed the firefighters’ advice and prepared for leaving. Finally, the firefighter came back and took him out of the building.

The whole loop is smooth and complete, considered the situation of the lobby and stair-room, his “Decision” is reasonable.

Case 22, Begum family

The woman of this family was woken by the light of the flame. The situation is “Yellow Zone”. She dialed 999 and was told the firefighters would come to her. After that, the situation turned to “Red Zone”. She communicated with 999 and her relatives several times. On her fourth phone call to 999. She was advised to leave the building, she refused. Then, the same thing happened again. Finally, her body was found in the lobby, and his family’s bodies were found in the flat.

This case can be used as a negative example. The women of this family kept obtaining information from various means. However, the loop stuck on the “Observation” process, did not enter “Decision” processes. She refused 999’s leaving advice, but there is no active loop was executed to protect her family. Finally, her family died in the fire.

Case 23, Samuel Daniels

At first, the situation of the flat is “Green Zone”, he was woken by the smell of the smoke. He checked the flat, lobby and stair room. The situation of the lobby kept “Green Zone”. Because of the smell still existed, he decided to leave the flat with his father. Then he checked lobby again, he found the smoke in the lobby. The situation of the lobby turned to “Yellow Zone”. He tried to leave the flat with his father, but his father had difficulties with mobility and got dementia and refused to leave. At this time, the situation of the lobby turned to “Red Zone”. He left the flat alone and asked the firefighters for help. The firefighters went to his flat. And he waited in the stair-room with the other firefighters. After a period of time, he was asked to leave the building by the firefighters, then he left the building. Finally, his father died in his flat.

All of his loops are smooth and decisive. In the third loop, considering his father’s physical condition, his “Decision” is reasonable. And he left the building because he followed the firefighters’ orders. Although his father died in the fire, it has no relationship with his reaction to the fire.

Case 24, Sener and Hanife Macit

At first, the situation of the flat is “Green Zone”, the man was woken up by the fire

engine. They checked the lobby twice and got their relative's leaving advice. After they make preparation for leaving the flat, they found the situation of the lobby had turned to "Red Zone". They dialed 999 twice and got "Stay put" advice. However, their relative advised them to leave the flat. Then, they tried to leave the flat again but failed because of the smoke. After that, they dialed 999 twice and got the leaving advice but they refused. They tried the third time but failed again for the same reason. They dialed 999 again and got the same advice. They tried the last time and made it to leave the building.

From the result that they could evacuate on their own, the "Action" caused their trial to fail three times. Besides, the situation that the loops were stuck on the "Action" part extended the time of the loops. Although they encountered obstacles in the "Action" part of the loop, the other parts of the loop were proper and smooth.

Case 25, Richard Fletcher and Hime Gashaw

At first, the situation of the flat is "Green Zone", they saw the fire engine coming. they didn't find the sign of the fire and go to the bed. After a period of time, they were woken by a popping sound and checked the lobby. they found the situation lobby is "Red Zone". They decided to ignore the "Stay put" advice and left the flat immediately. Finally, they left the building.

In the first loop, they check the situation but found nothing, their decision was reasonable. After they found the fire, they avoid the misleading of the "Stay put" advice, and their loop is smooth and decisive.

Case 26, Clarita Ghavimi

At first, the situation of the flat is "Green Zone", she was woken by the smoke alarm. She checked the lobby and found the situation of the lobby is "Red Zone". She checked the lobby again and thought the situation of the lobby worsened. She decided to stay in the room. After a while, she found the smoke spread into the flat, the situation of the flat turned to "Yellow Zone". She decided to leave the flat immediately. Then she put a wet towel over her mouth and left the flat. Finally, she was rescued by any other occupants in the stair-room.

From the result, in her first loop, her "Orientation" part mislead her "Decision" process. However, after she found the situation of the flat turned to "Yellow Zone", her second loop is smooth and decisive.

Case 27, Paul Menacer

At first, the situation of the flat is "Green Zone", he was woken by the screaming. Then he checked the lobby and found the situation of the lobby is "Red Zone". He went back to his bedroom and block the gap in the front door to stop smoke from coming in. After a while, he decided to leave. In his process of evacuating, he knocked on his neighbors' doors and notified them. Finally, he left the building.

From a general point of view, his loop is smooth and decisive.

Case 28, Milad Kareem and Rebin Sabir

At first, the situation of the flat is “Green Zone”, the smell of the smoke and the shouting sound made them check the situation. They found a firefighter and the firefighter told them to stay. However, at the same time, the local occupants told them to leave. It made them confuse. After about 10 to 15 minutes, they found the smoke spread into the room, the situation of the flat turned to “Yellow Zone”. Then, they checked the lobby and found the situation of the lobby is “Red Zone”. They communicated with the firefighters and were told to stay at the flat and the firefighters would rescue them. After a while, two firefighters came to their flat and told them to keep waiting for rescue. Finally, the firefighters put a ladder on the window and got them out of the flat.

Following the firefighters’ order in the fire is a basic principle, and they lived on the fifth floor made them could get more resources of rescue than the higher floor. With the command of firefighters, there is no O.O.D.A loop could save them from the fire as well. However, the occupants of the higher floor need much more independent judgment ability, this is when the O.O.D.A loop comes in handy.

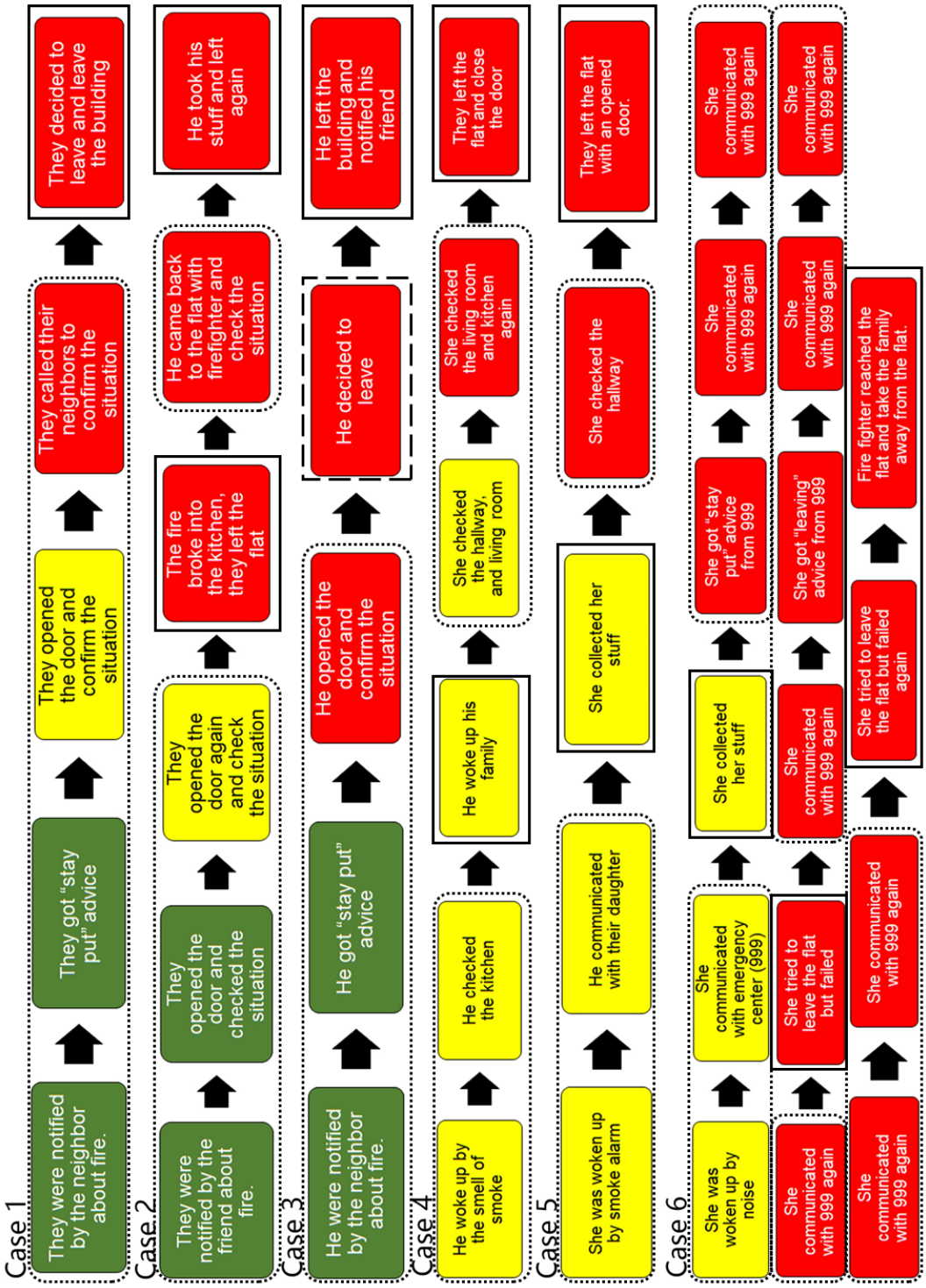


Figure 5-3 The flowchart of human behavior in the fire (Part 1)

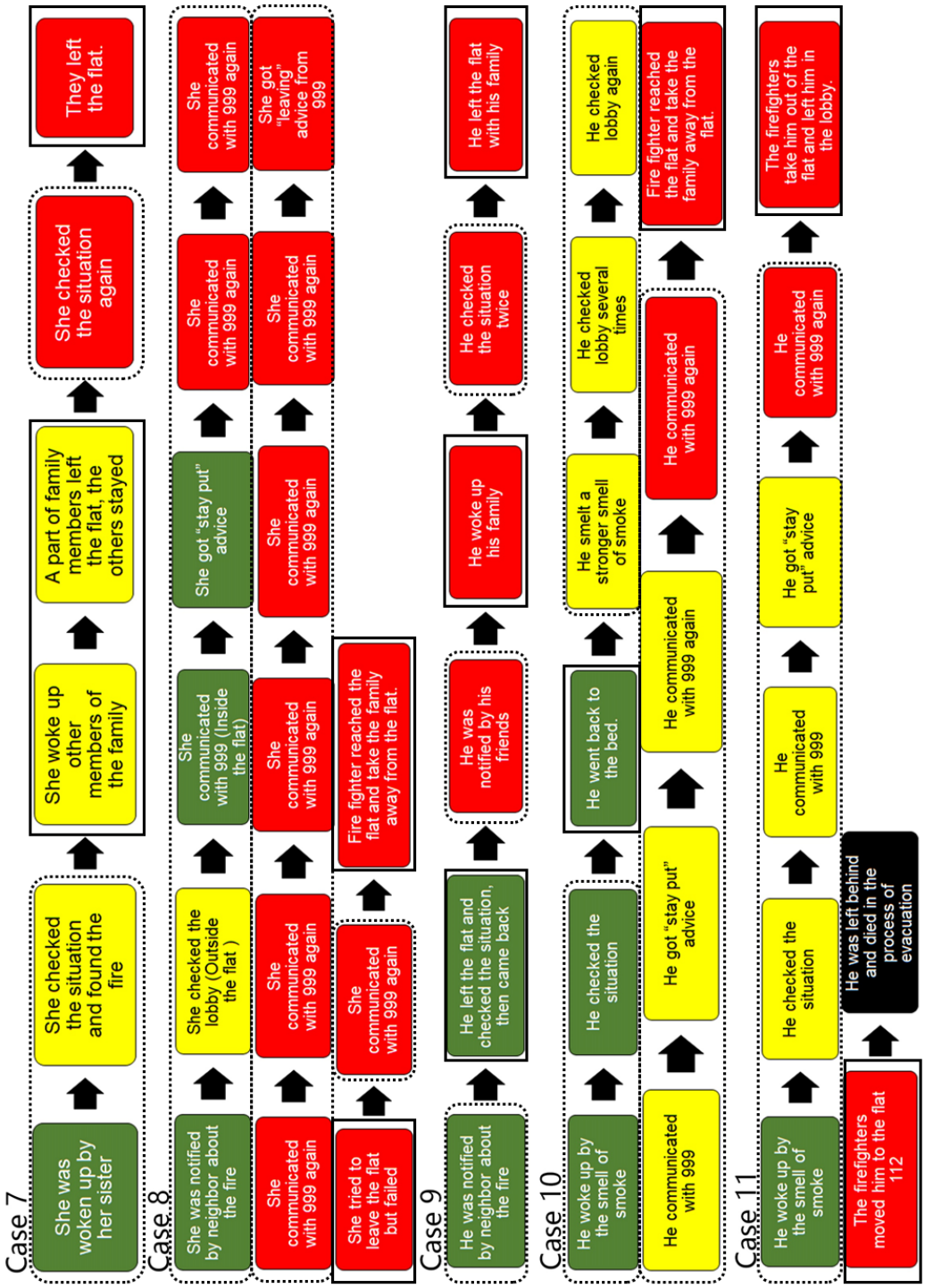


Figure 5-4 The flowchart of human behavior in the fire (Part 2)

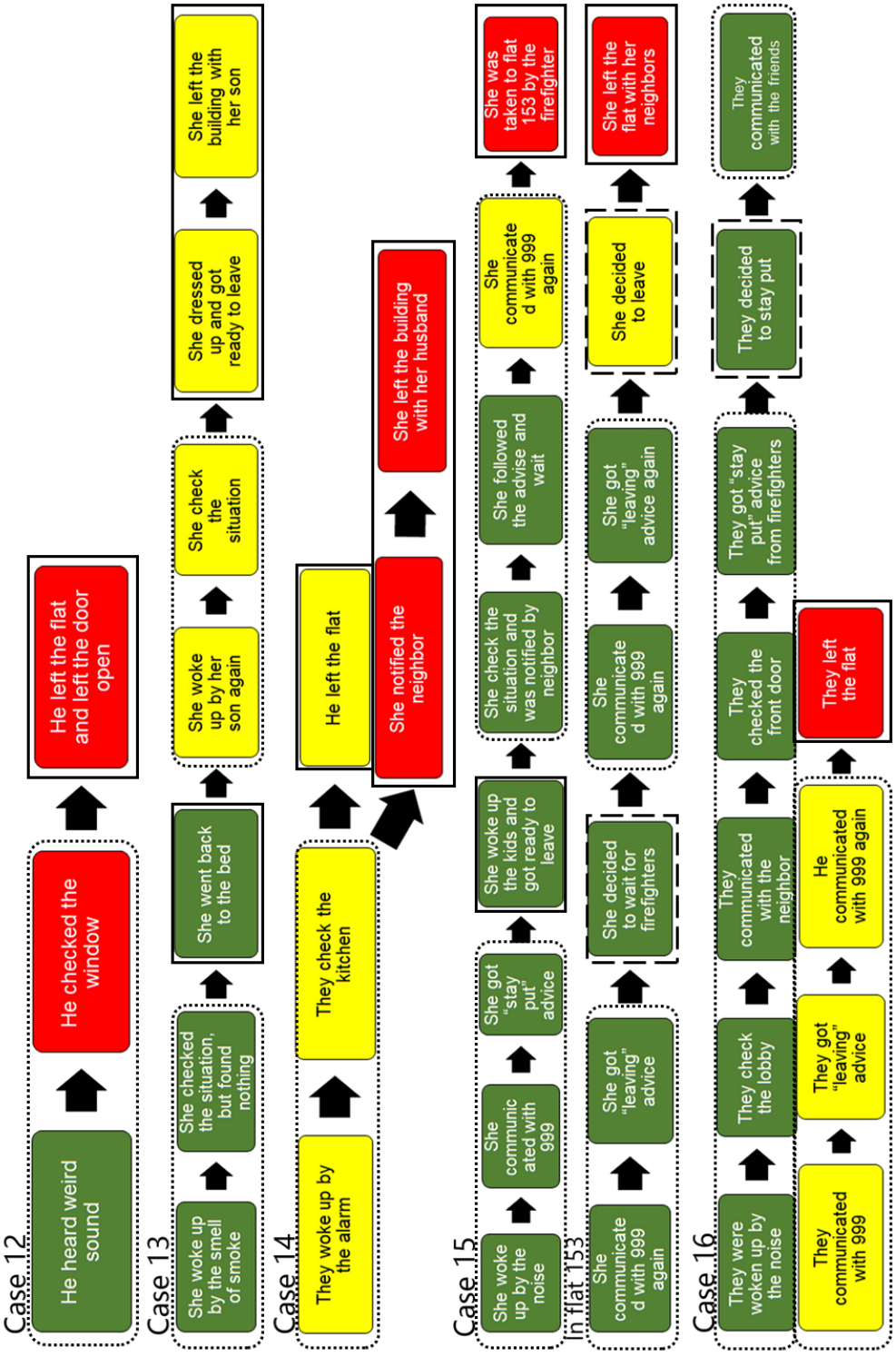


Figure 5-5 The flowchart of human behavior in the fire (Part 3)

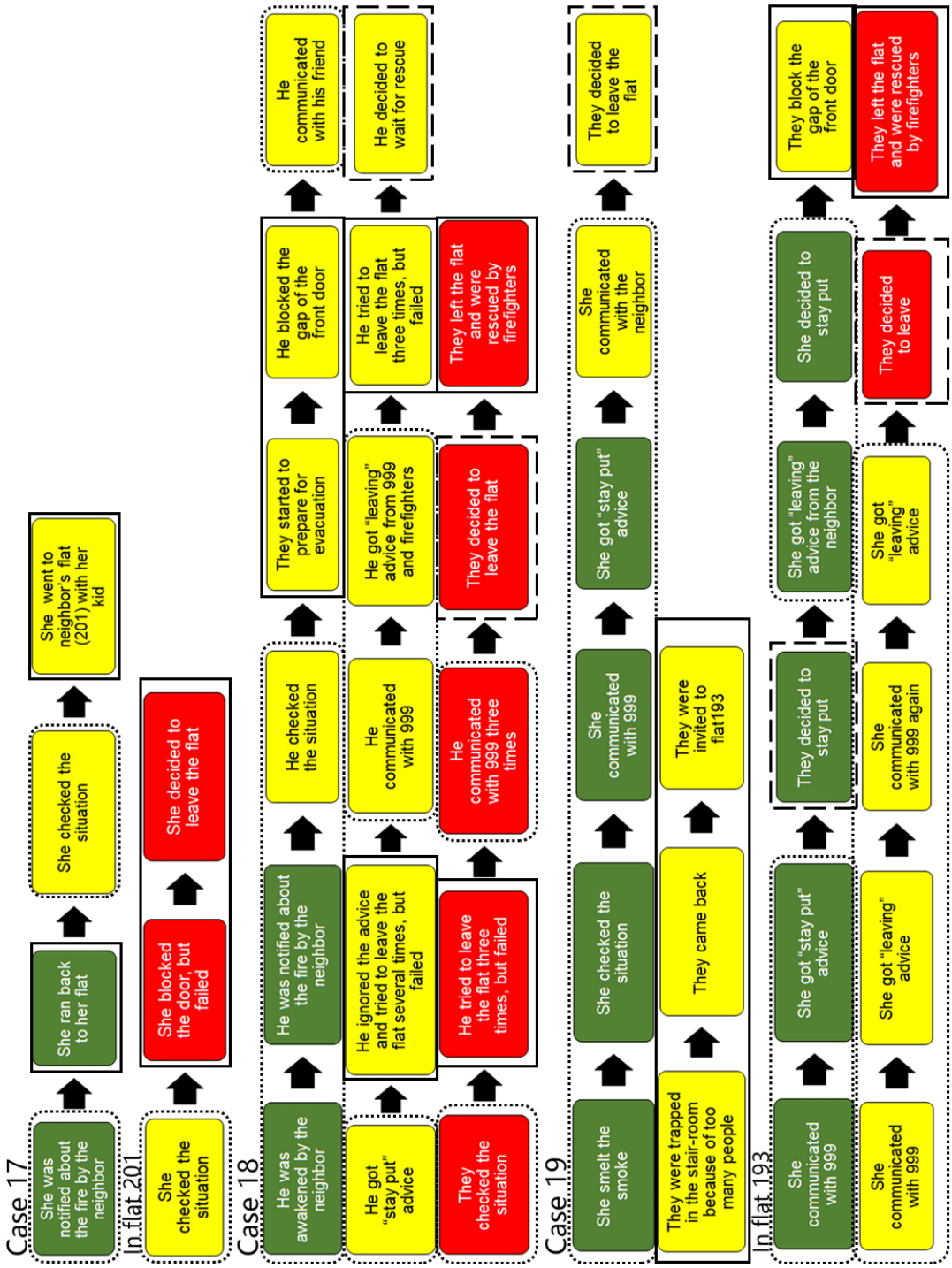


Figure 5-6 The flowchart of human behavior in the fire (Part 4)

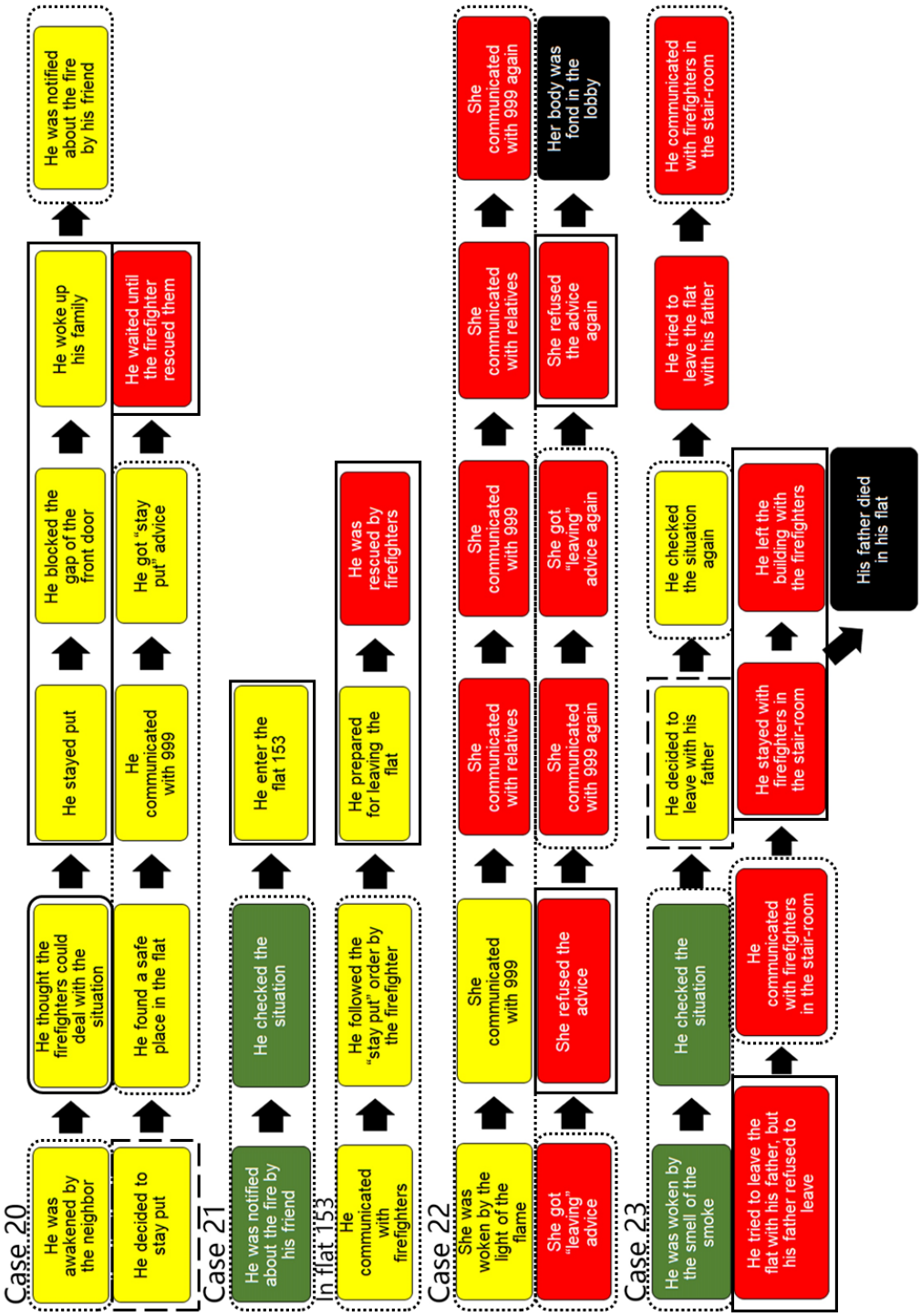


Figure 5-7 The flowchart of human behavior in the fire (Part 5)

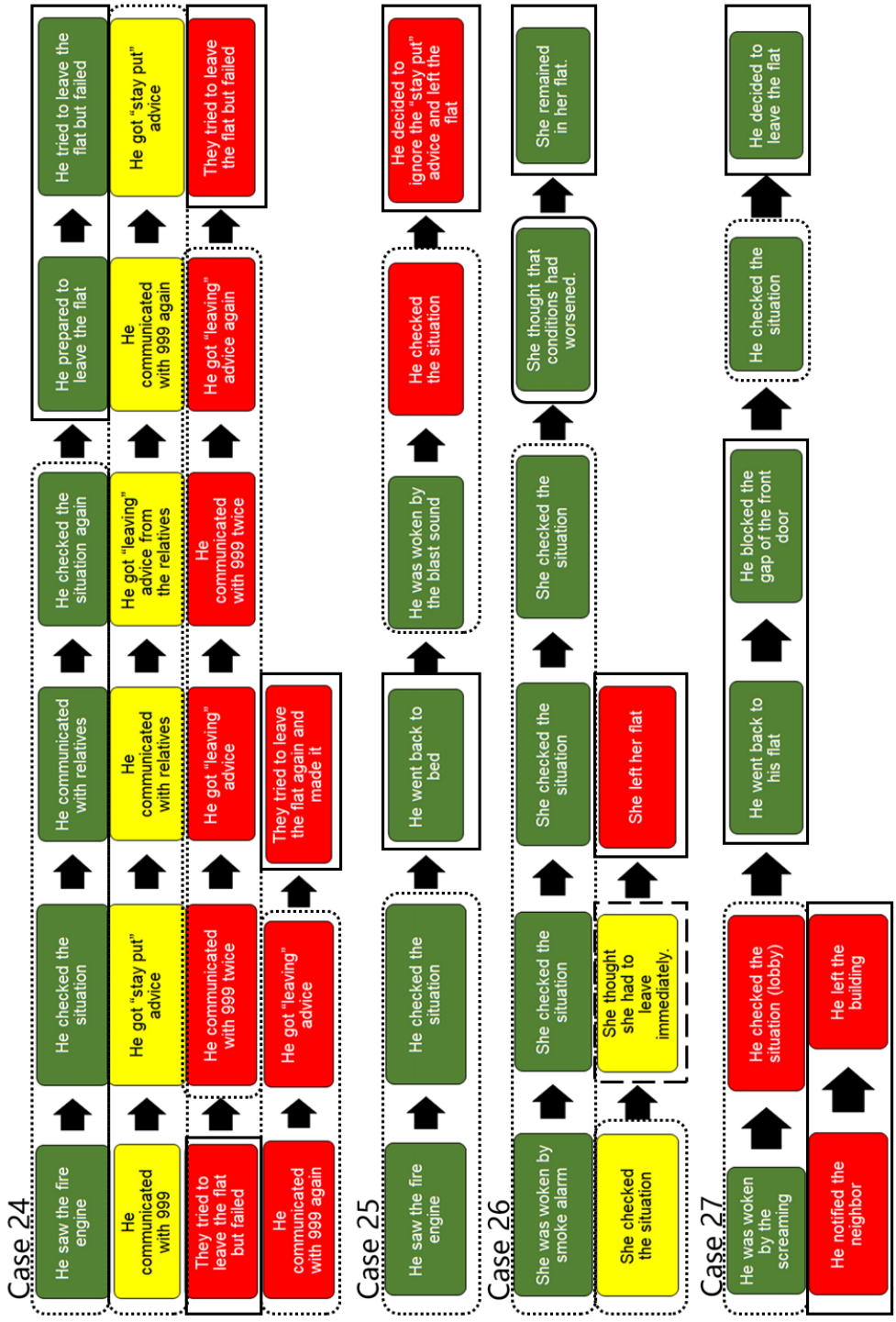


Figure 5-8 The flowchart of human behavior in the fire (Part 6)

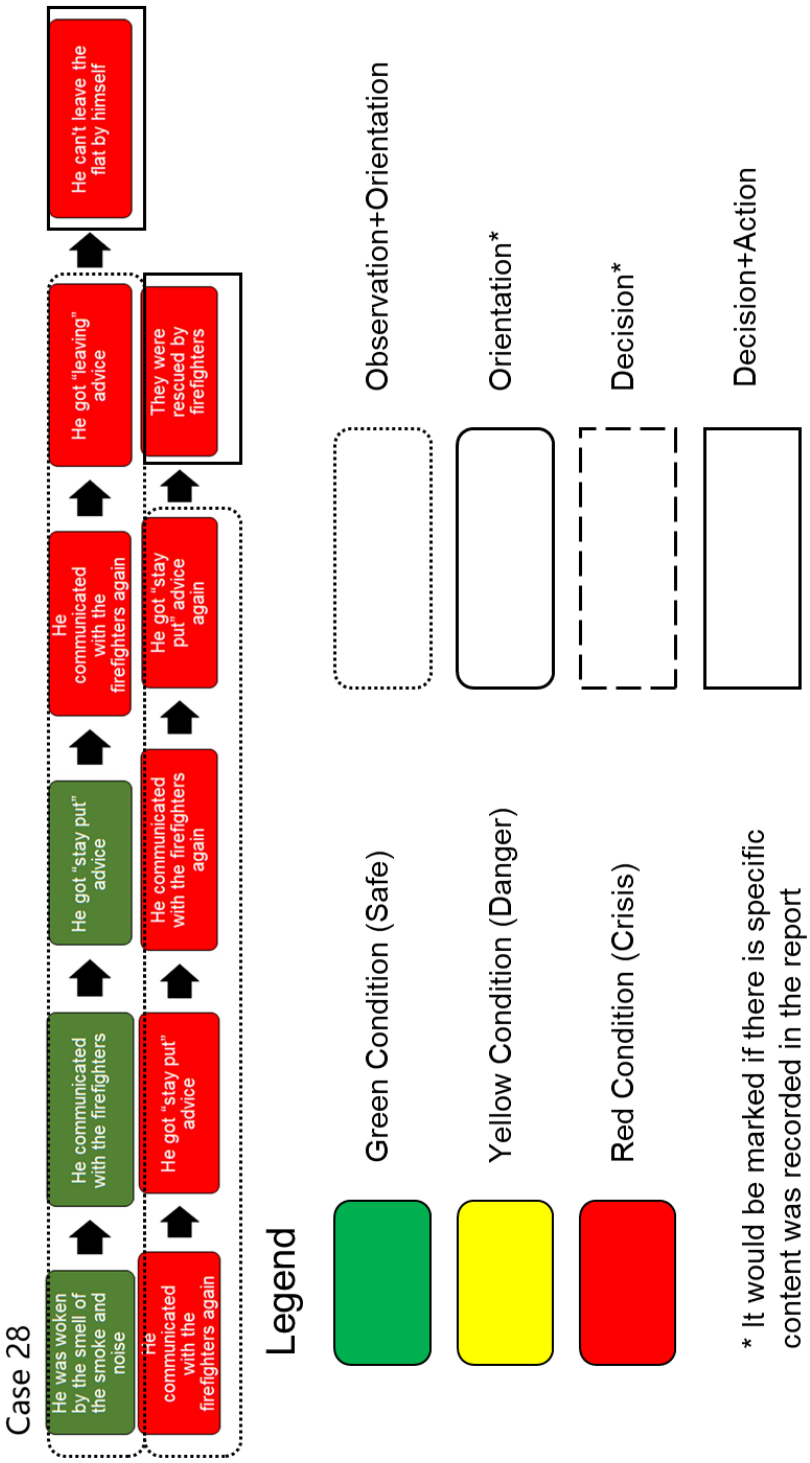


Figure 5-9 The flowchart of human behavior in the fire (Part 7)

5.5. The summary of the human behavior analysis

From 28 cases that analysis and evaluation above, all the occupants have an obtaining information behavior when they found the sign of the fire whatever by any means. Then they naturally made judgments on the information they have obtained. Although just two cases (Case 20 and Case 26) described what they thought after their observation in a limited way, their "Orientation" behavior could be reflected in their “Decision” process. From their “Decision”, the most interfering factor on “Orientation” part is “Stay put” advice, it made the occupants’ lose the opportunity that evacuates in a good condition. As the introduction in the “Fire case” episode, the “Stay put” strategy is reasonable in a conventional fire event. It was established within the condition that the buildings’ compartmentation is in an integrity state. However, in the exterior fire event, because there is no compartmentation in the exterior wall, and the compartmentation of the interior had been compromised, the “Stay put” strategy couldn’t work as it should. Although all the occupants have “Observation” and “Orientation” behavior, some cases show that some of the occupants’ loop was stuck on the “Decision” part or “Action” part for some reasons. Because their loops couldn’t go on smoothly, their behavior stuck on the “Observation” and “Orientation” parts, and repeat them until the situation worsened to force them to continue the loop. However, in this case, the forced loop would put them at risk. Without the rescue of firefighters, they could easily lose their lives in this environment. In Case 19, after the occupants got to know the fire resource, compared with their behavior in the early stage (before they went to the neighbor’s flat), they slowed down their loop and decided to wait for the firefighter’s rescue. Until the environment worsened to “Red Zone”, they started moving again. And finally, they left the flat in poor conditions of evacuation. This case could prove the description in dynamics of human behavior, “Past experience with the fire will cause an individual to make certain assumptions and expectations about the fire that may not always hold true.” Here “Past experience with the fire” could include all means of accumulation of the experience such as the fire safety education or the publicity from the media. This case could prove the description in dynamics of human behavior, “Past experience with the fire will cause an individual to make certain assumptions and expectations about the fire that may not always hold true.” Here “past experience with the fire” could be the experience that was obtained from the fire safety education or the publicity from the media or the stereotype of the fire that was obtained from daily life. Therefore, occupants should make decisions based on current information that they obtain, minimize reliance on experience as much as possible.

From the aspect of fire safety education, the “Decision” part could be strengthened by “Attitude and response” training at the third level of the knowledge system, the purpose

of the FIG is to train the participants' decision-making ability, fits the purpose of the FIG. The "Action" part could be strengthened by actual fire demonstration or fire drill.

Reference

1) International Fire Service Training Association, FIRE AND LIFE SAFETY EDUCATOR Third Edition, pp. 53-54, 2011.02
2) International Fire Service Training Association, FIRE AND LIFE SAFETY EDUCATOR Third Edition, P53, 2011.02
3) Grenfell Tower Inquiry, GRENFELL TOWER INQUIRY: PHASE 1 REPORT, Volume 2, P134, 2019.10

Chapter 6. The operation of the FIG

6.1. Introduction

The operating method of the FIG for multi-story residential building would refer the Fire Image Game for the elderly facility that was developed by Prof. Ohnishi. However, because of the dynamic of the human behavior and human behavior of the staff of the elderly facility is different from the occupants of the residential building, the corresponded role in the FIG training, the operating method would be different. Therefore, the FIG for multi-story residential buildings would refer to the FIG for the elderly facility's basic ideology, combined with FLSE's guiding principles and OODA theory, to propose an operating method of Fire Image Game for multi-story residential buildings.

6.2. The workshop type of the FIG

6.2.1. Table and chair placement

The participants need to wear name tags to instill a sense of participation. If there are too many participants, they need to be divided into groups and in the process of the workshop, some people will not be able to say anything and will be left to the states of unattended. If possible, limit the number to 6 to 7, and at most 10 people for each group. The mode of the table and chair placement would reference the FLSE-defined conference type.

6.2.2. Nomination of facilitator

The facilitator is a person who has the role of intervening in discussions while maintaining a neutral position on discussions in participatory workshops and coordinating discussions so that deep discussions can be held toward mutual understanding. The facilitator may also serve as a participant, and may be selected as a facilitator from the participants (players).

The role of facilitator could be said that be close to the role of "caddy" in golf. Since he is not a leader, his main role is to give the player a chance to talk with prudence and proceed smoothly that couldn't deviate from the basic principles of fire safety. The facilitator would give advice when the division of roles is not decided within the group, when the direction of the discussion becomes strange, or when the progress is stuck in group work. Even in that case, instead of directly teaching "this is better", he presents the issue "what will happen from this perspective" or "what kind of result the action will bring" so as to draw out the imagination of the player.

6.2.3. The preparation of the floor plan

Because the main part of most high-rise or multi-story residential buildings is

composed of standard floors. The workshop needn't all the floor plan like the FIG for the elderly facility, a 1/100 scale standard floor plan is enough. If there is no specific residential building's floor plan, the same type of floor plan would be fine as well. (Corridor type, side-corridor type, mid-corridor type, or stair-room type). Although any other scales would be fine, the scale should meet the request that could make the participant imagine the width or length of the corridor or the stair-room. Besides, the floor plan must show at least the stairs, balconies, and corridors in addition to the household and public area. In addition to the doors of each room, fire doors that close in an emergency must also be filled in.

Based on the practice of evacuation in the resident's fire, the occupants' just need to evacuate to the ground floor would be safe, the map around the site could be prepared, but it is not required.

6.2.4. The preparation of FIG kit

At least a model of smoke, fire extinguisher on each floor, etc. is required. Because these models are placed on the floor plan during the exercise, it is desirable that the size of the model fits in the private room of the plan view. As for the number of occupants, if you have a three-people family at night, prepare a model for three people. Place the model of the fire extinguisher in the specified position. Besides, so that you can see the smoke spreading status along the time axis, place a transparent vinyl (colored one is preferable) showing the smoke spread status on the plan view and use magic ink to mark the smoke over time. Showing the spreading range makes it easier to imagine places that are blocked by smoke and cannot pass through for the participants. And this step presents the OODA loops "Observation" part.

6.2.5. The preparation of time chart

As the first step of FIG, it is necessary to clearly share the image of what have done as an occupant in the event of a fire. For this reason, prior to FIG, create a time chart that shows the activities of the occupant. The time chart is created so that the vertical axis shows the passage of time since the fire broke out or the process of the fire and the horizontal axis. And the blank after the vertical axis records the participants' "Orientation" and "Decision" in the fire.

6.2.6. The proceed and record of FIG

The decisions and discussions within the group are basically carried out by the participants except the facilitator.

6.2.7. Group size and facilitator

A maximum of about 10 people will be grouped together, and each group will have one facilitator.

6.2.8. Division of roles

Roles include facilitator, facilitator, recorder, fire and smoke and occupants. Share between participants.

The behavior of occupants during a night fire was described in the last episode. Human behavior depends on a variety of conditions, such as knowledge, experience, and objective environment. Under the condition that the fire spread pattern is “exterior fire”, it is necessary for participants to discuss these “Decisions” processes. These activities themselves could create a lot of "awareness" to the participants and it is a meaningful experience for them.

First, participants discuss and set what kind of activities in daily life could cause a fire. Next, imagine where and what kind of behavior each family member will be doing at the time of the fire and fill in the time chart while discussing what kind of problems will occur with the fire spread. Depending on the conditions determined in advance before performing FIG, it may not be possible to respond flexibly. If the participants have a problem during FIG, they need the flexibility to correct the conditions and start over again as well.

The main purpose of FIG is to respond to evacuation immediately after a fire, in the evacuation process, some unexpected situations may happen, such as the occupants who have physically handicapped calls for help or the misleading information appears, this kind of event would interfere the occupants’ OODA loop and may cause them to lose the opportunity to evacuate on time. For such kind of situation, participants need to discuss and consider a solution to get the best of win-win consequences. Besides, recording in the time chart could remind the participants what they could respond to the fire until they could evacuate safely. And the recorded content is the basis for subsequent discussion. as well. In this way, a time chart is an effective tool for considering what is necessary as a proactive response in the premise of an emergency.

6.2.9. Assumption of the time that the fire occurred

Based on the record of the true event and the people’s living habits, people have living habits that fall asleep at noon or at night. People are usually slow to react to abnormal conditions in this situation. To improve the challenge of training, the time could choose mid-noon or midnight.

6.2.10. Assumption of the place of fire resource

Because of the exterior fire would spread fast along the exterior wall of the building in the early stage. Compared with the single fire resource of the conventional type of fire, although exterior wall fires are usually a single source of ignition, when the people perceive the fire, the fire source in the people’s awareness at that time is more like multipoint concurrency. From the record of the GRENFELL TOWER INQUIRY report,

the judgment of the fire resource in this situation is neither helpful nor meaningful for occupants' evacuation. Therefore, in FIG's training, participants need to make decisions to the specific imagined scene in the process of the training.

6.2.11. Calculation of evacuation limit time

Because occupants are distributed throughout the residential building. The time when the fire was detected, and the circumstances of the fire spreading when the fire was detected are different for each household. And due to the location of the occupants on one floor, the evacuation routes are also different. Compared with the staff of the elderly facility, there is no standard evacuation limit time for them. In addition, under normal circumstances, the occupant only needs to take care of his family members in the process of evacuation. His range of attention is much smaller than that of the staff in the elderly facility. Therefore, for the occupants of a high-rise residential building, the principle of FIG training is within a reasonable range, the shorter the evacuation time, the better; from the aspect of O.O.D.A theory, the less the number of the loop, the better.

6.2.12. The situation of the front door

Based on the living habit of the occupants, the door could be seen as closed by default. The fire door of the stair-room could be seen as closed or opened by the local management regulations.

6.2.13. The operating of the FIG

After the preparation, according to use the FIG kit, each participant who's in charge places the kit and reproduces a series of actions of the occupants after the fire occurs. To make a trial in the assumed scenario, considering the most proper reactional behavior under the most unfavorable situation through O.O.D.A theory. Depending on the plan, such as stairways where the occupants are congested may be the most severe conditions or the smoke exhausting function failure evacuation route would be the most severe condition in the fire. The operation of the FIG for the multi-story residential buildings would be separated into two stages.

Stage one is the initial stage, after the occupants find any signs, they should judge the situation whether the fire occurs. And based on their experience, to make decisions such as notifying other people or checking situations, etc. Be cautious that because the participants have known that they are participating in a fire safety-related workshop, it may have an impact on their judgment.

Stage two is the fire spreading stage, based on the law of exterior fire, there is a clear signal of the fire could be seen by the occupants such as thick smoke, the light of the flame, etc. In their process of training, some emergency events such as physically handicapped people calling for help could be interspersed by the facilitator. Although these events force the participants to make some ethical choices, there is no right or

wrong from the rational level. This measure could stimulate discussion among participants.

6.2.14. The record of the FIG

Records are kept by the person in charge of recording in group work. The contents to be recorded are the description of the scenario, the series of actions of the occupants (up to where they were evacuated), the items for which opinions were divided within the group, how they were selected in that case, the reason, etc. Besides, it is necessary to confirm whether there is a problem with the behavior of the occupants and if there is a problem, reconsider the coping strategy.

After group work, each group facilitator reports the discussion contents in the front of the facilitator and everyone.

6.3. Adaptation of FIG's operation to respond to the current Corona-pandemic

6.3.1. Introduction

Since 2020, the Corona pandemic appears worldwide, to avoid close contact leading to the spread of the epidemic. The related policy that prohibition of gatherings that may cause close contact was published whatever in China government and Japan government. Therefore, it was difficult to obtain the chance to cooperate for holding a FIG workshop that the occupants could talk with each other whatever in China or Japan. To advance the experiment to evaluate the effect of FIG, the FIG's workshop-type working model need to improve to adapt the current situation. The improved working model is called "Remote-type". The "Remote-type" of FIG should obey the principles as the follow shows.

1. Minimize personnel dependence.

   Because there is no fire safety workshop that could be held, and for most ordinary people, especially the elderly, to hold fire safety workshops through remote meeting software, the operating threshold is too high. It is impossible to gather the people around and nominate the facilitator or any other functional roles through discussion. Therefore, it is necessary to consider a way to allow this training system to operate without a functional role, especially under the condition that the lack of a facilitator.

2. Maximum guarantee that the discussion takes place.

   In FIG training, the discussion or thought exchange plays a key role. Without the discussion or thought exchange, the FIG could not achieve the purpose that improve the participants' decision-making ability through thought exchange. For the same reason, 6~7 people's group discussion is impossible, through the adaption improvement of the FIG, at least ensure the participants could discussion with their family and set topics for this purpose.

3. Ensuring the progress of the FIG process

Without discussion, the proceeding of FIG training is impossible. Especially the simulation of the progress of the fire spreading scenario. Therefore, to have a method for FIG training to advance automatically in an unattended manner would be helpful.

Based on these three principles, we design an automatic training system through a web questionnaire platform. In order to advance the process of FIG training, based on the characteristic of the web questionnaire platform that after the responder finished one question, the next question would show up automatically, the description of the scenario would appear at the stem of the question. In order not to give the participants a clear fire signal to train their "Orientation" ability, the progress of the fire scenario would become more and more severe with the time pass. And the changes should be smooth with no obvious "gap". And the description of the scene must be objective to avoid affecting the judgment of the participants. All the description of the scenario comes from the testimony of the GRENFELL TOWER FIRE INQUIRY. It could improve the authority and persuasive of the training. In order to fit the OODA theory, the participants need to judge the situation through choose one option from "Green", "Yellow", "Red" options after reading the description of the scenario.

Because of the lack of a facilitator, the occupants' behavior became a single-choice question to make sure the participants would not deviate too far away from the basic principles of fire safety. At the same time, in order not to limit their imagination, the options should be as many as possible. Therefore, the options are picked from FLSE's common behavior in the fire and summarization from GRENFELL TOWER FIRE INQUIRY's testimony. To ensure that the options are both authoritative and persuasive. However, in GRENFELL TOWER FIRE INQUIRY's record, although some behaviors deviate from the basic principles of fire safety, that behavior made the occupants escape by chance. These behaviors were included in the options as well. The purpose is to stimulate discussion among participants. However, based on their choice, the corresponding instruction content would show up at last to tell the participants that these behaviors do not conform to the basic principles of fire safety knowledge. It should also be explained that even if the escape is successful through these behaviors, it is just a fluke and not worthy of emulation. (Figure 6-1) (Figure 6-2) (Figure 6-3)

In the process of evacuation, some questions or options about some emergency events such as physically handicapped people calling for help would be shown up, these events force the participants to make some ethical choices, there is no right or wrong from the rational level. The participants' choice would reflect on a suspenseful ending to reflect their worry with the consequence they cause.

After designing all the single-choice questions, all the questions would be connected with logical jumping. In order to reflect the influence of the participant's choice on the OODA loop and his entire evacuation process, based on the participant's choice, the question would logically jump to the corresponding question. Finally, corresponding to their choices, there will be different endings. There are six endings and one additional ending was set. In order to stimulate discussion among participants, rigidly judging whether the participant's choice is right or wrong should be avoided, all the endings are happy endings that they evacuate safely even if the behaviors they adopted deviate from the basic principles of fire safety. The different ending shows up could stimulate discussion among participants. And it would give participants an adventure-game-like feeling. It could increase the fun of the whole training. (Figure 6-4) (Figure 6-5) (Figure 6-6) (Figure 6-7)

According to designing of the automatically training system, the functional role would be replaced by the word description. The facilitator's job was replaced by instruction content. Because the test was proceeded in China, to avoid contradicting the evacuation principles of local fire safety education, the instruction content was chosen the fire safety evacuation education content that was published on the website by the government of China[1)]. After the participants submit the questionnaire, all their choice would be recorded automatically by the system which means the time chart would not be needed anymore. All the participants would just play the role of occupants is enough. Although the discussion between 6-7 people's group is impossible, based on FLSE summarized dynamics of human behavior, even discussions with three or four people in the family unit could provoke a collision of ideas as well. Finally, participants' attitudes and emergency response capabilities would be improved.

1. In the middle of the night, you heard the sirens of the fire truck outside and vaguely saw the flashing of the police lights.
And your decision:
① Do nothing for the time being, just wait and see what
② Go to the corridor outside to confirm the situation
③ Confirm the situation from your neighbors
④ Confirm the situation from the police, fire brigade or other relevant departments
⑤ Wake up the family
⑥ Get ready for evacuation

2. After a few minutes, it seemed to smell of smoke
And your decision:
① Do nothing for the time being, just wait and see what
② Go to the corridor outside to confirm the situation
③ Confirm the situation from your neighbors
④ Confirm the situation from the police, fire brigade or other relevant departments
⑤ Wake up the family
⑥ Get ready for evacuation

3. After another few minutes, there seemed to be a thin layer of smoke floating in the room (light white, like cigarette smoke)
And your decision:
① Do nothing for the time being, just wait and see what
② Go to the corridor outside to confirm the situation
③ Confirm the situation from your neighbors
④ Confirm the situation from the police, fire brigade or other relevant departments
⑤ Wake up the family
⑥ Get ready for evacuation

4. The neighbor knocked on the door, saying that another floor might be on fire.
And your decision:
① Do nothing for the time being, just wait and see what
② Go to the corridor outside to confirm the situation
③ Confirm the situation from your neighbors
④ Confirm the situation from the police, fire brigade or other relevant departments
⑤ Wake up the family
⑥ Get ready for evacuation

5. A few minutes passed again, and the smoke became a bit thicker (gray). It seemed that a small crackling sound was heard.
And your decision:
① Do nothing for the time being, just wait and see what
② Go to the corridor outside to confirm the situation
③ Confirm the situation from your neighbors
④ Confirm the situation from the police, fire brigade or other relevant departments
⑤ Wake up the family
⑥ Get ready for evacuation

6. After a few minutes, the fire from outside seemed to be seen from the window.
And your decision:
① Do nothing for the time being, just wait and see what
② Go to the corridor outside to confirm the situation
③ Confirm the situation from your neighbors
④ Confirm the situation from the police, fire brigade or other relevant departments
⑤ Wake up the family
⑥ Get ready for evacuation

Figure 6-1 The question settings' decision part of remote type FIG (Part 1)

7. After a few minutes, the smoke in the room turned black.

And your decision:
① Evacuation immediately
② Waiting for rescue from the fireman at home
③ Go to a neighbor's house and wait for the rescue of the fireman

8. The smoke spread from the corridor to the house through the gap in the front door
And your decision:
① Evacuation immediately
② Waiting for rescue from the fireman at home
③ Go to a neighbor's house and wait for the rescue of the fireman

9. The flame came into the room from the window or exhaust fan.
And your decision:
① Evacuation immediately
② Waiting for rescue from the fireman at home
③ Go to a neighbor's house and wait for the rescue of the fireman

10. Finally decided to escape, now...
And your decision:
① Just leave the door open, get ready for evacuation through the stairwell
② Close the door and get ready for evacuation through the stairwell
③ Just leave the door open, get ready for evacuation through the elevator
④ Close the door and get ready for evacuation through the elevator

11. At this time, if someone in your family or neighbors is physically inconvenient (such as disabled or sick, etc.) and is calling for help, they cannot escape by their own power.
And your decision:
① Take them and escape together (this may slow you down)
② First ensure your own personal safety
③ Seek help from other people or the fire brigade

12. There is heavy black smoke (visibility of about 1-2 meters) coming out of the elevator shaft in the corridor
And your decision:
① Turn to evacuate through the stairwell
② Still evacuate through the elevator
③ Go back to your room and make plans

13. The temperature in the corridor has risen
And your decision:
① Continue to evacuate
② Go back to your room and make plans
③ Move to a neighbor's house and make plan

14. The temperature in the corridor is unbearable
And your decision:
① Go back to your room and make plans
② Move to a neighbor's house and make plan

Figure 6-2 The question settings' decision part of remote type FIG (Part 2)

15. When escaping through the stairwell, the stairwell was crowded and it was difficult to go downstairs
And your decision:
① Wait until the crowd is not too crowded and continue to escape
② Go up and move to the neighbor's house to stay temporarily
③ Go back to your own or neighbor's room and make plans

16. At this time the stairwell is full of smoke
And your decision:
① Hold on, keep going down
② Go up and move to the neighbor's house to stay temporarily
③ Go back to your own or neighbor's room and make plans

17. While waiting in your own home or neighbor's house, you...
And your decision:
① Contact the fire brigade or the police and ask them to help
② Prepare to evacuate again

18. When you decide to evacuate with your neighbor
And your decision:
① First, make sure that your evacuation smoothly and safely
② Ensure that everyone escapes smoothly and safely, and strive for no one to fall behind

19. At this time, the firefighter said on the phone "I am moving towards your position"
And your decision:
① It feels like the timing is good, so escape first instead of waiting for the firefighters.
② Wait patiently for the fire brigade to come to rescue in the house

Figure 6-3 The question settings' decision part of remote type FIG (Part 3)

Ending 1. Successfully escaped through the elevator

Ending 2. Finally, I met the firefighters who came to the rescue in the stairwell and was saved

Ending 3. Finally, I met the firefighters who came to the rescue on my evacuation route and was saved.

Ending 4. Finally, the firefighters came and everyone was saved

Ending 5. Finally, I met a firefighter who came to the rescue on my evacuation route and was saved. But the neighbor who escaped together was lost on the road and never saw it again. His whereabouts are unknown.

Ending 6. Finally, we met a firefighter who came to the rescue on my evacuation route and everyone was saved.

Additional ending. That family member or neighbor has not seen him since, and it is unclear whether he escaped smoothly or was rescued by firefighters.

Figure 6-4 The ending part of remote type FIG

Instruction 1. Before evacuation, you should first judge the dangerous and safe places, and then decide the method of escape, and you must not act blindly, otherwise, haste makes waste, and the opportunity of evacuation will be delayed.

Instruction 2. When disasters occur, people tend to have normalized prejudice in their psychology, which is also called the ostrich effect. Normalized prejudice is a kind of cognitive bias. It is a social psychology or disaster psychology vocabulary, which refers to a phenomenon that a person ignores or underestimates that brings unfavorable information to him. In natural disasters, fires or accidents, treat some signs as an extension of normal life and ignore information that is not good for you or make things like "It's okay for me", "It's okay now," or "It is not the time." Such kind of the wrong estimation leads to missed escape opportunities. Therefore, when abnormal situations and signs are found, take action, obtain as much external information as possible, and provide "information" support for your next decision.

Instruction 3. When evacuation, the door should be closed, which can block the spread of smoke and buy more time for yourself and others to evacuate.

Instruction 4. In a fire evacuation, it is natural to ensure your own safety. However, in the process of evacuation, ignoring the help of others and only focusing on the safety and smoothness of one's own escape, there is no legal responsibility, but there may be psychological barriers caused by moral self-blame or guilt, such as post-traumatic stress disorder (PTSD).),etc. Therefore, for your own mental health, when you are confronted with such a situation, you should be lending a helping hand to those who ask for help as much as possible without endangering your own safety.

Instruction 5. Evacuation through stairwells is a relatively common way to escape, and stairwells are usually equipped with active and passive smoke exhaust equipment to avoid smoke poisoning during the escape. However, due to equipment failure and other reasons, smoke may also enter the stairwell. (Such as the 2010 high-rise residential fire in Jing'an District, Shanghai) and there is also the possibility of passing through the fire and smoke area on the way to escape. When you have to pass through a fire area or a densely smoky area, there is generally still residual air that can be used 30 cm from the ground. You should try to wrap your body with soaked clothing, cover your mouth and nose, and stay close to the ground. Keep your palms and elbows when crawling. , Knee close to the ground, and escape along the edge of the wall, so as not to lose direction. Or prepare a special mask for fire evacuation, because there is a catalyst that can neutralize carbon monoxide and other toxic gases in the canister, which can be used by survivors for 30 minutes in the fire scene, which greatly improves the success rate of escape in the fire scene. And the special fire-fighting masks are not expensive. If it is possible, please prepare them in advance for yourself and your family. (Remember: the activated carbon filter element of ordinary gas masks cannot filter toxic gases such as carbon monoxide, and cannot be used in the fire site)

Instruction 6. When waiting for rescue indoors, do not hide under the bed or in the closet. Try to enter the bathroom, toilet and other places with water sources. Use soaked bedding and clothing to block the door gap, splash water to cool down, and call for help.

Figure 6-5 The instruction part of remote type FIG (Part 1)

Instruction 7. Try not to take the elevator to escape during a fire, because the smoke will accumulate in the elevator car, and the carbon particles in the smoke will accumulate on the metal contacts and cause a short circuit, which will make the car stay on the smoky floor and cause suffocation or poisoning of the survivor. And please do not use the fire elevator to escape as well, because this behavior will hinder the normal rescue process of the firefighters. Please try to choose the stairwell to escape.

Instruction 8. Due to the rapid spread of smoke and fire upwards, try to escape downwards instead of upwards, but if the fire is very strong, the floors below the fire source are completely blocked, or the stairwell is crowded due to too many people causes you are unable to escape downward. Moving upwards to a safer floor (such as the refuge floor of a super high-rise building) and wait for rescue.

Instruction 9. Communicate with firefighters to clearly indicate where you are, the state of the environment, and your physical condition (such as the 9 Line MEDEVAC Request). This allows firefighters to make faster and better decisions and rescue you from the fire as soon as possible.

Figure 6-6 The instruction part of remote type FIG (Part 2)

Reference

1) The Central People's Government of the People's Republic of China, Evacuation and self-help knowledge, http://www.gov.cn/ztzl/2006-05/27/content_292878.htm, 2006.05.27 (In Chinese)

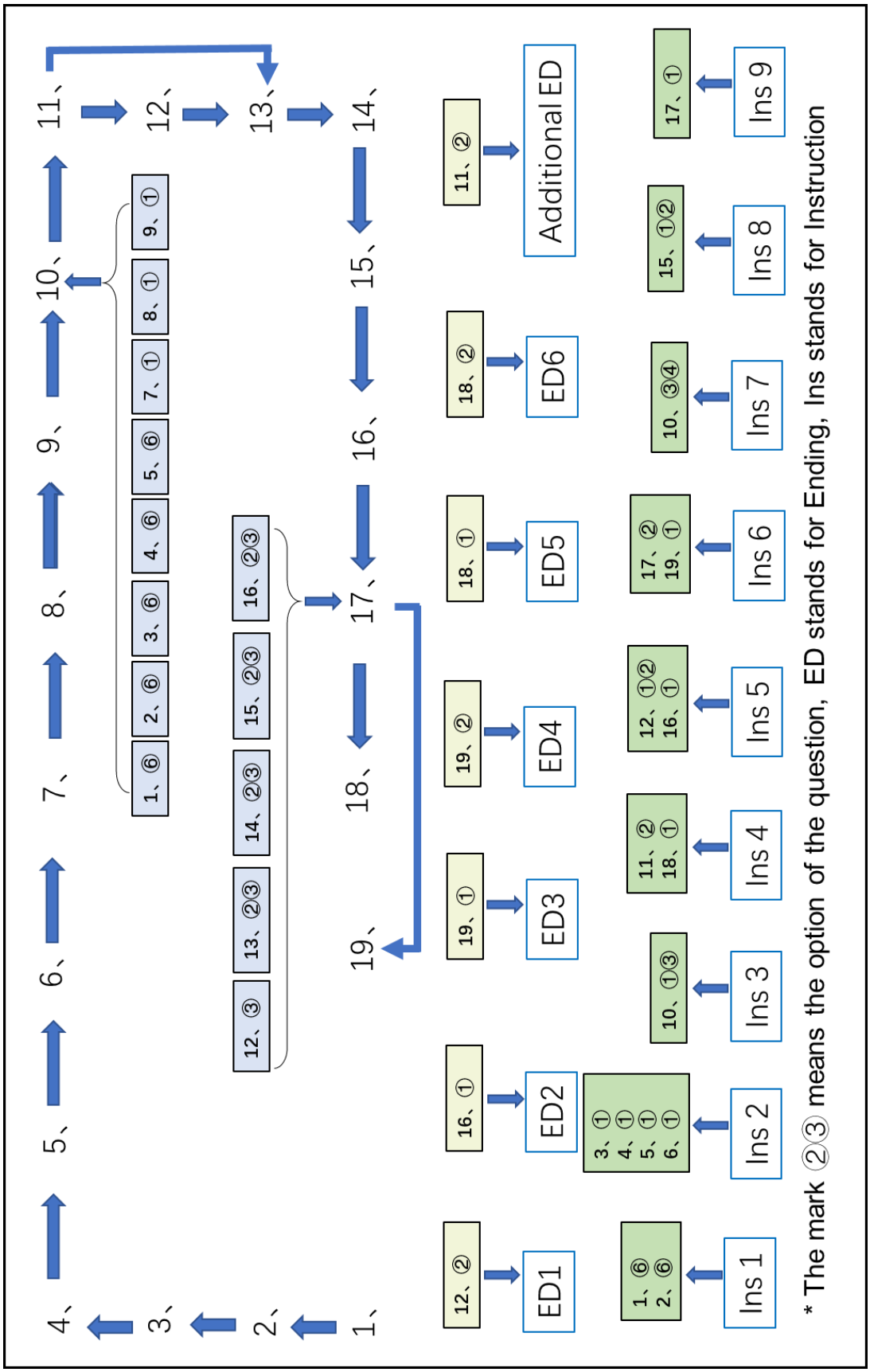


Figure 6-7 The flowchart of remote type FIG

Chapter 7. The development of the fire safety game

7.1. Introduction

At the level of fire safety knowledge, fire safety education could be divided into two domains, theory and practice. The theory is to strengthen the public's fire safety knowledge from the aspect of the theory according to the presentation or any other lecture methods. Practice is to strengthen the public's fire-related equipment operation ability through demonstration or any other methods. Based on the previous studies, the purpose of the research is to develop a new educational program with a high acceptability and accessibility method in the domain of theory at the level of fire safety knowledge.

This research selected and summarized the fire cases happened in recent years and develop a serious game about fire safety and evacuation education that was called fire safety sugoroku for high-rise residential building (short as SUGOROKU). The purpose of the SUGOROKU is to provide a tool that could supplement fire safety-related knowledge and warming-up before the formal training, so that participants could participate in formal training in a better state.

7.2. The developing process of Fire safety and evacuation education game

7.2.1. Introduction

For promotion the effective of FIG, the participant would complete their knowledge blind spot before the FIG start. Considered with the time will not be so abundant in a fire safety workshop, the method of supplement knowledge needs to transmit much more knowledge to the participant in a shorter time. Compared with the conventional lecture, a serious game has much more acceptability and accessibility for the participant. For the type of serious game, the rule of the game should be simple so that could fit anybody at any age. The pace of the game should be slow so that the participant has enough time to read the content and keep the knowledge in their mind. As a game, it should be fun for the participant. Therefore, compared with card game, the research decided choose sugoroku, a kind of Japanese board game as the form of game.

7.2.2. The designing processes

7.2.2.1. The content of SUGOROKU

For the content of SUGOROKU, the research chose < Actual situation of fire > that was published by the Tokyo Fire Department and four fire cases occurred in Shanghai, London, and Tokyo. <Actual situation of fire> was published every year from 2009 to 2018. It recorded the fire situation that occurred in the previous year through data and diagrams. From 2014, <Actual situation of fire> added specific fire cases. Therefore, those typically or rare fire cases from the aspect of fire prevention, management, and

evacuation from 2014~2018 version <Actual situation of fire> were picked as content of the game.

At first, the building in the fire case was separated into high-rise residential building and multi-story residential building based on the situation whether the building has the obligation of fire safety equipment's setting up or not in the Fire Services Act. Because of the SUGOROKU was developed for high-rise residential building, the fire cases that happened in high-rise residential building as a priority choice. However, the typical fire cases that happened in the ordinary residential building were chosen as well for supplement knowledge blind spot. For the specific fire cases, Shanghai Jing'an district high-rise residential building fire case, London Grenfell Tower fire case, Hiroshima Motomachi residential building fire and Tokyo "Skycity Minamisuna" high-rise residential building fire case's experience or knowledge about fire prevention, management, and evacuation was added as well.

7.2.2.2. The content's arrangement and summarization

At first, each picked up fire cases' information about the usage of building, casualty, time, the floor that the fire takes place, fire cause and the residents or manager's emergency response was extracted and put it into a diagram. Then based on the diagram's information, further picked typical fire cases or the fire cases that could provide educational information. (Table 7-1) (Table 7-2) These cases' information about the description and comment of the fire department were made cards and classified as the cooking fire cases, the cigarette fire cases, the electric fire case, the stove fire cases, the elderly fire cases, and the fire management cases these six categories. (Figure 7-1)

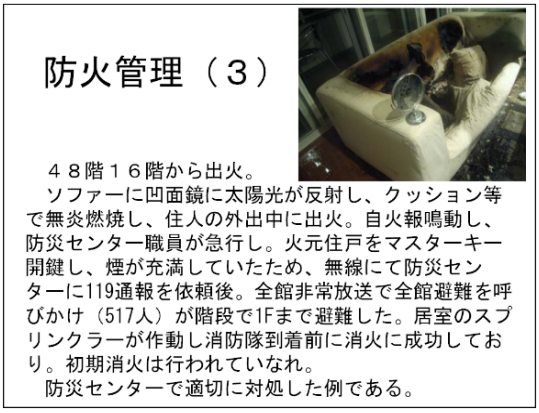


Figure 7-1 The example of fire case card

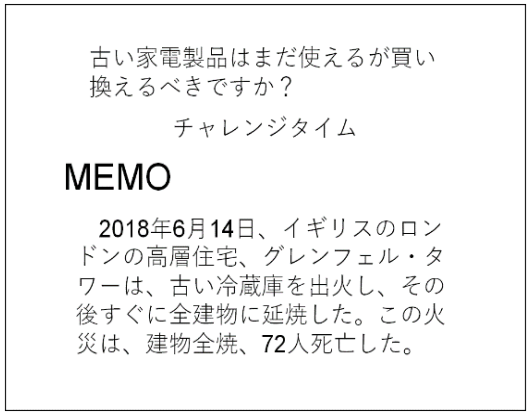


Figure 7-2 The mass of SUGOROKU's checkerboard

Table 7-1 The diagram of the high-rise residential building's fire case

1996[1]	Apartment * (28F)	24F	6 injuries	1 person in the room	In the other room	16:00	Ringing	No Active	Kitchen	Unknown	Unknown	Unknown	Residents in the room evacuated	NO	Manager of DCC	NO	Fire extinguisher, hydrant. etc
2013[2]	F-1(43F)[A]	27F	1 injury (smoke)	YES	In 30F	8:00	No Ringing	No Active	Balcony	Cigarette end	Sofa	Cigarette end spilled from the ashtray and ignited the sofa	YES	Staff of DCC executed	Residents	Fire Extinguishing is impossible was judged (NO)	Detail unknow
	F-1(27F)[B]	2F	1 injury (extinguishing)	YES	In the upper floor	22:00	Ringing	Activated	Kitchen	Cooking oil	Oil coagulant	Over-heated oil ignited	Unnecessary (NO)	NO	Staff of DCC	Used the water for extinguising (YES)	Sprinkler
	Apartment (12F)[C]	9F	None	Unknown	In the other floor	8:00	Unknown	No Active	Bedroom	Humidification element	Dehumidifying air cleaner	Humidification element ignited and spread to the other stuff	NO	NO	Administrator	NO	Detail unknown
	F-1(33F)[D]	27F	None	Going out	In 31F	9:00	Ringing	Activated late	Bedroom	Unknown	Unknown	Unknown	NO	NO	Neighbors	The staff can't enter the room (NO)	Sprinkler activation is late
	F-1(14F)[E]	7F	2 injuries (smoke)	2 people in the room	In the other room	18:00	No Ringing	No Active	Livingroom	Cigarette end	Stuff in the room	Unknown	YES	NO	Residents	NO	Detail unknown
2014[3]	Apartment (14F)[F]	5F	None	4 people(wife and 3kids)	Unknown	8:00	No Ringing	No Active	Livingroom	Air cleaner's plug	Outlet	Spark came out near the outlet	Unnecessary (NO)	NO	wife	NO	Detail unknown
2015[4]	Apartment (48F)[G]	16F	None	Going out	517 people in each floor	17:00	Ringing	Activated	Livingroom	Sofa	Sofa	Concave mirror reflected the sunlight and ignited the sofa	YES	Emergency announced by DCC (YES)	Staff of DCC	Sprinkler activated (YES)	Sprinkler
2016[5]	Apartment (31F)[H]	14F	None	1 person in the room	Unknown	19:00	No Ringing	Activated	Kitchen	Cooking oil	pot	Over-heated oil ignited	NO	NO	Staff of DCC	Sprinkler activated (YES)	Sprinkler
2017[6]	Apartment (13F)[I]	7F	None	2 people in the room	Unknown	18:00	Ringing	No Active	Kitchen	Gas furnace	Flammable gas	The fire from the gas furnace ignited the flammable gas	NO	NO	Passerby	Unnecessary (NO)	Fire extinguisher

Remark: All the high-rise residential buiildng have fire management system.
The specific page of each case as the follow shows.
A. Reference2. P226
B. Reference2. P239
C. Reference2. P246
D. Reference2. P259
E. Reference2. P284
F. Reference3. P234
G. Reference4. P260
H. Reference5. P266
I. Reference6. P244

A: Floor that fire take place
B: Be at the site
C: Automatic Fire Alarm Equipment
F-1: Compound Appication Building
DCC: Disaster Control Center

Table 7-2 The diagram of the multi-story residential building's fire case

Year	Usage (Floors)	A	Casualty	B	Other reside nts	Time (about)	C	Sprinkler	Situation				Evacuation guidance	Report	Fire Extinguishing (YES/NO)	Equipm ent	Fire manage ment
									Place	Fire cause		Evacua tion					
										Break out	Catch fire	Situation					
2013[2]	Apartme nt (8F) [A]	6F	1 dead	YES	Unkn own	3:00	None	None	Bedroom	Cigarette	Futon	The fire of cigarette ignited the futon	NO	NO	Newsman	NO	NO	YES
	Resident (2F) [B]	1F	NONE	YES	NO	19:00	None	None	Livin-groom	Clothes	Clothes	Clothes fell on the stove	NO	NO	Resident's son	Putting out the fire with water	NO	NO
	Resident (3F) [C]	1F	3 dead, 1 injured	YES	YES	4:00	None	None	Livin-groom	Cigarette	Tatami	The fire of cigarette ignited the tatami	NO	NO	Resident	NO	NO	NO
	Resident (2F) [D]	1F	1 dead	YES	YES	22:00	None	None	Corridor	Outlet	Stuff around the outlet	Tracking fire occurred and spread	NO	NO	Neighbors	NO	NO	NO
	Resident (2F) [E]	2F	1 injured	YES	YES	8:00	Ringing	None	Bedroom	Quilt	Quilt	Quilt contacted with heater	NO	NO	Resident	Putting out the fire with water	NO	NO
	Resident (2F) [F]	1F	NONE	YES	YES	19:00	Failed to ring (covered by plastic bag)	None	Kitchen	Cooking oil	Pot	Over-heated oil ignited	NO	YES*	Passerby	Putting out the fire with water (failed)	NO	NO
	Resident (2F) [G]	1F	2 dead	YES	YES	3:00	None	None	Livin-groom	Power cord	Stuff around the power cord	Broken power cord short-circuited	NO	NO	Neighbors	NO	NO	NO
2014[3]	Resident (2F) [H]	1F	2 dead	YES	Unkn own	15:00	None	None	Livin-groom	Cigarette	Flammable stuff	Cigarette's fire ignited the combustible around the ashtray	NO	NO	Unknown	NO	NO	NO
	Resident (10F) [I]	6F	1 injured	YES	Unkn own	15:00	Failed to ring (Out of battery)	None	Kitchen	Cooking oil	Pot	Over-heated oil ignited	NO	NO	Passerby	Used wet bath towel cover the pot	NO	YES
2015[4]	Resident (2F) [J]	2F	NONE	YES	Unkn own	9:00	Ringing	None	Bedroom	Quilt	Quilt	Quilt contacted with heater	NO	NO	Resident	Putting out the fire with water	NO	NO
	Resident (3F) [K]	1F	1 injured	YES	YES	11:00	None	None	Livin-groom	Clothes	Clothes	Clothes fell on the stove	NO	NO	Staff of management corporation	Putting out the fire with fire extinguisher	Fire extingu isher	NO
2016[5]	Resident (8F) [L]	3F	1 injured	YES	YES	13:00	None	None	Kitchen	Cooking oil	Pot	Over-heated oil ignited	NO	NO	Neighbors	Putting out the fire with water	NO	NO

A: Floor that fire take place
B: Be at the site
C: Automatic Fire Alarm Equipment
*: Passerby guided the occupants to evacuate

The specific page of each case as the follow shows.

A. Reference2. P227
B. Reference2. P236
C. Reference2. P248
D. Reference2. P258
E. Reference2. P256
F. Reference2. P257
G. Reference2. P249
H. Reference3. P250
I. Reference3. P261
J. Reference4. P235
K. Reference4. P258
L. Reference5. P246

7.2.2.3. The design of the checkerboard of SUGOROKU

The checkboard was separated into four phases by the timeline of the fire cases, fire prevention phase, fire extinguishing phase, evacuation phase, and post-evacuation phase.[7] Because of the fire case cards' content is difficult to fill in the limited space of the checkerboard's mass, it needs to be simplified as one sentence about the knowledge point. The "MEMO" was added to explain the knowledge point. Most of the "MEMO" use the real fire case to increase the persuasive and strengthen the participant's memory through reading the "MEMO".

For increasing the playability of the SUGOROKU, part of the masses added rewards or punishments. When the behavior in the mass is appropriate, the participant would get a bonus to move forward. When the behavior in the mass is inappropriate, the participant would get a punishment to move backward. The "YES or NO Challenge" is set for promoting the communication among the participant through making discussion for the knowledge points. The "Challenge time" is set for increasing the playability, the behaviors that are described in the masses are neither good nor bad. According to these four "tricks", the participant could strengthen their memory further by reading the sentence repeatedly. (Figure 7-2) At last, all the masses were pasted on an A2 paper. The whole game was separated into four phases, fire prevention phase, fire extinguishing phase, evacuation phase, and post-evacuation phase. The game covers the whole process in the fire. (Figure 7-3)

Reference

1) Ministry of Construction, Hiroshima city Motomachi housing fire investigative commission,「Hiroshima city Motomachi housing fire investigative commission final Summary」,1997.04.14 (In Japanese)
2) Tokyo Fire Department, Actual situation of fire (2014), 2014.09 (In Japanese)
3) Tokyo Fire Department, Actual situation of fire (2015), 2015.09 (In Japanese)
4) Tokyo Fire Department, Actual situation of fire (2016), 2016.09 (In Japanese)
5) Tokyo Fire Department, Actual situation of fire (2017), 2017.09 (In Japanese)
6) Tokyo Fire Department, Actual situation of fire (2018), 2018.09 (In Japanese)
7) HORIUCHI Saburo, New edition Building fire protection, Asakura Shoten, P154, 1994.08 (In Japanese)

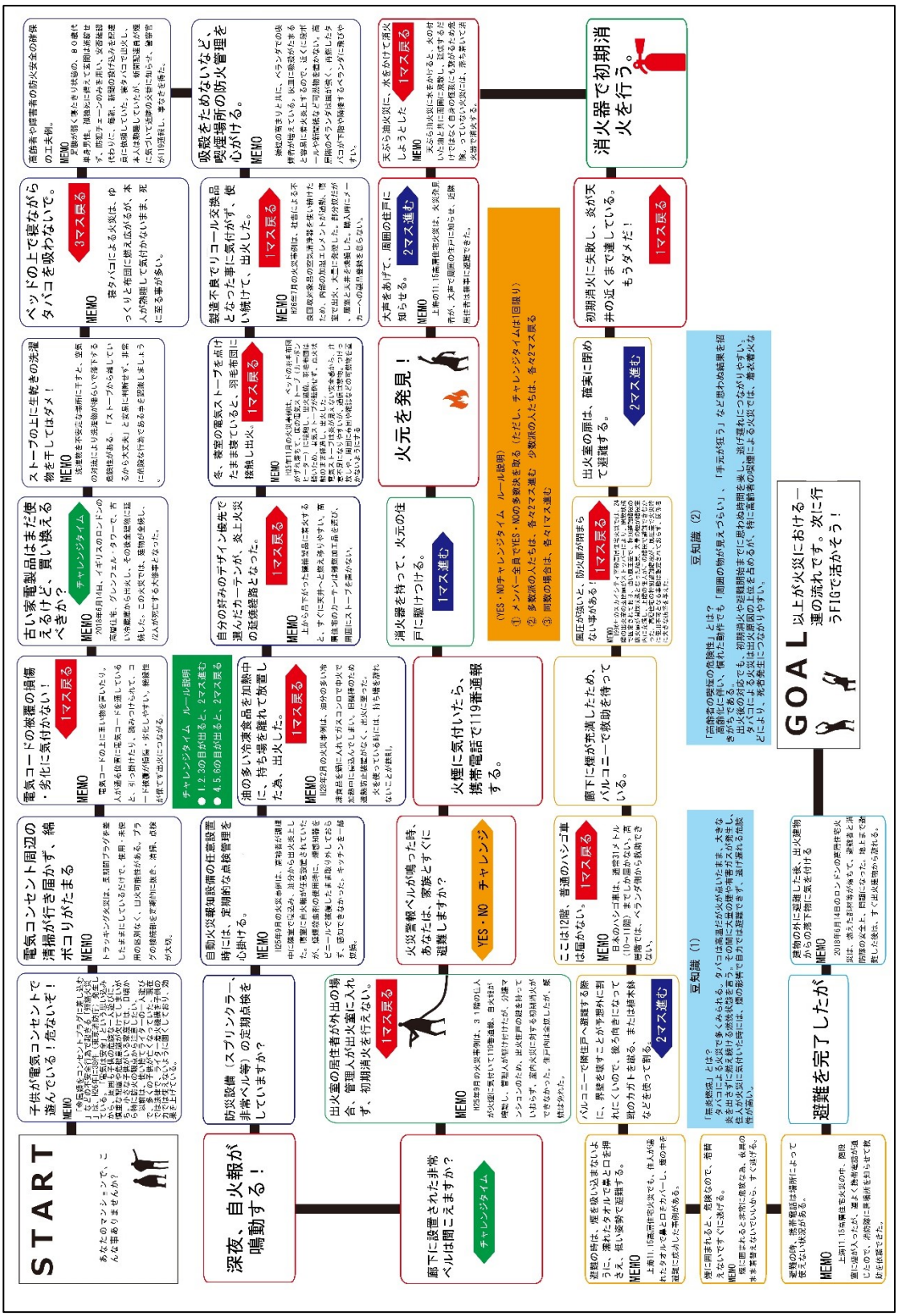


Figure 7-3 The checkerboard of SUGOROKU

Chapter 8. The evaluation of the FIG

8.1. Introduction

As the Episode 3 introduced, the evaluation of the FIG adopted the impact evaluation. The effectiveness of FIG would be measured through the participants' attitude's changes by questionnaire survey.

Due to the corona pandemic, in order to avoid close contact, it was difficult to obtain cooperation for holding a FIG workshop that the residents could talk with each other in Japan when the pandemic did not converge. Therefore, the object of the research was switched to China that had been got rid of the corona infection. As a result of the author's recruitment of collaborators independently, the employees of the "China Petrochemical Corporation Tianjin Branch" who live in the high-rise residential building were chosen as the object of the research. Through the network, the collaborators from outside Tianjin were able to participate the test as well. The test was conducted in China through the internet by the family unit from July 29th to August 1st, 2021. The questionnaires were distributed by QR code before and after the SUGOROKU through the web questionnaire system "WJX.cn". The test sequence is "Pretest-SUGOROKU-Posttest of SUGOROKU-FIG-posttest of FIG". 289 people finished the questionnaire and submitted it. Because the game and the questionnaire are integrated into a whole, after they finished the game, they could fill the questionnaire and submit it immediately. Therefore, the recovery rate is 100 percent.

8.2. The situation of the participant

8.2.1. The basic attributes of the participants

The basic attributes of the participants, includes participants' age, gender, living conditions, and fire safety educational experience.

For the age of the participants, in 289 participants, the age distribution as figure shows. The participants of the test covered most age groups. Because the operation method of the test like scanning the QR code is complicated for the elderly that aged over 70, the maximum age group is 60-69. (Figure 8-1)

For the living condition of the participants, based on China's fire safety designing code, the building with over 10 floor is high-rise residential building (includes 10 floor), the building with below 10 floor is multi-story residential building. In 289 participants, 81 participants live in high-rise residential building, accounting for 28.0 percent, 208 participants live in high-rise residential building, accounting for 72.0 percent. (Figure 8-2)

For the gender of the participants, in 289 participants, 130 participants are male,

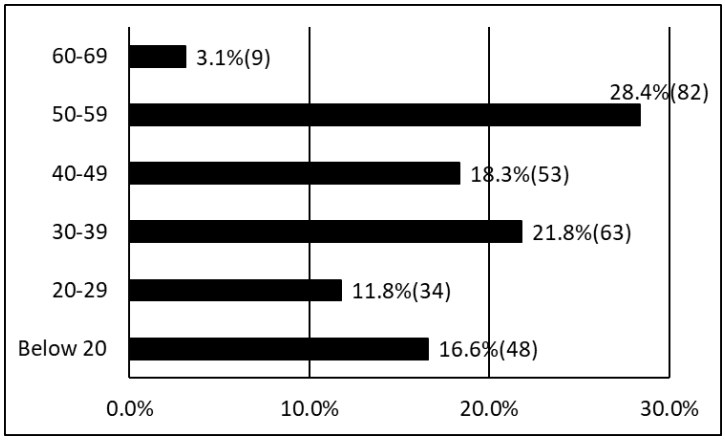


Figure 8-1 The age of the participants (N=289)

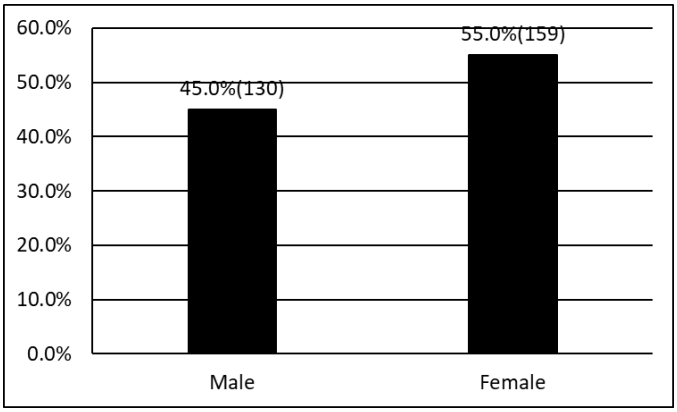


Figure 8-2 The gender of the participants (N=289)

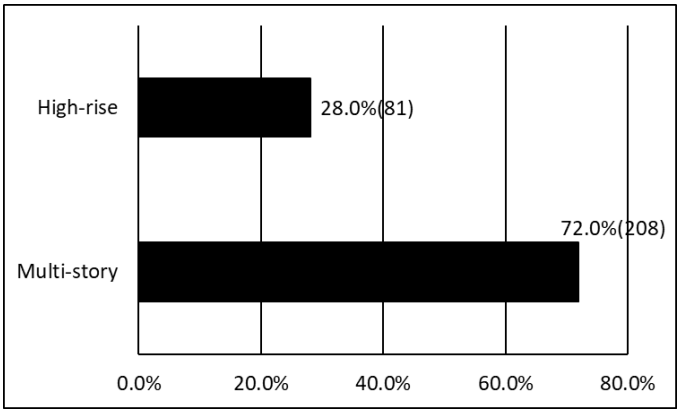


Figure 8-3 The living condition of the participants (N=289)

accounting for 45.0 percent, 159 participants are female, accounting for 55.0 percent. (Figure 8-3)

For the fire safety education level of the participants, in 289 participants, 263 participants have experienced comes from a variety of education methods, accounting for 91.0 percent. In the group that have fire safety education experience, “Learning from

publicity method" and "Workplace held fire safety lecture" account for a large proportion, accounting for 68.5 percent. It shows that fire safety education that in the first and second knowledge level has been extensively carried out in the object area. (Figure 8-4)

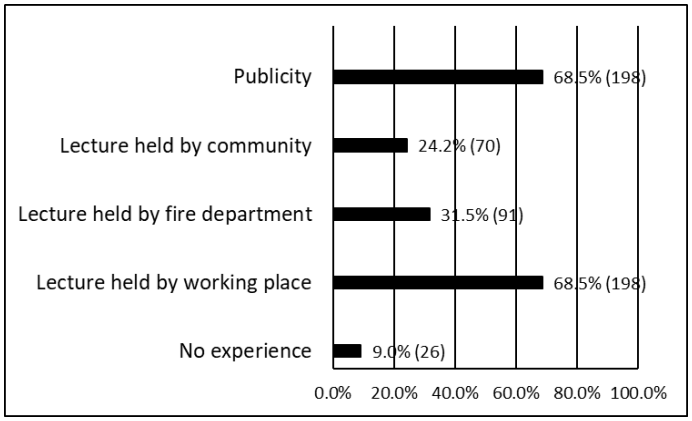


Figure 8-4 The fire safety education experience of the participants (Multi-choice, N=289)

According to the cross statistics with ages and the situation of the fire safety education, it shows that the situation of the fire safety education in each age group. In the age that over 60 years old, the non-experienced people in fire safety are more than any other group. For the age group that from 30 to 59, the workplace held fire safety education accounts for a large proportion, it means the fire safety involved vocational Education is the most common way for obtaining fire safety knowledge for this age group. (Figure 8-5)

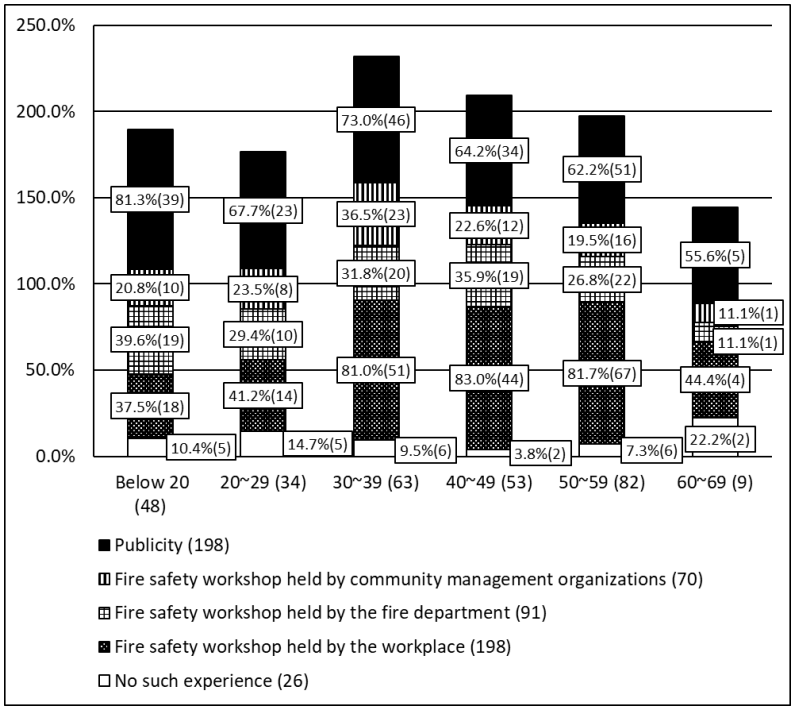


Figure 8-5 The fire safety education experience of the participants with age (N=289)

8.2.2. The situation of the participants

Before the SUGOROKU and FIG begin, the situation about participants' concern or interests in fire safety is necessary. From the statistics, about 60.9 percent of the participants take a positive attitude, 33.2 percent of the participants be neutral and 5.8 percent of the participants take a negative attitude. After the SUGOROKU, it would be evaluated through comparative research before and after the game. (Figure 8-6)

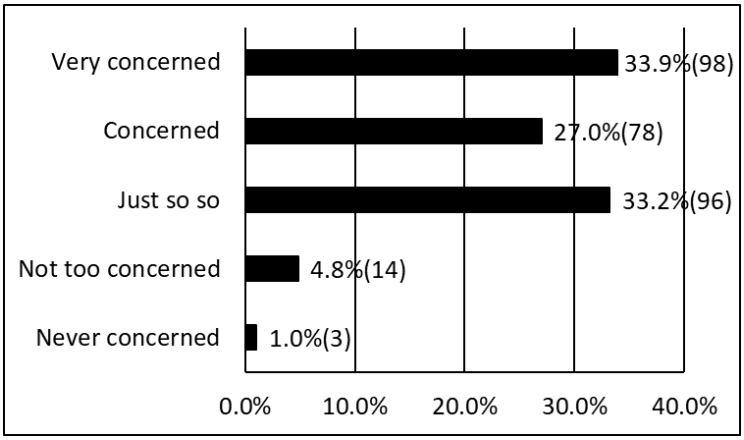


Figure 8-6 The level of the participants' concern or interests in fire safety (N=289)

According to the cross statistics with ages and the situation about participants' concern or interests in fire safety, it shows most of the participants in each age group take a positive attitude for fire safety except the age group between 20 to 29. (Figure 8-7)

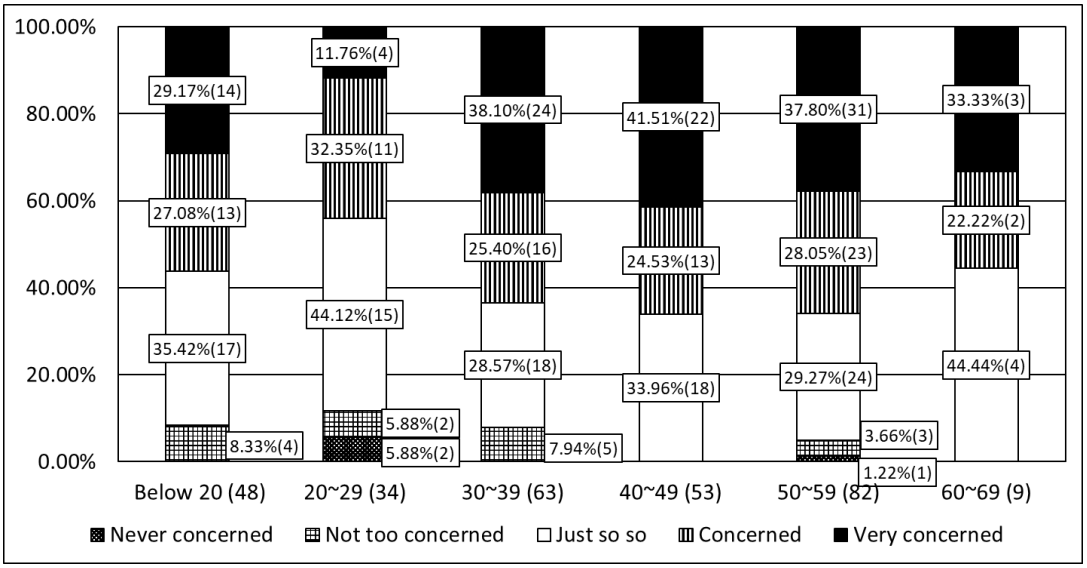


Figure 8-7 The level of the participants' concern or interests in fire safety with age (N=289)

According to the cross statistics with the situation of the fire safety education and the situation about participants' concern or interests in fire safety. It shows, the non-experienced group's positive attitude is much smaller than any other groups that have fire safety education before. It means current fire safety education plays a certain role in promoting the public's concern or interest in fire safety. (Figure 8-8)

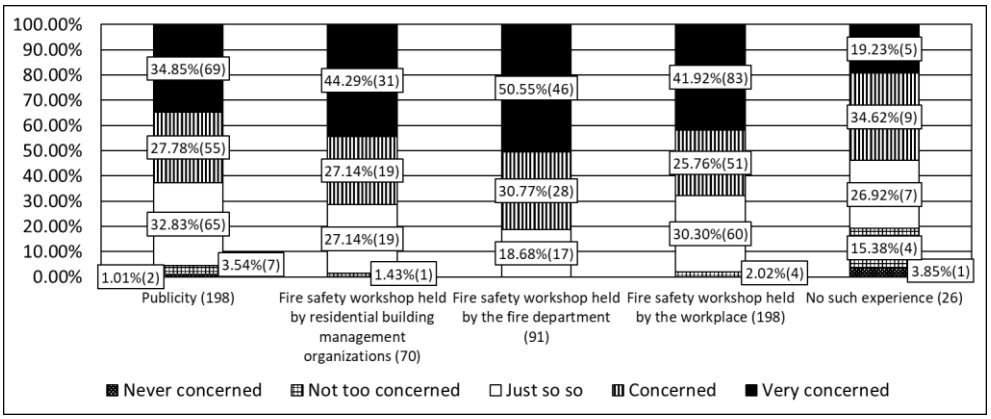


Figure 8-8 The level of the participants' concern or interests in fire safety with fire safety education experience (N=289)

According to the cross statistics with the type of building and the situation about participants' concern or interests in fire safety. for their response to the question, "Very well" means the participants hold a highly positive attitude to the corresponding content, on the contrary, the answer "Not at all" means the participants hold a highly negative attitude to the corresponding content. For taking a positive attitude, the participants who lived in high-rise residential buildings is a little higher than the participants who lived in multi-story residential buildings, accounting for 61.7 percent and 60.6 percent respectively. For the participant who was taking a neutral attitude, the participants who lived in both types of residential building were equal. (Figure 8-9)

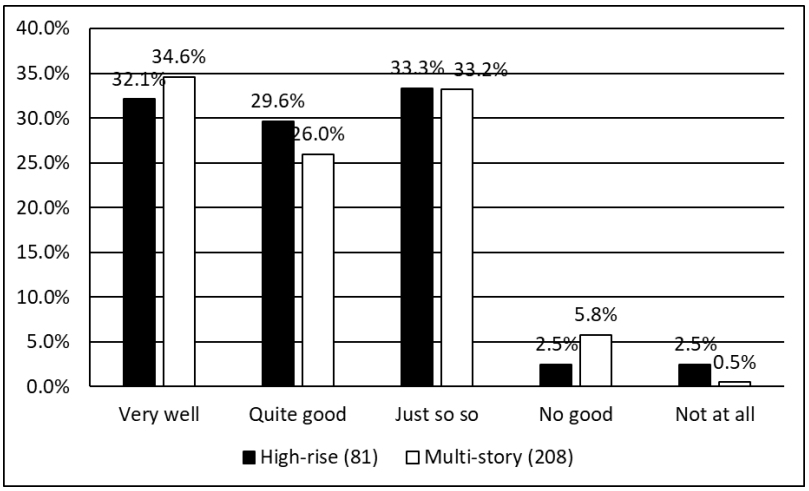


Figure 8-9 The level of the participants' concern or interests in fire safety with living condition (N=289)

For the specific content of participants' concerns and interests in fire safety, most of the occupants take positive attitude on the content "The information exchange in the fire with neighborhood", accounting for 71.7 percent. Next is the content "The purpose and method of installation of fire safety equipment in the residential building", accounting for 68.8 percent. The third is the content "Clean up the combustibles inside the house and public spaces", accounting for 66.5 percent. It reflects people's understanding of fire safety to a certain extent. (Figure 8-10)

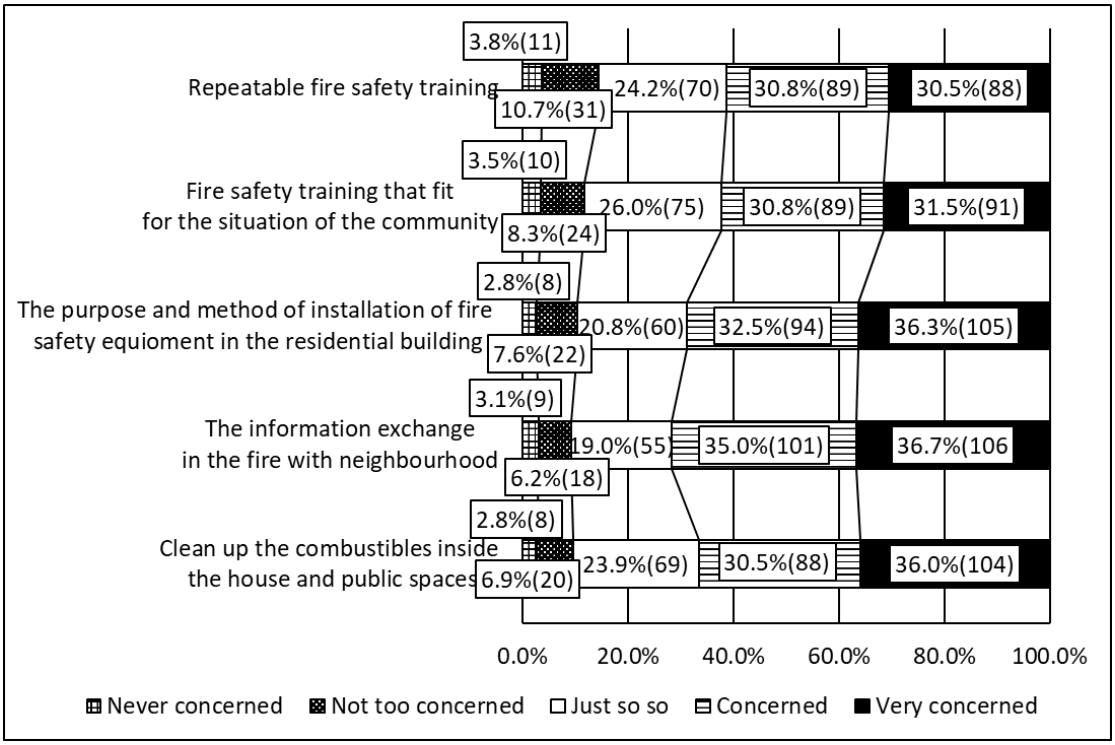


Figure 8-10 The specific content of the participants' concern or interests in fire safety (N=289)

The content "Clean up the combustibles inside the house and public spaces" could reflect the participants' attitude towards fire safety management. According to the cross statistics with ages and the attitude about the content "Clean up the combustibles inside the house and public spaces", it shows except the group that from 20 to 29, the other groups, especially the group that from 30 to 69 take a positive attitude towards fire safety management of their own real estate. According to the cross statistics with the type of building and the attitude about the content "Clean up the combustibles inside the house and public spaces", it shows the number of the high-rise residential building lived participants who took positive attitude is more than the people who lived in multi-story residential buildings, accounting for 72.8 percent and 63.9 percent respectively. (Figure 8-11) (Figure 8-12)

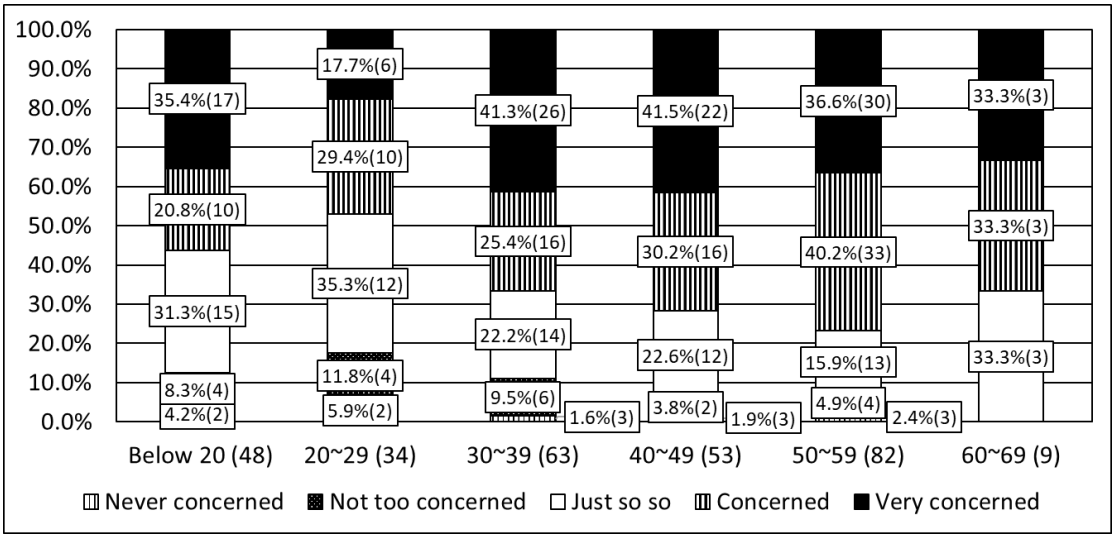


Figure 8-11 The specific content "Clean up the combustibles…" of the participants' concern or interests in fire safety with age (N=289)

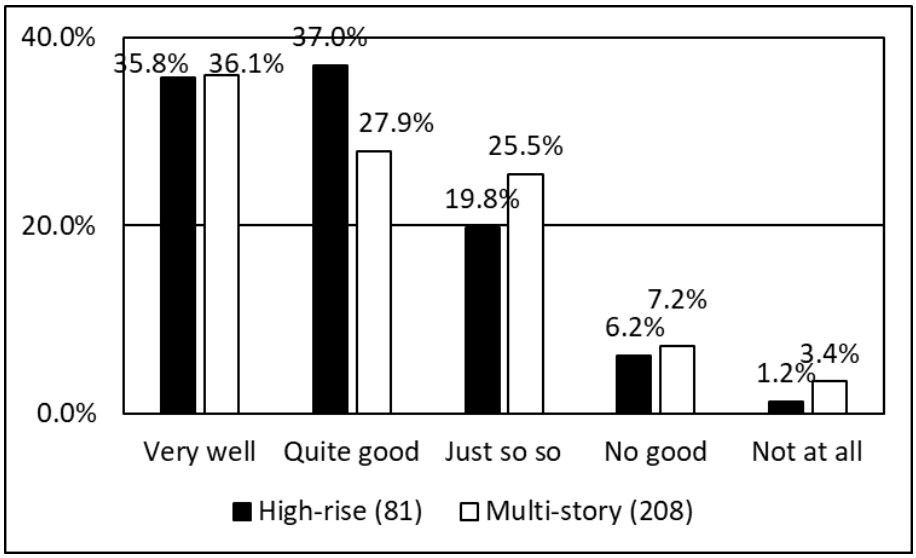


Figure 8-12 The specific content "Clean up the combustibles…" of the participants' concern or interests in fire safety with living condition (N=289)

The content "The purpose and method of installation of fire safety equipment in the residential building" could reflect the participants' attitude towards fire prevention measures of their real estate. According to the cross statistics with ages and the attitude about the content "The purpose and method of installation of fire safety equipment in the residential building", its trend is similar to the content "Clean up the combustibles inside the house and public spaces". It shows except the group that from 20 to 29, the

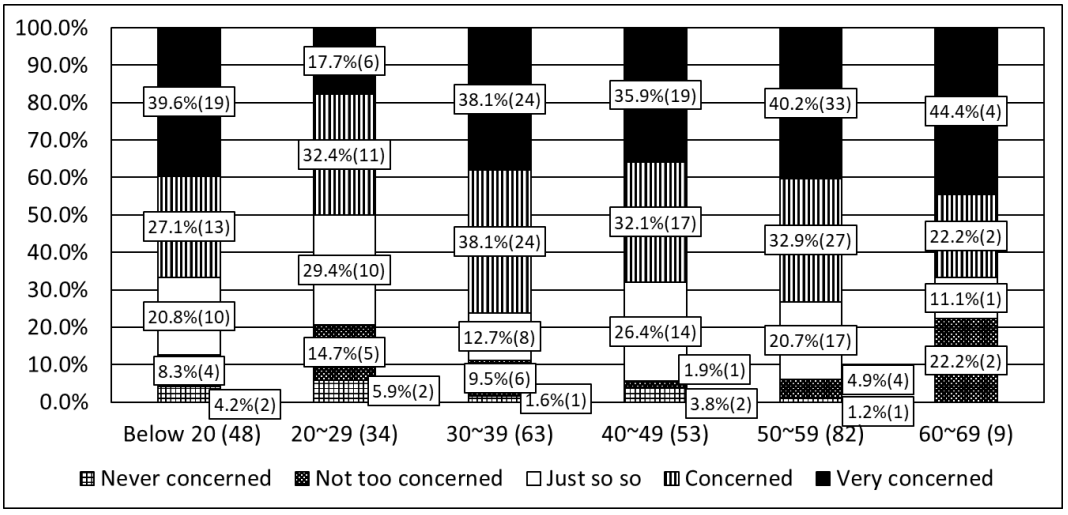


Figure 8-13 The specific content "The purpose and method…" of the participants' concern or interests in fire safety with age (N=289)

other groups take a positive attitude towards fire prevention measures of their real estate. (Figure 8-13)

Combined with sociological research about the impact of natural population structure on housing demand, The 20~23 age group and 36~40 age group have the greatest impact on housing demand in China. Especially 36~40 age group, as incomes in the 36~40 age group increase, the need for improved housing increases. In another word, in 36~40 age group will hold the current real-estate stably. Until they stepped into the over 60 age group, the demand for housing would be decreased.[1)]

It conforms to the cross-statistical age distribution. It shows that the purchase of real estate will have an impact on the fire safety attitude of the occupants. For the group that the age below 20, most of them live with their parents and obtain fire safety education from the junior school or senior school. It has an impact on the minors' fire safety attitude. For the group that from 20 to 29, most of the people live in rented houses at this age. It may have an impact on their fire safety attitude because they don't have their own real estate. And after 30 years old, after the publics buy their own real estate, they started to pay attention to the fire safety of their house.

According to the cross statistics with the situation of the fire safety education and the attitude about the content "Clean up the combustibles inside the house and public spaces", and the content "The purpose and method of installation of fire safety equipment in the residential building", it shows, the current fire safety education could have a certain impact on the improvement of participants' attitude to the fire safety management and the concern about fire prevention measures. (Figure 8-14) (Figure 8-15)

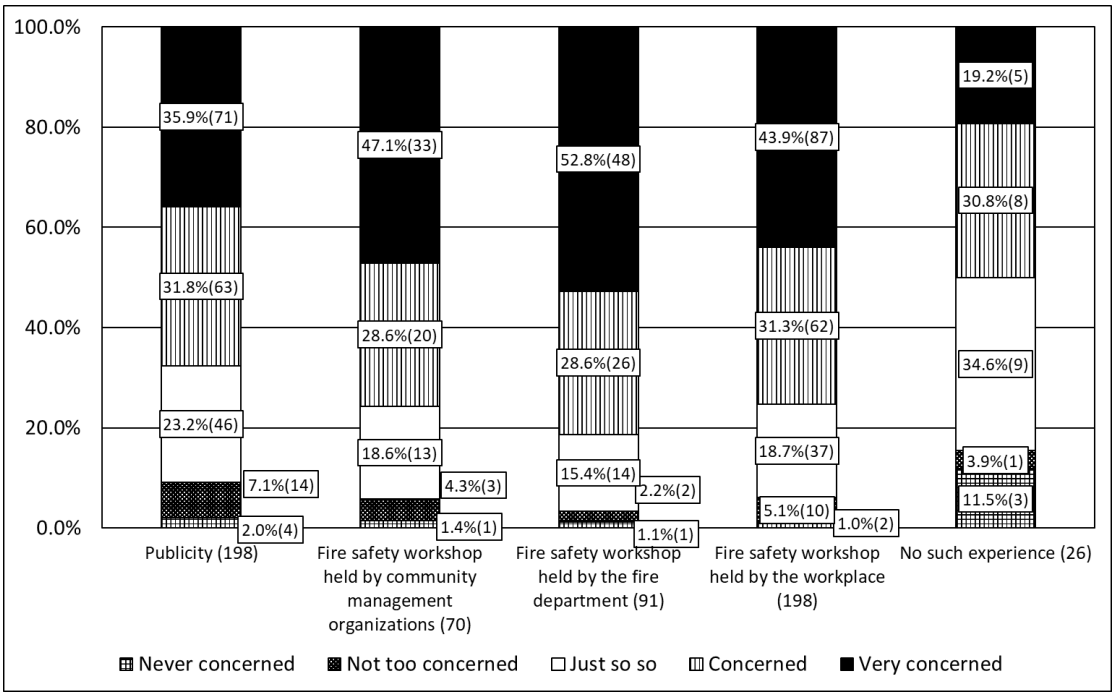


Figure 8-14 The specific content "Clean up the combustibles…" of the participants' concern or interests in fire safety with fire safety experience (N=289)

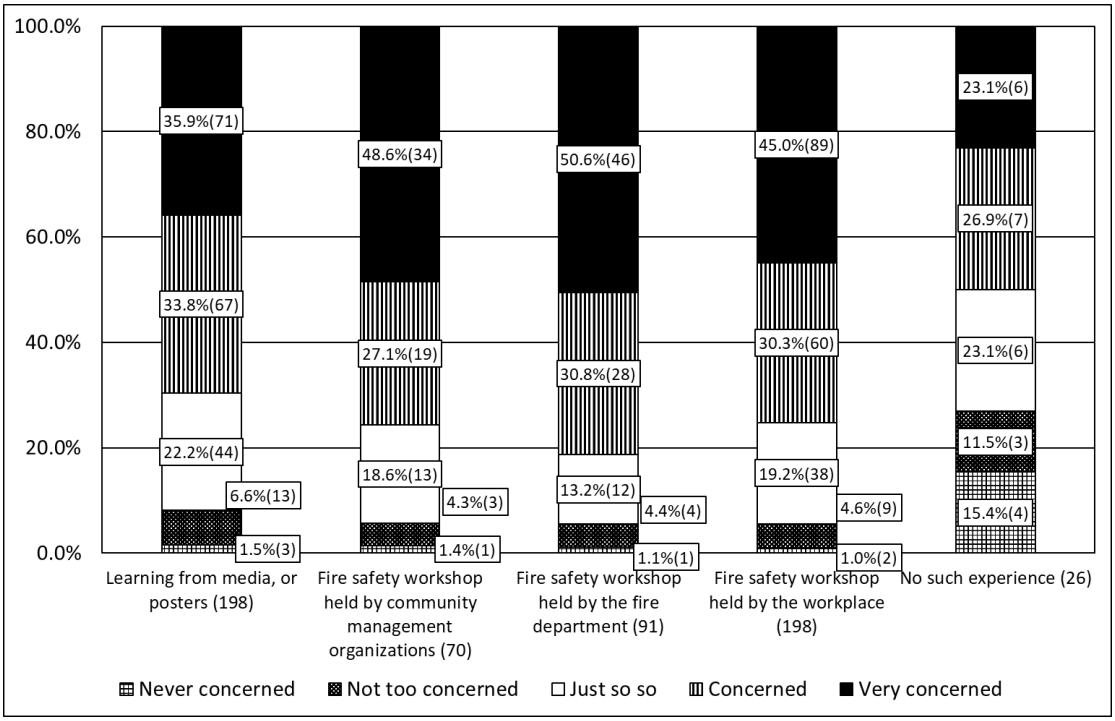


Figure 8-15 The specific content "The purpose and method…" of the participants' concern or interests in fire safety with fire safety experience (N=289)

According to the cross statistics with the type of building and the attitude about the content "The purpose and method of installation of fire safety equipment in the residential building", it shows the number of the high-rise residential building lived participants who took positive attitude is more than the people who lived in multi-story residential buildings, accounting for 70.4 percent and 68.3 percent respectively. (Figure 8-16)

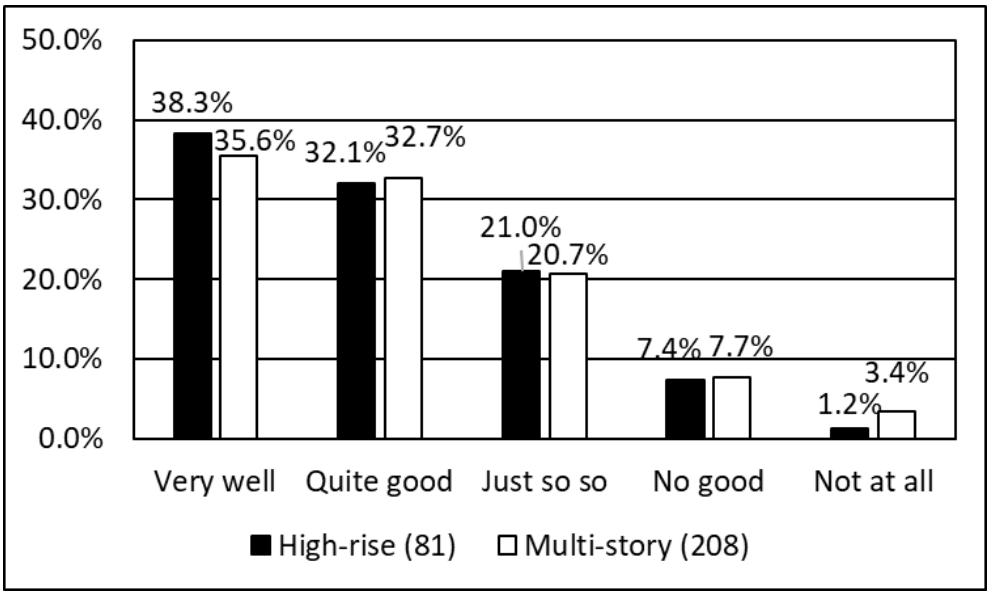


Figure 8-16 The specific content "The purpose and method…" of the participants' concern or interests in fire safety with living condition (N=289)

8.2.3. Summary

According to the simple statistic and cross statistic, the participants' concern about fire safety could be determined. Compared with the similar research to the staff of the elderly facility[2)], because of the difference of the objective condition such as the fire safety equipment or the fire safety education level, the occupants of the residential building and the staff of the elderly facility's specific concerning is different.

8.3. The evaluation of the SUGOROKU

For the SUGOROKU, although most of SUGOROKU content was designed based on Japan's fire case report and comply with Japan's national conditions, from the vision of fire safety knowledge, most of the knowledge fit for both China and Japan. For example, SUGOROKU introduces the method of breaking the partition, the method was designed for breaking the partition between the balcony in Japan for horizontal evacuation. However, the residents may meet the partition issue in the evacuation process in China, they could use the same method to address such issue. Another example is the content

that introduces nonflammable certification household products. Although China does not have such a system yet, letting China's residents know about such a system of a foreign country has benefits for improving their awareness of fire safety. And the fire safety-related law system of China keeps developing fast, such a system may appear in the future as well.

For fire safety education, if any education methods could inspire the people's interest in this field, it would be much more helpful for improving educational effectiveness. Especially as a supplement method and a warming-up tool for FIG, if the SUGOROKU could inspire participants' interest in fire education, it would be helpful for the next stage of FIG. Therefore, the research measures the effectiveness of SUGOROKU according to the made comparison of people's interest in fire education before and after playing SUGOROKU. From the total of participants' interest's change before and after the SUGOROKU, the number of participants who chose "very concerned" increased by 11.1 percent, the number of participants who chose "Concerned" increased by 6.2 percent, the number of people who chose "Just so so" decreased 15.2 percent, the number of people who chose "Not too concerned" decreased 1.4 percent, the number of people who chose "Never concerned" decreased 0.7 percent after playing SUGOROKU. It shows, as a tool that inspires the participants' interest or warming-up before FIG training, it achieves the purpose that designed for. (Figure 8-17)

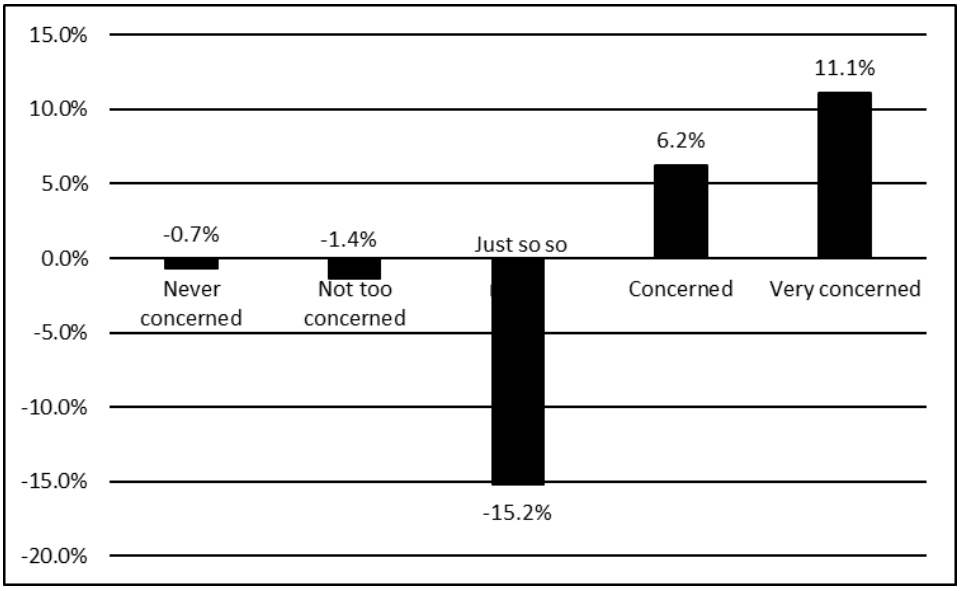


Figure 8-17 The change of the participants' concern or interests in fire safety before and after the test (N=289)

Then the questionnaire research analyzed the relationship between their concern's change and their living condition and fire safety education experience through a cross statistic.

For the relationship between living conditions and participant's concern's change. The positive answer of high-rise residential building's residents increased 11.1 percent and multi-story residential building's residents increased 19.8 percent. The neutral answer decreased 9.9 percent and 17.3 percent respectively. It shows SUGOROKU is effective for occupants of multi-story residential buildings as well. (Figure 8-18)

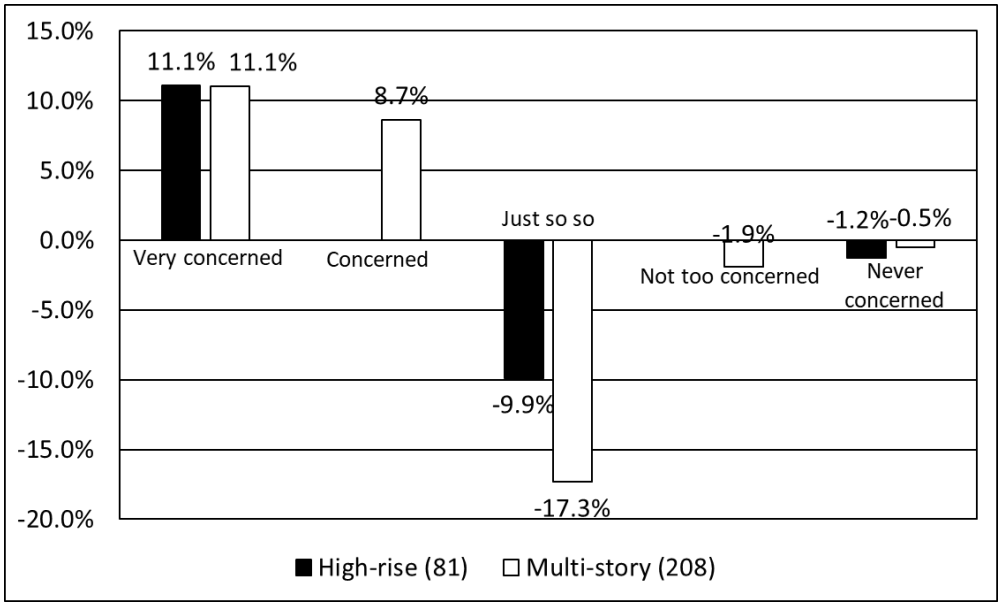


Figure 8-18 The change of the participants' concern or interests in fire safety before and after the test with living condition (N=289)

For the relationship between fire safety education experience and the change of participants' concerns change, the participants who have fire safety education experience's positive answer generally increased, and the neutrally answer generally decreased. In these groups, the people who held experience from publicity increased the most, accounting for 15.6 percent. The second is the people held experience from fire safety workshops held by working place, accounting for 12.2 percent. The number of people who never had a fire safety education increases the least. SUGOROKU was mainly designed to supplement the fire safety knowledge, some of the basic knowledge of fire safety was not introduced. The effect of SOGOROKU is not obvious for participants who have no fire safety education experience. (Figure 8-19)

For the participants' impression of the SUGOROKU, in 289 participants, most of the participants thought the SUGOROKU could broaden the horizons about the emergency response in the fire, accounting for 84.8 percent. Next is the participants thought it is useful as the background knowledge of fire training, accounting for 84.7 percent. The number of participants who thought "Quantity and time is appropriate" is the least, accounting for 78.9 percent. It shows that as a fire safety knowledge supplement tool, it

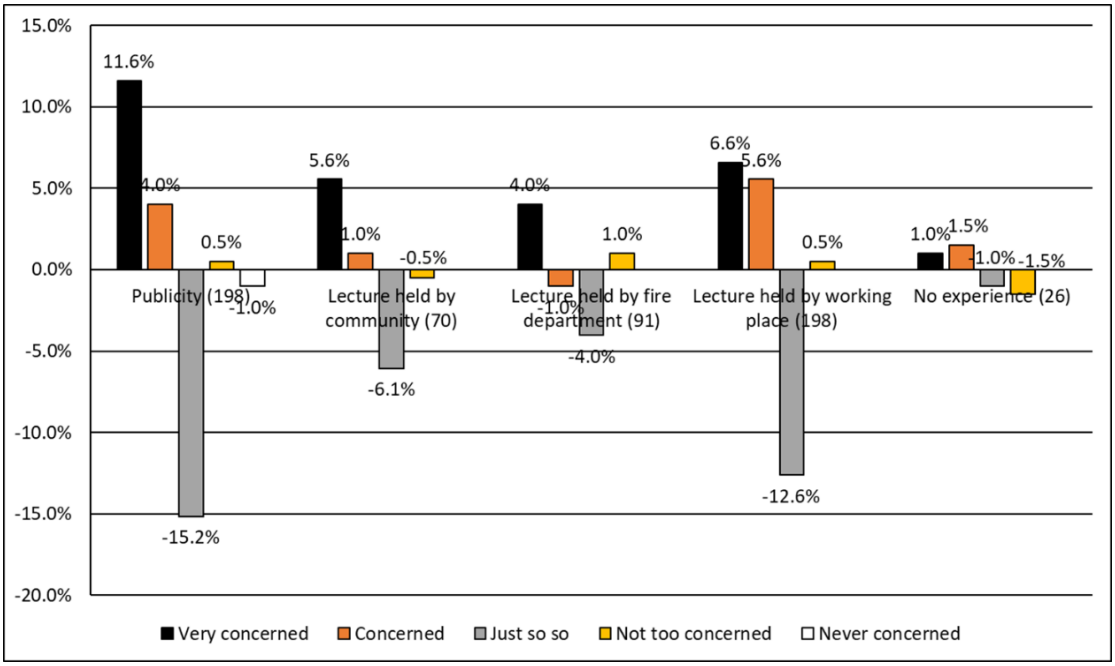


Figure 8-19 The change of the participants' concern or interests in fire safety before and after the test with fire safety education experience (N=289)

achieves the purpose that was designed for. From the participants' impression, the capacity and the time of the game still need to adjust. (Figure 8-20)

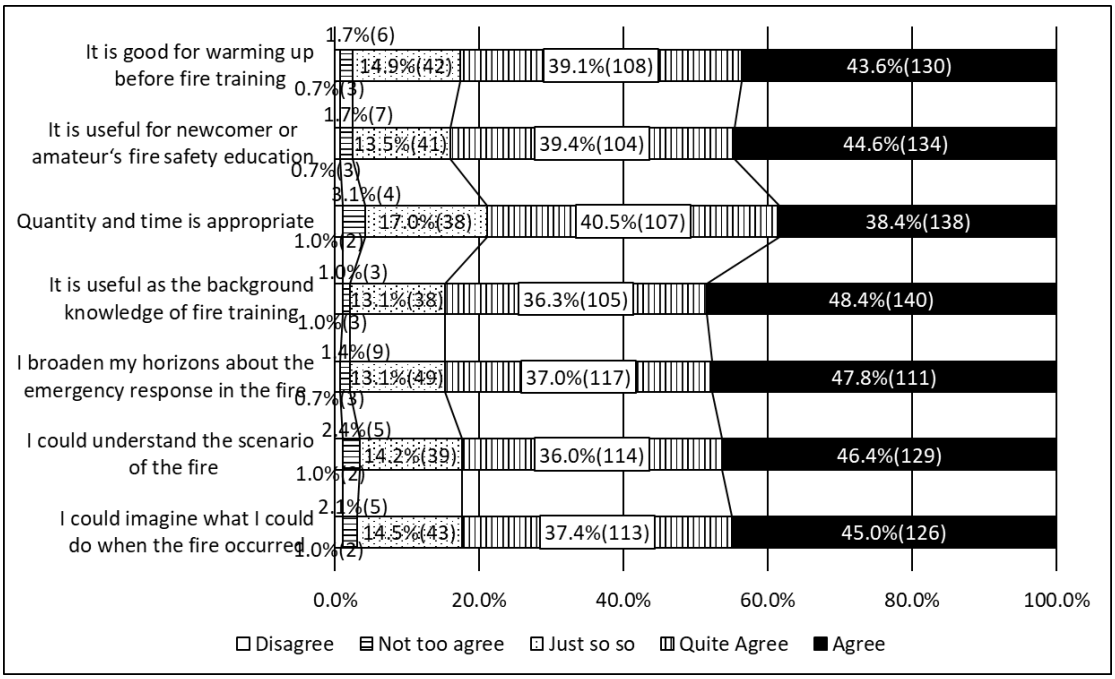


Figure 8-20 The participants' impression of the SUGOROKU(N=289)

For future improvement and refinement, the participants' feedback and suggestion for SUGOROKU's improvement are important. In 289 participants, most of the participants hoped the mass of checkerboard and playability could be strengthened, accounting for 45.3 percent. Next is the participants hoped the illustration and design could be clear enough, accounting for 43.9 percent. Combine the impression to the SUGOROKU about quantity and time, the content and the time of game still need balance. Therefore, the solution so far is that add more details and illustrations. Besides, adding the multimedia method to strengthen the fun of the game in the future could be considered. (Figure 8-21)

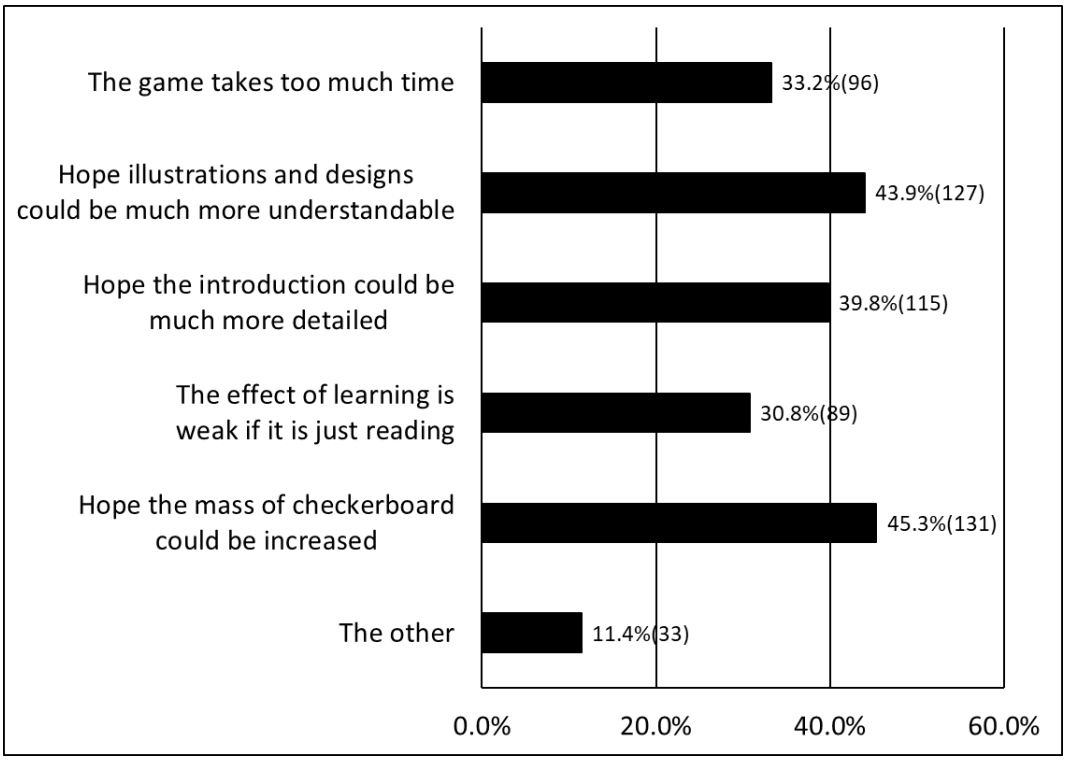


Figure 8-21 The participants' advice and suggestions to the SUGOROKU (Multi-choice, N=289)

8.4. The evaluation of the FIG

For the thoughts on FIG, in 289 participants, most of the participants thought their fire safety knowledge's breadth has increased after FIG, accounting for 90.0 percent. Next is the participants thought they obtained other participants' ideas or opinions after FIG, accounting for 89.6%. Last is the participants thought the FIG fit the status quo of their residential building, accounting for 84.4 percent. (Figure 8-22)

Because of the FIG incorporates OODA theory, the participants' attitude's change in these four aspects after FIG is important. OODA theory is often used as formulation of air combat tactic or business strategy, before they participated the test, almost all people

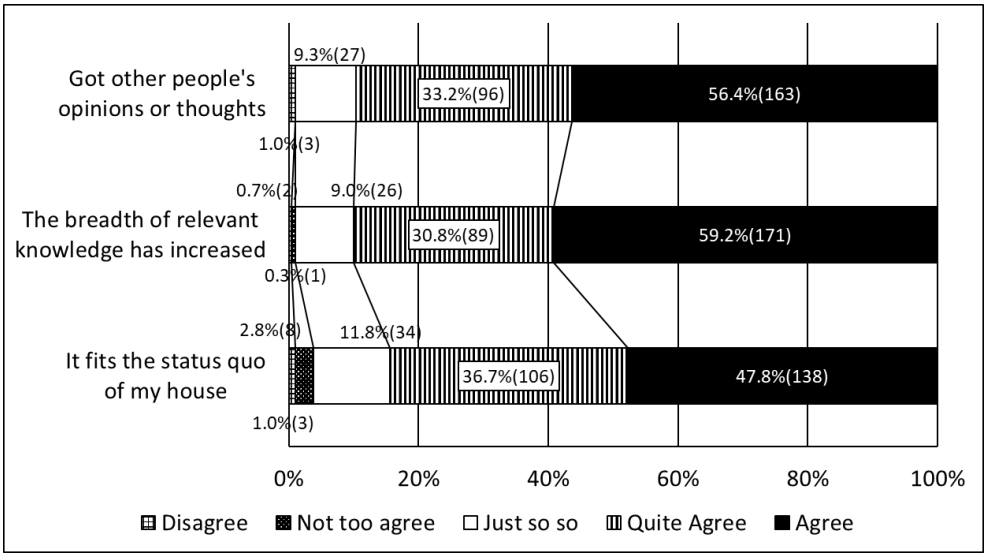


Figure 8-22 The participants' thoughts to the FIG (N=289)

were never exposed to this theory in their daily life. However, thanks to the publicity or public fire safety education, the participants have a certain concept of fire safety. The research could determine their attitude change according to calculating the D-value between their pretest and posttest. Compared with the participants' changes in the concern level of the fire safety, the altitude change to OODA theory more like the change from 0 to 1. Therefore, the research chose a multi-choice question to determine which aspect of the OODA theory do the participants start to pay attention to after the FIG training. In 289 participants, most of the participants thought "Decision" ability changed, accounting for 77.5 percent. Next is the attitude for "Action" ability changed, accounting for 69.6 percent. Attitude for "Orientation" ability changed accounting for 68.5 percent. Last is the attitude for "Observation" ability changed, accounting for 63.7 percent. The main purpose of developing FIG is to improve the decision-making ability of participants, the statistics show it achieved the purpose that was designed for. (Figure 8-23)

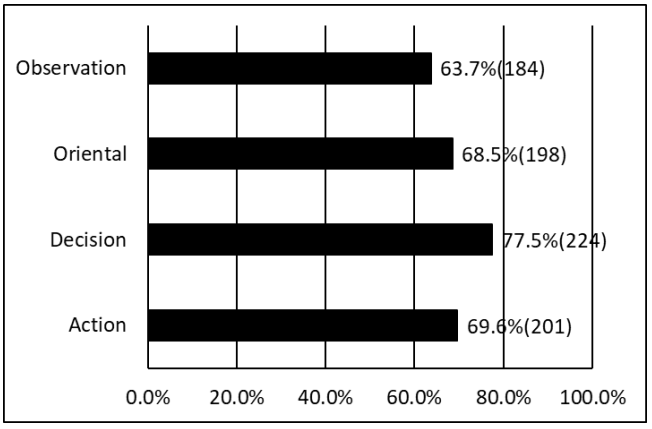


Figure 8-23 The content which aspects of the OODA theory do the participants start to pay attention to after the FIG training (Multi-choice, N=289)

According to cross statistics, the research could determine which types of participants the FIG is effective for. According to cross statistics with the situation of fire safety education experience, and attitude change from aspect of OODA, it shows the group "Lecture held by fire department" had an obvious attitude change in "Decision" ability, accounting for 84.6 percent in their group. The overall data of the group "No experience" is obviously low. It means, for the people who have no basic fire safety knowledge, the effectiveness of the FIG is slightly low. (Figure 8-24)

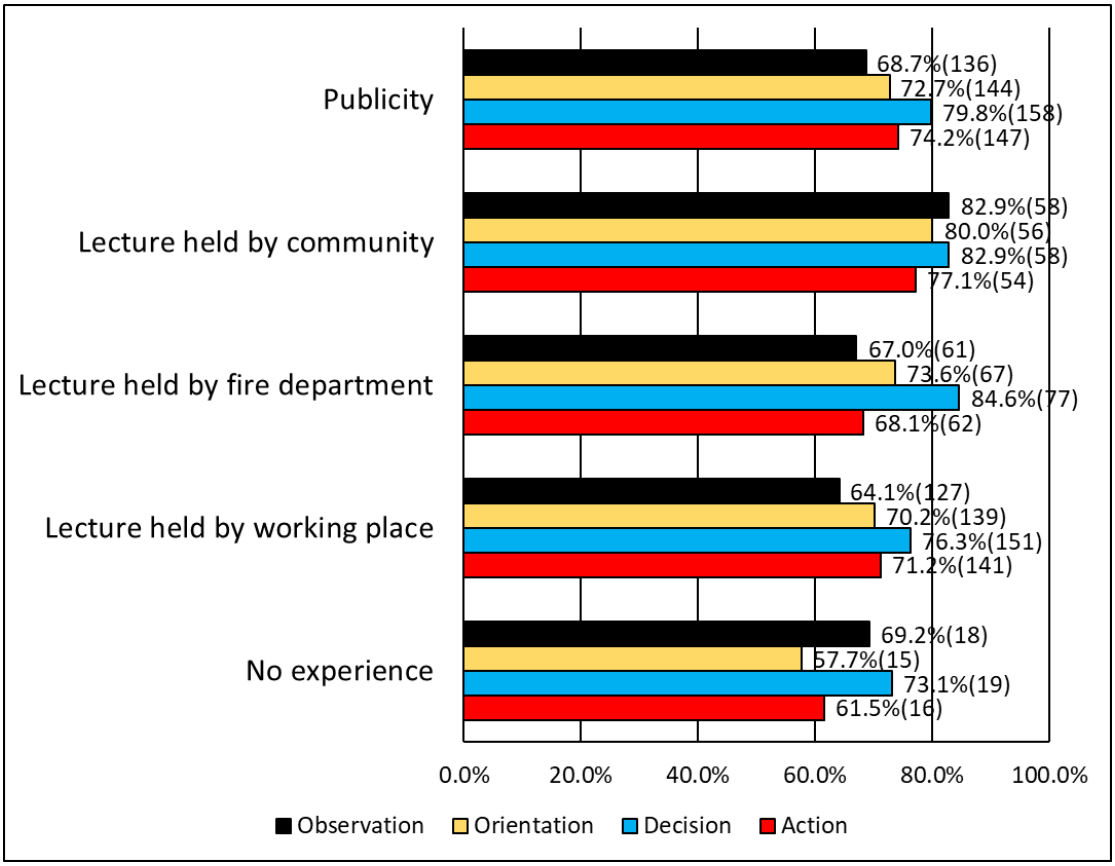


Figure 8-24 The attitude change after the FIG training with fire safety education experience (N=289)

According to cross statistics with the age and attitude change from aspect of OODA, it shows in "60 to 69" group, attitude change in "Decision" ability is the most prominent, accounting for 77.8 percent in their group. Next is the "Below 20" group, accounting for 87.5 percent in their group. It could be presumed that the participants in these two groups realized the importance of "Decision" ability more than any other groups after FIG training. (Figure 8-25)

The discussion content during FIG training shows which content participants think is more important or worth discussing for them. In 289 participants, most of the participant discussed about the route of evacuation, accounting for 68.2 percent. Next is about the

information exchange of the fire with family or neighbor, accounting for 61.6 percent. The least is the season and time of the fire occur, accounting for 37.4 percent. (Figure 8-26)

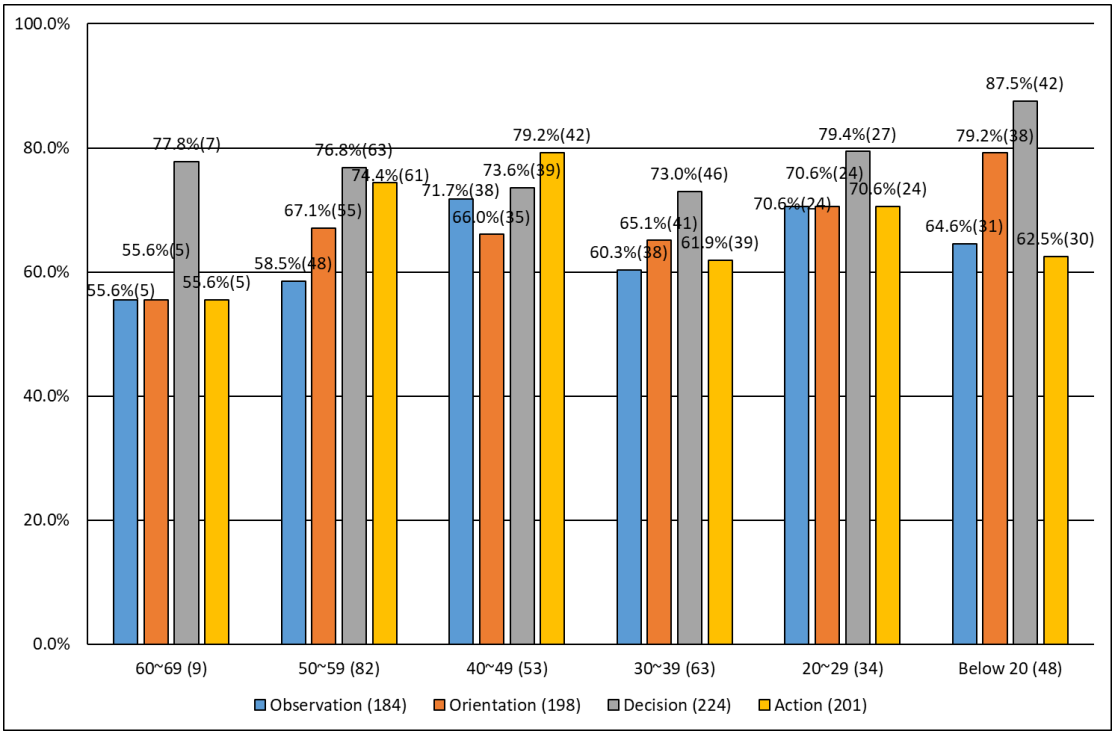


Figure 8-25 The attitude change after the FIG training with age (N=289)

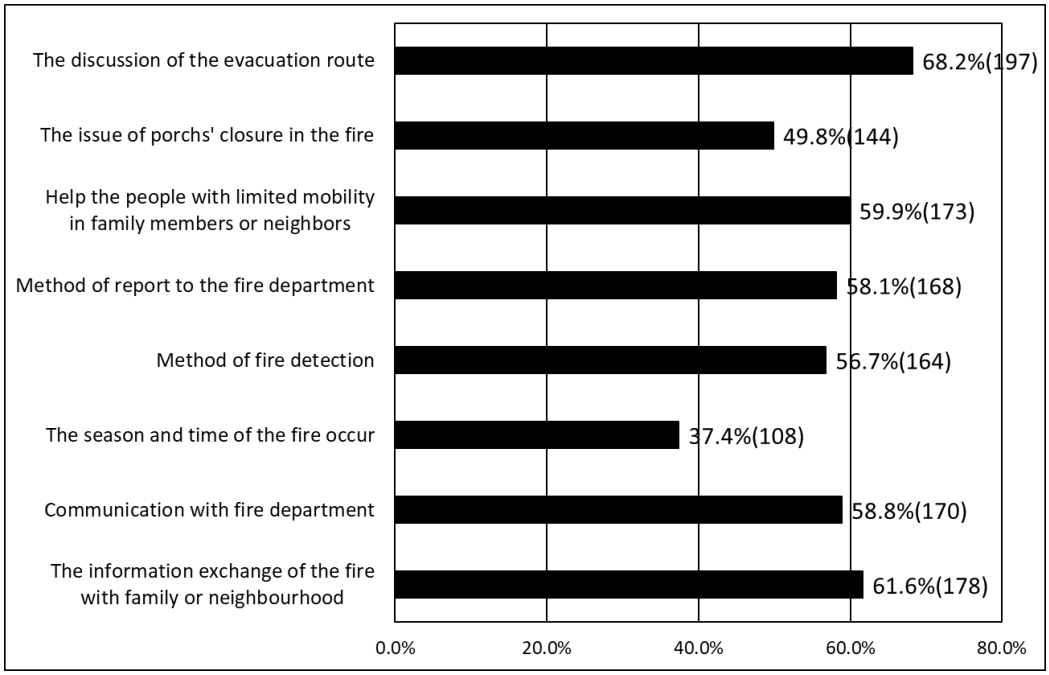


Figure 8-26 The discussion content during FIG training (Multi-choice, N=289)

According to cross statistics with the age and the discussion content, it shows in the "30 to 39", "40 to 49", "50 to 59", and "60 to 69" groups, the discussion content about evacuation route is the most, accounting for 66.7 percent, 73.6 percent, 73.2 percent, and 77.8 percent in their group respectively. In the "20 to 29" group, discussion content about the method of fire detection is the most, accounting for 73.5 percent in their group. In the "Below 20" group, discussion content about the information exchange of the fire with family and neighbor is the most, accounting for 72.9 percent in their group. It shows the different concerning content in the group of minors, young people, and middle-aged people. (Figure 8-27)

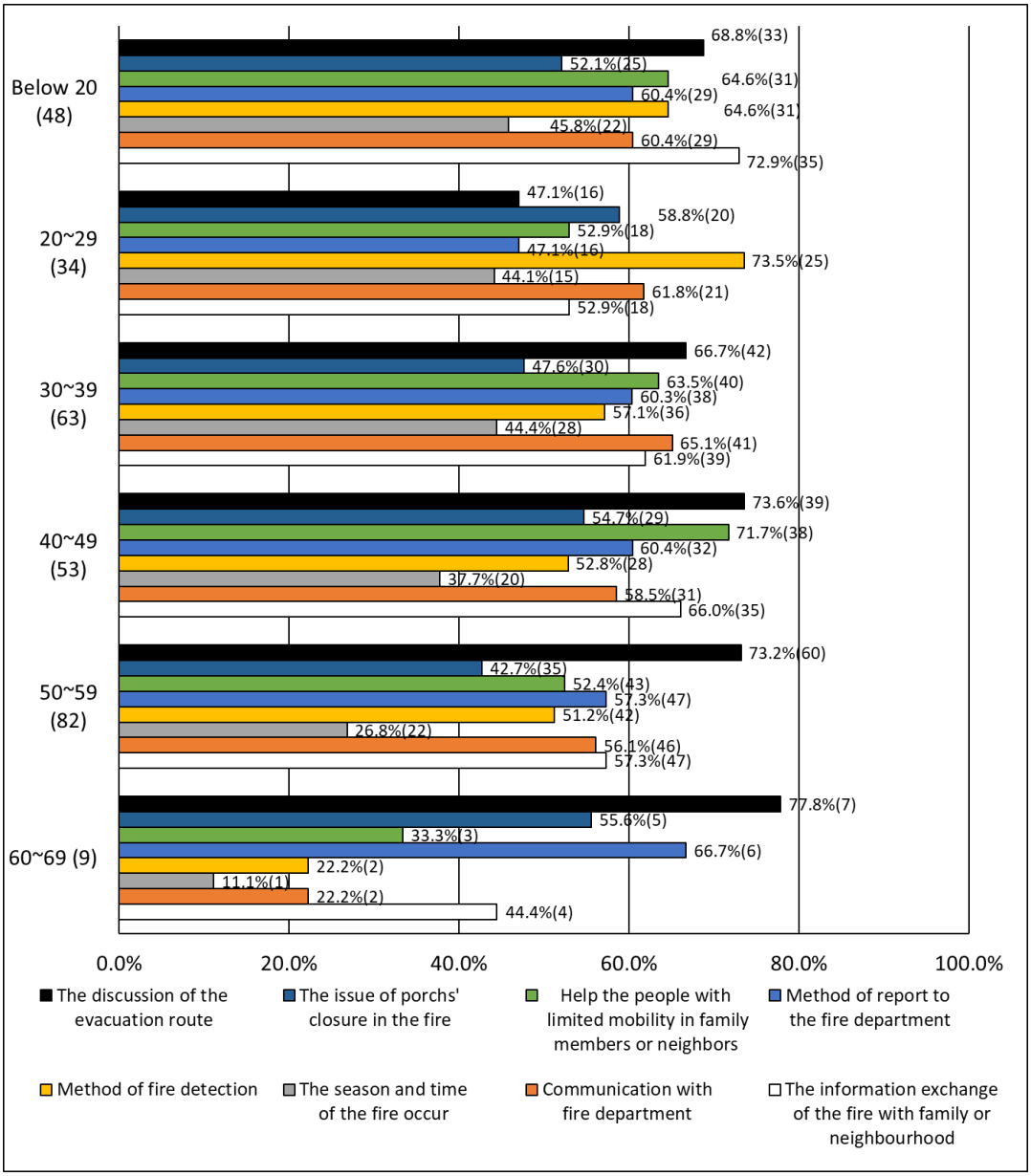


Figure 8-27 The discussion content during FIG training with age (N=289)

The change of interests or concern content after FIG training shows the change of the participants' attitude. In the 289 participants, most of the participants changed their concerning content about the purpose and the method of installation of safety equipment in the residential building, accounting for 80.6 percent. It means the participants changed their attitude in fire detection and prevention method of the residential building. (Figure 8-28)

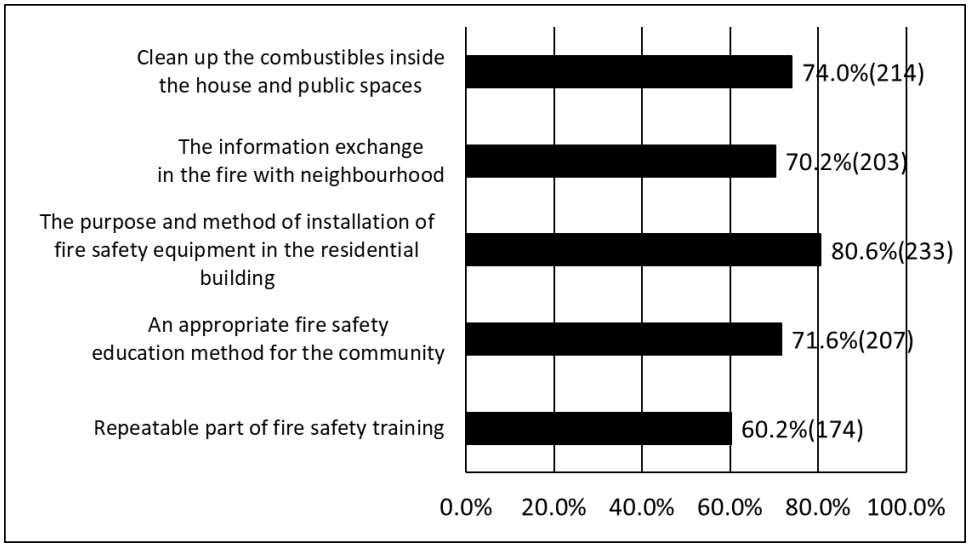


Figure 8-28 The change of interests or concern content after FIG training (Multi-choice, N=289)

According to cross statistics with age and the change of interests or concern content, it shows in the "60 to 69" group, most of the participants changed their attitude about "Clean up the combustibles inside the house and public space", accounting for 88.9 percent. It means that combined with the living habits of the elderly that collect and accumulate combustibles at home, such kind of change would be a good sign that has a benefit for fire protection. In "50 to 59", "40 to 49", "30 to 39", "20 to 29", and "Below 20" group, the content "The purpose and the method of installation of safety equipment in the residential building" is the most, it means the people started to pay attention to the fire detection and prevention equipment installed in the house after FIG training. Combined with the specific content of participants' concerns and interests in fire safety that were introduced before, it shows that the FIG has an impact on participants' attitude change. (Figure 8-29)

For the issue of the residential building that the participants considered, according to the comparison between the same answer in pretest and posttest, it could show the change participants' attitude after FIG training. In 289 participants, except the content "The situation of the neighbor", decreased 0.3 percent. The other issues that the

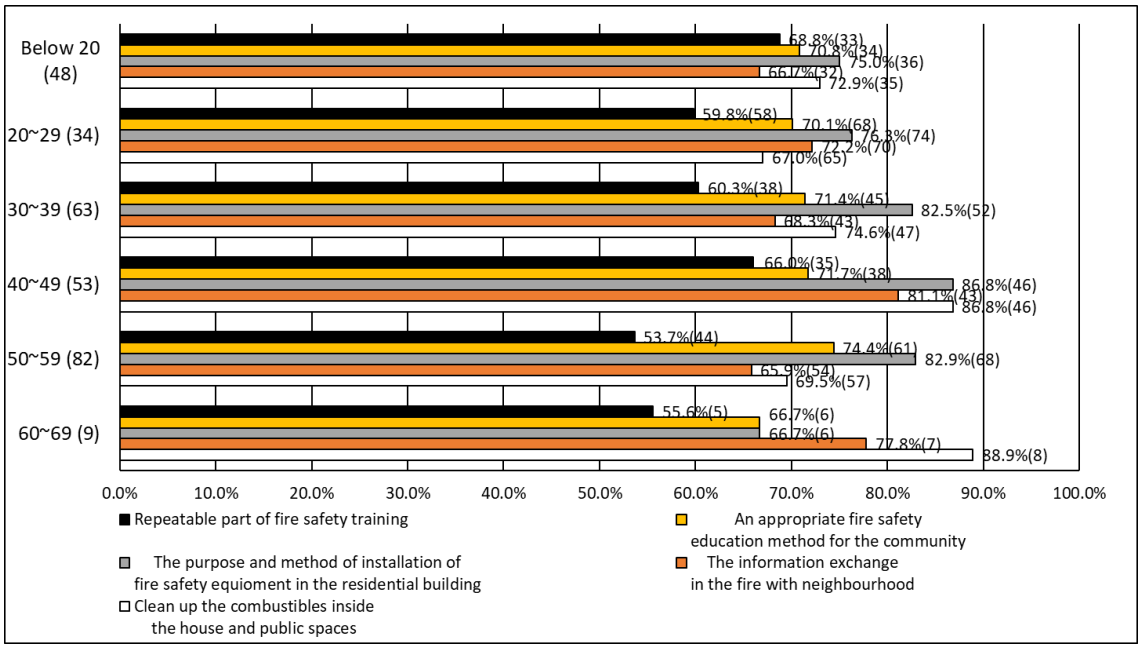


Figure 8-29 The change of interests or concern content after FIG training with age (N=289)

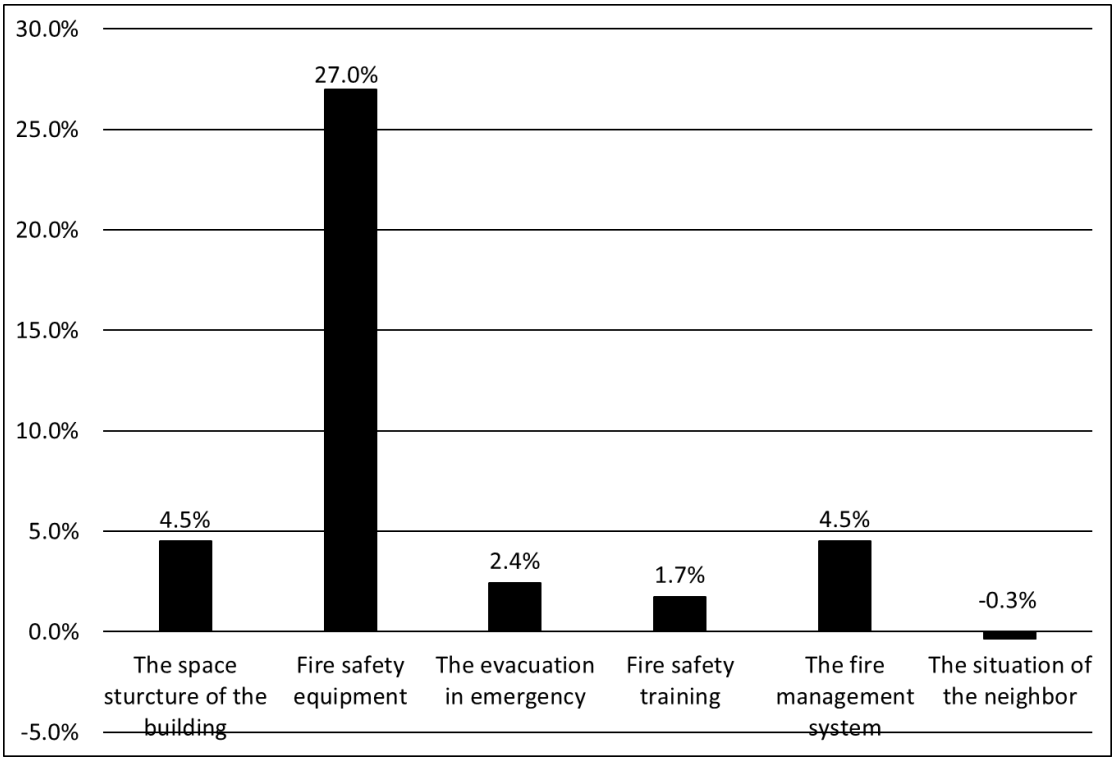


Figure 8-30 The changes in participants consideration before and after FIG training (N=289)

participants considered had increased to varying degrees, especially the issue “Fire safety equipment”, increased 27.0 percent. This result could correspond to the change of participants’ interests or concerns. (Figure 8-30)

According to cross statistics with the residential building type and the issue of the residential building that the participants considered. The issue that the people who live in high-rise residential buildings considered changed most in the content “The spatial structure of the building”, increased 35.8 percent in their group, next is the content “Fire safety equipment”, increased 17.3 percent. The number is less than the participants who live in the multi-story residential building. The issue of the residential building “Fire safety equipment” that the participants who live in the multi-story residential building considered increased 25.5 percent. Because high-rise residential buildings have longer evacuation routes than multi-story residential buildings in the vertical direction, the number of participants who live in the high-rise residential building paying attention to the spatial structure of the building after FIG training increased. Because high-rise residential buildings have more complete fire protection equipment than multi-story residential buildings, the number of participants who live in the multi-story residential building paying attention to the fire safety equipment issue after FIG training increased. (Figure 8-31)

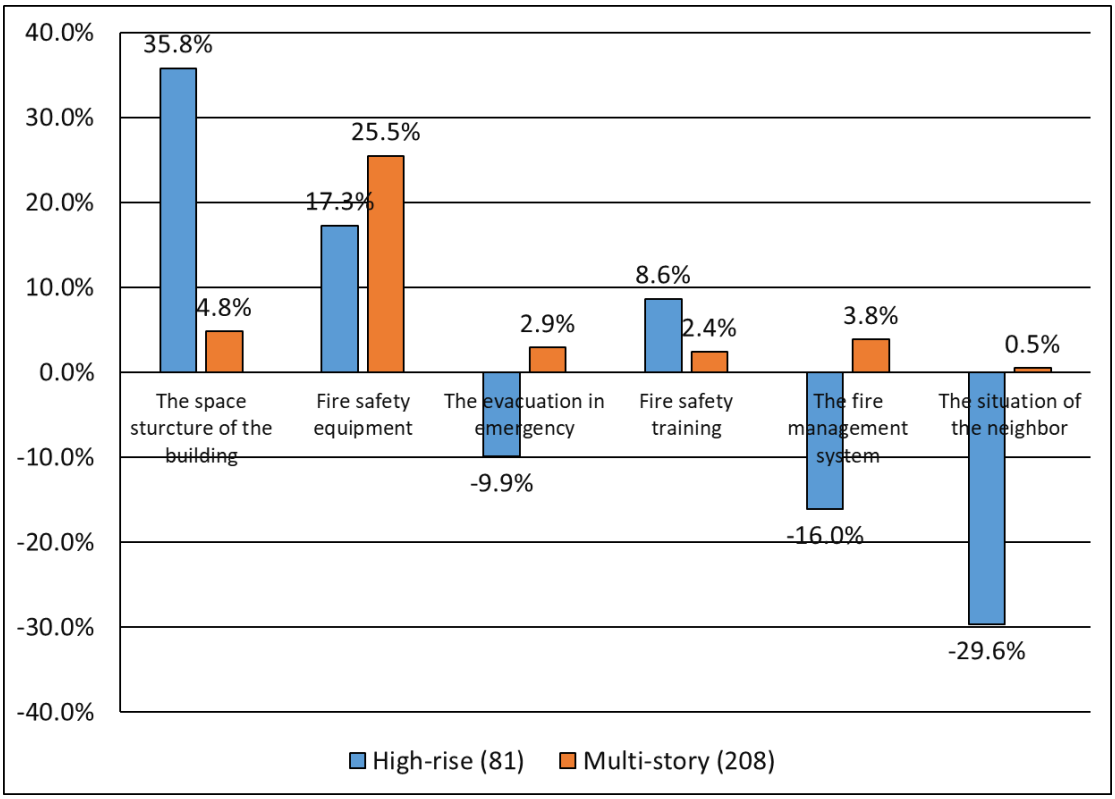


Figure 8-31 The changes in participants consideration before and after FIG training with living condition(N=289)

Summary

The SUGOROKU and FIG was tested in China through the internet and verified the effectiveness through a questionnaire by FLSE-defined impact evaluation. There were

289 people who participated in the test.

For the participants' basic situation, according to questionnaire research, it determined that the participants' fire safety awareness is different due to the type of the building they live, their age and experience of fire safety education, combined with the securities company's report, it may have a relationship with the situation of purchase of real-estate.

From the participants' feedback, for the SUGOROKU, as a supplement knowledge and warming-up tools of the FIG education plan, the SUGOROKU achieves the purpose that was set. Most of the people thought it could broaden participant's horizons about the emergency response and be a useful method as the background knowledge education for fire training in the fire. According to the cross statistic, SUGOROKU's effectiveness is much more obvious for people who have experience in fire safety education. Besides, its content is not only fit for the high-rise residential buildings' residents but also fit for the residents who live in the ordinary residential buildings. However, the participants reflected that it still needs some more balance in the content's quantity and the time of gameplay Besides, adding the multimedia method to strengthen the playability of the game in the future could be considered.

For the FIG, as an educational project that main purpose is to improve the participants' attitude and emergency response ability through training the occupants' "Decision" part in the OODA loop, from the participants' feedback, most of the participants though their "Decision" part changed after FIG training, it shows the FIG has achieved the purpose that the was designed for. However, for the people who have no basic fire safety knowledge, the effectiveness of the FIG is slightly low.

From the attitude's change before and after the SUGOROKU game and FIG training, it has a different impact on the different groups of people. For the discussion contents in the process of the FIG, the participants that the age below 20 discussed information exchange is the most, the participants that the age between 20 and 29 discussed fire detection is the most, any other participants that the age between 30 to 69 discussed evacuation route is the most. For the change of the interests or concerns' specific content after the FIG, it shows the change of the participants' attitude. After the FIG training, the elderly group aged between 60 and 69 started to pay attention to the issue that collecting and accumulating combustibles at home. The other groups of the participants paid more attention to the residential building's fire safety equipment, it has the benefit for strengthen the occupants' fire safety awareness in daily life. From the change of the issue that the participants' considered, most of the participants generally paid more attention to the situation of the fire safety equipment in their residential building after FIG training. Combined with the current situation of high-rise residential buildings and

multi-story residential buildings, the participants' considered issues became different due to the building' type that they live in.

Reference

1) Zhang Chong, Research on housing demand from the perspective of generalized population structure, Journal of Chongqing Technology and Business University (Social Sciences Edition), Vol.32, NO.2, pp. 16-24, 2015.04 (In Chinese)
2) MA Zhiyao, OKADA Naoko, OHNISHI, Kazuyoshi, MURAI Hiroki, A study on the Fire Safety Awareness of Elderly Facility Staff, Proceedings of the Housing Studies Symposium 2017, pp. 207-216, 2017,12

Chapter 9. Conclusion

9.1. Conclusion

The research introduced the designing process of an educational program for the occupants of multi-story residential buildings. This educational program includes fire safety SUGOROKU and Fire Image Game. And for evaluating the SUGOROKU and FIG's effectiveness, the program was tested through the internet questionnaire platform in China.

9.1.1. FIG

Fire Image Game is an educational project that purpose is mainly to improve the participants' attitude and emergency-response ability. For designing the FIG's every component, the research analyzed the fire spreading pattern of exterior fire through case studies that occurred in Japan, China, and Britain; analyzed the floor plan of China's high-rise residential building according to make a comparative research between China, Japan, and the United Stats' related codes or laws and the changes of new code for fire protection design of buildings; combined with OODA theory that was proposed by the United States Air force, analyzing the human behavior in the fire through the testimony that was recorded in the inquiry report of Grenfell tower that published by the British government. Finally, reference the Fire Image Game for the elderly facility's operating method, combined with FLSE's guiding principles and OODA theory, to propose a Fire Image Game for multi-story residential buildings. Besides, based on the workshop-type FIG, to develop an automatic, adventure game-like FIG that was called remote-type FIG, to adapt to the new environment and new policies caused by the Corona pandemic.

9.1.2. SUGOROKU

SUGOROKU, as a fire safety educational game that was designed as a knowledge supplement and warming-up tool for the FIG training. The game's content was picked from Tokyo fire department published <Actual situation of fire>'s typical fire cases, rare fire cases and specific fire cases that happened in China, Britain and Japan. This content was summarized and organized as "Fire case card". The cards were classified as the cooking fire cases, the cigarette fire cases, the electric fire case, the stove fire cases, the elderly fire cases, and the fire management cases. Then the knowledge point was refined from the cards and adding "MEMO" to explain the knowledge point through introducing the related fire cases to make it become the masses of SUGOROKU's Checkerboard. At last, the masses were arranged following the scenario of the fire and add "tricks" to improve the playability.

9.1.3. The test of educational program

The SUGOROKU and FIG was tested in China through the internet and verified the effectiveness through a questionnaire by FLSE-defined impact evaluation. There were 289 people who participated in the test. From the participants' feedback, for the SUGOROKU, as a supplement knowledge and warming-up tools of the FIG education plan, the SUGOROKU achieves the purpose that was set. Most of the people thought it could broaden participant's horizons about the emergency response and be a useful method as the background knowledge education for fire training. According to the cross statistic, SUGOROKU's effectiveness is much more obvious for people who have experience in fire safety education. Besides, its content is not only fit for the high-rise residential buildings' residents but also fit for the residents who live in the multi-story residential buildings. However, the participants reflected that it still needs some more balance in the content's quantity and the time of gameplay. Besides, adding the multimedia method to strengthen the playability of the game in the future could be considered.

For the Fire Image Game, as an educational project that main purpose is to improve the participants' attitude and emergency response ability through training the occupants' "Decision" part in the OODA loop, from the participants' feedback, most of the participants though their "Decision" part changed after FIG training, it shows the FIG has achieved the purpose that the was designed for. However, for the people who have no basic fire safety knowledge, the effectiveness of the FIG is slightly low.

From the attitude's change before and after the SUGOROKU game and FIG training, it has a different impact on the different groups of people. For the discussion contents in the process of the FIG, the participants that the age below 20 discussed information exchange is the most, the participants that the age between 20 and 29 discussed fire detection is the most, any other participants that the age between 30 to 69 discussed evacuation route is the most. For the change of the interests or concerns' specific content after the FIG, it shows the change of the participants' attitude. After the FIG training, the elderly group aged between 60 and 69 started to pay attention to the issue that collecting and accumulating combustibles at home. The other groups of the participants paid more attention to the residential building's fire safety equipment, it has the benefit for strengthen the occupants' fire safety awareness in daily life. From the change of the issue that the participants' considered, most of the participants generally paid more attention to the situation of the fire safety equipment in their residential building after FIG training. Combined with the current situation of high-rise residential buildings and multi-story residential buildings, the participants' considered issues became different due to the building' type that they live in.

9.2. Future outlook

In the future, Fire Image Game will pursue higher scalability applicability and conduct tests in more countries and regions. After perfecting the method and content of the logical jumping, based on the characteristic of the automatic type of the FIG, it could be much easier to spread and obtain rich data. If combined with big data and AI machine learning, perhaps in the future, through the Internet of Things and connection with the fire department, a terminal could provide the occupants with the best solution to evacuation in the event of a fire. So as to reduce the death rate of the occupants in the fire.

Acknowledgements

This paper summarizes the research results of the author for five years while studied in the doctoral program at the Graduate School of Engineering, Kobe University.

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I should finally like to express my gratitude to my beloved parents and friends who have always been helping me out of difficulties and supporting me without a word of complaint.

2022.01.15

MA Zhiyao

Related papers

Chapter 1, Chapter 8：
MA Zhiyao, OKADA Naoko, OHNISHI, Kazuyoshi, MURAI Hiroki: A study on the Fire Safety Awareness of Elderly Facility Staff, Proceedings of the Housing Studies Symposium 2017, pp. 207-216, 2017,12

Chapter 4：
MA Zhiyao, HOKUGO Akihiko, OHNISHI Kazuyoshi: A research for China's new code for fire protection design of buildings in residential building's fire safety design, Proceedings of the Housing Studies Symposium 2018, pp. 29-38, 2018,11

Chapter 7:
MA Zhiyao, OHNISHI Kazuyoshi: STUDY ON THE DEVELOPMENT OF FIRE SAFETY GAME FOR MULTI-STORY RESIDENTIAL BUILDING, peer-reviewed papers of Mansion studies (Under review, 2021.9.30 Contributions accepted)

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MA Zhiyao, OKADA Naoko, OHNISHI Kazuyoshi, MURAI Hiroki: Study on Fire safety inspiration activity for the elderly facility: Part21: The relationship between the floor type and staff's anxiety based on the research in Kobe, 2016, Proceedings of JAFSE Annual Symposium (2017), pp.26-27, 2017.05.20.

MA Zhiyao, OKADA Naoko, OHNISHI Kazuyoshi, MURAI Hiroki: A Study on the Fire Safety Awareness of Elderly Facility Staff-The analyzation of staff's anxiety against night fire based on the mathematical quantification theory class III-, Summaries of technical papers of Annual Meeting, Architectural Institute of Japan (2017), pp. 107-110, 2017.08

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KOBAYASHI Kyoichi, etl. Status and issues of fire prevention and safety measures for elderly welfare facilities in Japan, Symposium on fire prevention and safety of welfare

facilities for the elderly in East Asia. 2019.12

MA Zhiyao: The Comparative Research of Fire Safety Education between the US, Japan and China, Asian Law and Society Association (ALSA), 4th Annual Meeting in OSAKA, Japan, 2019.12

Doctoral Dissertation, Kobe University
"A study on the development of fire safety educational project for occupants of multi-story residential building (中高層住宅居住者向け火災安全教育に関する研究)", 130 pages
Submitted on January 20, 2022
The date of publication is printed in cover of repository version published in Kobe University Repository Kernel.

Appendix

The questionnaire

1. Your gender.

①. Male

②. Female

2. Your age.

①. Below 20 years old (20 is not included) (49)

②. 20~29 years old

③. 30~39 years old

④. 40~49 years old

⑤. 50~59 years old

⑥. 60~69 years old

⑦. Over 70 years old

3. The highest floor of your residential building is _____.

4. What fire-related educational activities have you participated in the past (Multi-choice)

①. Publicity

②. Fire safety workshop held by community management organizations

③. Fire safety workshop held by the fire department

④. Fire safety workshop held by the workplace

⑤. No such experience

	Low		Mid		High
5. Please select from the following values for your concern or interest in fire safety	①	②	③	④	⑤

6. Please select from the following values for your concern or interest in the following content

	Never concerned		Just so so		Very concerned
6-1. Clean up the combustibles inside the house and public spaces	①	②	③	④	⑤
6-2. The information exchange in the fire with neighbor	①	②	③	④	⑤
6-3. The purpose and method of installation of fire safety equipment in the residential building	①	②	③	④	⑤
6-4. An appropriate fire safety education method for the community	①	②	③	④	⑤
6-5. Repeatable part of fire safety training	①	②	③	④	⑤

7. Which of the following fire safety issues do you think you have in your residential building? (Multi-choice)

①. The spatial structure of the building

②. Fire safety equipment

③. The evacuation in emergency

④. Fire safety training

⑤. The fire management system of the community

⑥. The situation of the neighbor

Thank you for completing the fire safety game, please answer the three sets of questions below

	Low		Mid		High
8. Please select from the following values for your concern or interest in fire safety now.	①	②	③	④	⑤

9. After you finish the fire safety game, here are your thoughts:

	Disagree		Just so so		Agree
9-1. I could imagine what I could do when the fire occurred	①	②	③	④	⑤
9-2. I could understand the description of the fire	①	②	③	④	⑤
9-3. I broaden my horizons about the emergency response in the fire	①	②	③	④	⑤
9-4. It is useful as the background knowledge of fire training	①	②	③	④	⑤
9-5. Quantity and time is appropriate	①	②	③	④	⑤
9-6. It is useful for newcomer or amateur's fire safety education	①	②	③	④	⑤
9-7. It is good for warming up before fire training	①	②	③	④	⑤

10. What do you think could be improved on this fire safety game? (Multi-choice)

①. The game takes too much time

②. Hope illustrations and designs could be much more understandable

③. Hope the introduction could be much more detailed

④. The effect of learning is weak if it is just need reading

⑤. Hope the mass of the checkerboard could be increased

⑥. The other

Thank you for completing the Fire Image Game, please answer the following questions

11. After you completed Fire Image Game, which of the following did you think was effective?

	Disagree		Just so so		Agree
11-1. It fits the status quo	①	②	③	④	⑤
11-2. The breadth of relevant	①	②	③	④	⑤
11-3. Got other people's opinions or thoughts	①	②	③	④	⑤

12. Which of the following topics did you discuss with others (or would you like to share with others) in today's Fire Image Game training. (Multi-choice)

①. The information exchange of the fire with family or neighbor
②. Communication with the fire department
③. The season and time of the fire occurred
④. Method of fire detection
⑤. Method of the report to the fire department
⑥. Help the people with limited mobility in family members or neighbors
⑦. The issue of porches' closure in the fire
⑧. The discussion of the evacuation route

13. Which aspect of OODA theory do you start to focus on after Fire Image Game training? (Multi-choice)

①. O (Observation), the ability to recognize or understand danger signs.
②. O (Orientation), the ability to interpret the signs of danger (the ability to analyze various information on the fire site).
③. D (Decision), the ability to make decisive decisions (the ability to make choices on the rich information on the spot and make proper action decisions in a short time)
④. A (Action), the ability to respond to various situations

14. Please select which of the following items have you increased your concern or interest. (Multi-choice)

①. Clean up the combustibles inside the house and public spaces
②. The information exchange in the fire with neighbor
③. The purpose and method of installation of fire safety equipment in the residential building
④. An appropriate fire safety education method for the community
⑤. Repeatable part of fire safety training

15. Which of the following fire safety issues do you think you have in your residential building after the Fire Image Game training? (Multi-choice)

①. The spatial structure of the building

②. Fire safety equipment

③. The evacuation in emergency

④. Fire safety training

⑤. The fire management system of the community

⑥. The situation of the neighbor

Statistical table of the questionnaire

1.

Your gender	Male	Female
Number	130	159

2.

Age	Number
Below 20 years old (20 is not included)	49
20~29 years old	34
30~39 years old	63
40~49 years old	53
50~59 years old	82
60~69 years old	9
Over 70 years old	0

3. The highest floor of your residential building is _____.

Floor	Over 10 floors (Include 10 floors)	Below 10 floors
Number	81	208

4. What fire-related educational activities have you participated in the past (Multi-choice)

Fire safety education experience	Number
Publicity	198
Fire safety workshop held by community management organizations	70
Fire safety workshop held by the fire department	91
Fire safety workshop held by the workplace	198
No such experience	26

	Low		Mid		High
5. Please select from the following values for your concern or interest in fire safety	3	14	96	78	98

6. Please select from the following values for your concern or interest in the following content

	Never concerned		Just so so		Very concerned
6-1. Clean up the combustibles inside the house and public spaces	8	20	69	88	104
6-2. The information exchange in the fire with neighbor	9	18	55	101	106
6-3. The purpose and method of installation of fire safety equipment in the residential building	8	22	60	94	105
6-4. An appropriate fire safety education method for the community	10	24	75	89	91
6-5. Repeatable part of fire safety training	11	31	70	89	88

7. Which of the following fire safety issues do you think you have in your residential building? (Multi-choice)

Option	Number
The spatial structure of the building	114
Fire safety equipment	145
The evacuation in emergency	185
Fire safety training	134
The fire management system of the community	160
The situation of the neighbor	103

Thank you for completing the fire safety game, please answer the three sets of questions below

	Low		Mid		High
8. Please select from the following values for your concern or interest in fire safety now.	1	10	52	96	130

9. After you finish the fire safety game, here are your thoughts:

	Disagree		Just so so		Agree
9-1. I could imagine what I could do when the fire occurred	3	6	42	108	130
9-2. I could understand the description of the fire	3	7	41	104	134
9-3. I broaden my horizons about the emergency response in the fire	2	4	38	107	138
9-4. It is useful as the background knowledge of fire training	3	3	38	105	140
9-5. Quantity and time is appropriate	3	9	49	117	111
9-6. It is useful for newcomer or amateur's fire safety education	2	5	39	114	129
9-7. It is good for warming up before fire training	2	5	43	113	126

10. What do you think could be improved on this fire safety game? (Multi-choice)

Option	Number
The game takes too much time	96
Hope illustrations and designs could be much more understandable	127
Hope the introduction could be much more detailed	115
The effect of learning is weak if it is just need reading	89
Hope the mass of the checkerboard could be increased	131
The other	33

Thank you for completing the Fire Image Game, please answer the following questions

11. After you completed Fire Image Game, which of the following did you think was effective?

	Disagree		Just so so		Agree
11-1. It fits the status quo	3	8	34	106	138
11-2. The breadth of relevant	1	2	26	89	171
11-3. Got other people's opinions or thoughts	3	0	27	96	163

12. Which of the following topics did you discuss with others (or would you like to share with others) in today's Fire Image Game training. (Multi-choice)

Option	Number
The information exchange of the fire with family or neighbor	178
Communication with the fire department	170
The season and time of the fire occurred	108
Method of fire detection	164
Method of the report to the fire department	168
Help the people with limited mobility in family members or neighbors	173
The issue of porches' closure in the fire	144
The discussion of the evacuation route	197

13. Which aspect of OODA theory do you start to focus on after Fire Image Game training? (Multi-choice)

Option	Number
O (Observation), the ability to recognize or understand danger signs	184
O (Orientation), the ability to interpret the signs of danger (the ability to analyze various information on the fire site)	198
D (Decision), the ability to make decisive decisions (the ability to make choices on the rich information on the spot and make proper action decisions in a short time)	224
A (Action), the ability to respond to various situations	201

14. Please select which of the following items have you increased your concern or interest. (Multi-choice)

Option	Number
Clean up the combustibles inside the house and public spaces	214
The information exchange in the fire with neighbor	203
The purpose and method of installation of fire safety equipment in the residential building	233
An appropriate fire safety education method for the community	207
Repeatable part of fire safety training	174

15. Which of the following fire safety issues do you think you have in your residential building after the Fire Image Game training? (Multi-choice)

Option	Number
The spatial structure of the building	127
Fire safety equipment	223
The evacuation in emergency	192
Fire safety training	139
The fire management system of the community	173
The situation of the neighbor	102